

Treatment of Radioactive Metallic Waste from Operation of Nuclear Power Plants by Melting - The German Way for a Consistent Recycling to Minimize the Quantity of Radioactive Waste from Operation and Dismantling for Disposal - 12016

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ABSTRACT

During maintenance of nuclear power plants, and during their decommissioning period, a large quantity of radioactive metallic waste will accrue. On the other hand the capacity for final disposal of radioactive waste in Germany is limited as well as that in the US. That is why all procedures related to this topic should be handled with a maximum of efficiency. The German model of consistent recycling of the radioactive metal scrap within the nuclear industry therefore also offers high capabilities for facilities in the US. The paper gives a compact overview of the impressive results of melting treatment, the current potential and further developments.

INTRODUCTION

During maintenance of nuclear plants, and during their decommissioning period, a large quantity of radioactive metallic waste will accrue (Fig. 1). The decontamination of these types of material and their release for general re-use later on is often unachievable due to complex geometry, surface conditions and/or problems caused by verification in fulfilling the legal limits for release. Another important point to consider is the high commitment of resources for staff and equipment when performing the treatment on site. Longer treatment activities also generate a higher dose for the staff involved. Furthermore, there is always a risk of increasing the quantity of radioactive waste if the decontamination procedure fails. In the outcome precious metal scrap will be dissipated and costs for final disposal of radioactive waste will be enhanced. To avoid these problems, the treatment of metallic waste by melting in external specialized facilities is a suitable solution. Depending on specific types of nuclides in the metallic waste, the melting process offers a very high factor of decontamination. The resulting ingots can often be directly released for general re-use. Alternatively the iron ingots can be recycled within the nuclear industry, e. g. for manufacturing casks for storage and transport of radioactive waste. The melting procedures which are available for almost all metal types require no extensive pre-treatment of the scrap on site. The small amount of radioactive residues arising from the melting process (slag, dust, blasting grits) can be treated by high-pressure compaction afterwards. Because of the German decision to resign from nuclear power in the near future, the capacity for treatment of metallic waste in Germany as described above will be further developed.

WASTE TREATMENT BY MELTING

Within its complete service for nuclear power plants, GNS takes over the metallic waste on site and performs all necessary transport, arranges the melting of the metallic waste in external facilities belonging to their partner SNT, and treats the resulting radioactive waste from the melting process including its conditioning for final disposal. The melting process itself comprises a pre-treatment by cutting and sorting of the metal scrap in advance to achieve a proper result. If necessary, the metal scrap also will be blasted to reduce the contamination before melting. All material streams will be permanently controlled by sampling and radiological analyses. The

ingots will be released for general re-use as far as possible or recycled to manufacture so called MOSAIK[®] casks, a special thick-walled cask for ILW/LLW waste.

Limit Values of Licensing and Acceptance

After many years of successful operation, the licence to accept metals and other foundry-useable materials was increased from the original 200 Bq/g to 1,000 Bq/g (total α , β , γ) in March 2008. An additional 10,000 Bq/g is allowed for the beta emitters Fe-55, Ni-63, C-14 and H-3. Other legal regulations limit the licence to 15 g/100 kg for nuclear fuel products for the whole process.

Nuclide-specific documentation of the activity inventory of a delivered batch has to be provided by the customer before delivery and is part of notification to the regulatory authority. A strict customer-oriented management process combined with extensive radiation protection measures during changes to both customer and campaign eliminates cross-contamination or at least, limits cross-contamination to the minimum procedurally possible.

Meltable Metals

The melting facility used for this procedure, so called CARLA facility, is suitable for treating all qualities of iron and steel such as cast iron, mild steel, stainless steel, zinc-coated steel and coated steels as well as non-ferrous metals like aluminium, copper, brass and lead. Composite materials consisting of stainless steel/lead, for example, can also be treated in CARLA by a special melting separation.

An optimized melting treatment is applied to every kind of metal to achieve the most effective decontamination. The electric induction furnace can be equipped with different compound crucibles.



Fig. 1: Metal scrap from nuclear power plants

Plant Technology

The concept of CARLA facility and its layout is the result of in-house development during the middle of the 1980s and combines the experience, requirements and learning from very different areas such as foundry technology, radiation protection (Fig. 2) and ventilation

technology. The result is a compact design with optimized throughput for each working area. The whole CARLA facility is largely incorporated within a dedicated building and consists of sorting and dismantling areas, the separately-housed melting area, the storage hall and the outdoor storage yard for containers and ingots. Offices for the operational team, radiation protection services including a measurement laboratory ensure that the facility as a whole can operate as an independent unit.

Deliveries, Storage and Handling Equipment

Supplied material, which usually is packed in 20' containers, can be stored in the storage hall as well as in the container storage yard. Both areas have access to dedicated cranes with capacities from 25 t to 32 t. These areas can accommodate up to around one hundred and fifty 20' containers. For deliveries by rail a special lifting unit for unloading the containers is available. Empty or lightly-loaded containers can be quickly and precisely handled by a 15 t fork lift.

A sealed and enclosed outdoor storage yard of approx. 700 m² is available for cast metal ingots. Deliveries may be stored up to 36 months until treatment, cast intermediate products like ingots can be stored for a maximum of 60 months.

All storage areas are arranged and managed as controlled areas and are monitored accordingly.

A common form of delivery is material packed as bulk goods in the containers. This material will be pre-treated in the sorting and dismantling area.

Dismantling and Sorting

In the sorting and dismantling area, it is a routine operation to handle parts and components up to the size of a 40' transport container for thermal and mechanical size reduction. A special dismantling layout, which utilises a temporary extension to the dismantling area and thus allows handling of even larger parts, is available for larger components.

Containers are docked at the container lock of the CARLA building and are unloaded through the front doors. It is also possible to place containers completely in the dismantling area for open-top unloading.

The material will be separated by material types and, if necessary, dismantled down to furnace-suitable sized pieces. Material is regarded as furnace-suitable in size if it has dimensions of < 500 mm x 500 mm x 1,500 mm. A hydraulic shear with a press capacity of 450 t is available for mechanical separation. Given that the shear compactor channel dimensions are 5,000 mm x 1,500 mm x 500 mm, approx. 75 % of the delivered bulk scrap can be processed in this manner. In particular cases, mechanical cutting using a band saw is applied, and this is a cutting technique which is effective and well-proven. Various hand tools complete the equipment available for mechanical dismantling.

Large or particularly thick-walled components can be thermally cut in the torch cutting chamber. Here, gas as well as plasma torches are available.

The combination of both methods, mechanical and thermal size reduction, provides a broad basis for an effective and successful dismantling process. Relocation of components to be

dismantled to storage and processing areas at CARLA can accelerate decommissioning projects and directly generate significant benefits for the customer and other stakeholders.

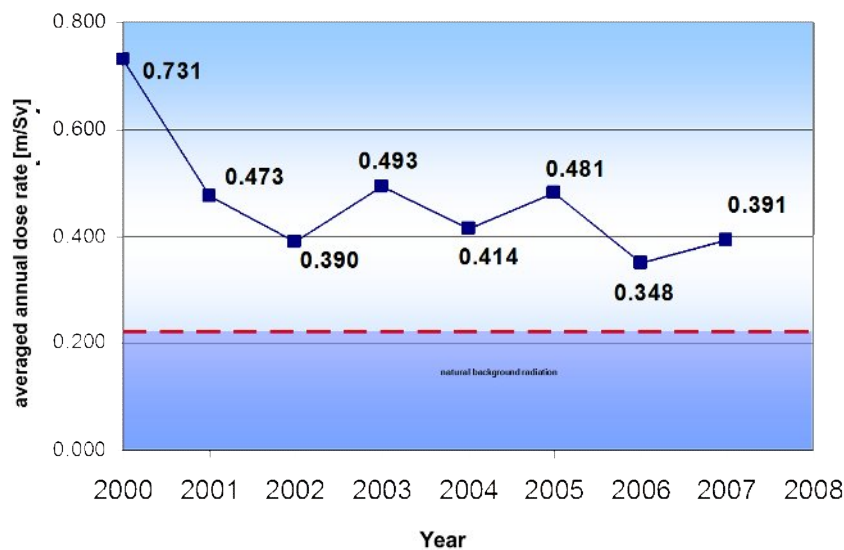


Fig. 2: Annual dose of CARLA workers

Another possible treatment step in the sorting and dismantling area is pre-decontamination in a blasting cabin. The bead blasting installation is an integral part of the process and was dimensioned in such a way that cabin and melting furnace have matching dimensions. As the blasting material used is exclusively steel beads, the beads can be recycled after use by melting. The blasting cabin has a dedicated filter system in which the resulting dust is specifically collected for each customer. The blasting cabin is usually used if release after melting is the primary target for a campaign. It is also utilised in most cases where the metallurgical make up of the material concerned makes it unlikely to be subsequently utilised within the nuclear environment for the production of cast iron containers. This dry abrasive technique of surface decontamination has been established for many years now and yields very good decontamination factors with low secondary waste accumulation.

When a sufficient amount of material has been prepared by sorting, dismantling and blasting, it will be handed over to the melting shop.

Melting Shop

The central element of the CARLA facility is the melting furnace. The whole material flow and the ventilation system are designed for this core component.

The furnace is a medium-frequency induction furnace with a capacity of 3.2 t for steel and a melting performance of 2 t/h at full load. Ventilation is configured with the use of an inner housing such that the main facility is separated from the furnace area, and the furnace can therefore be operated in parallel to the dismantling and sorting works.

The furnace is a high-powered unit and produces strong electromagnetic circulation in the melt. Both are essential aspects for successful recycling of contaminated metals.

The built-in furnace scale is integrated in the control unit and allows all charges and discharges to be recorded per furnace batch.

By use of various crucible materials and the application of special melting procedures, the furnace can be used for the melting of steel and iron as well as for non-ferrous metals like copper, brass and aluminium. Moreover, the furnace and ventilation concept allows for the processing of zinc-coated steel, a very demanding task which requires experienced foundry personnel. For various materials and types of contamination it is possible to draw upon special melting procedures and treatment algorithms, which have been developed internally and which have been demonstrably optimized.

The furnace operation, including charging of the furnace, is controlled via a panel which is separated from the area with special glass panes to allow observation of the operations. The safety of the operational staff is thereby increased, and at the same time the dose exposure is considerably reduced. For charging the furnace with scrap, a manipulator is available in addition to a crane with special grippers and magnets.

The CARLA furnace operation requires access of workers within the inner area for deslagging, measuring temperatures or taking samples, as these work activities are most effective when performed manually.

After melting, treatment, deslagging and sampling the melt is cast.

Casting of the Melt

The melt is usually cast into pre-heated, cylindrical permanent moulds, also called diecasts. The form of a diecast was designed so that the solidified metal ingot is approximately the same size as the inner dimensions of a 200 l drum. The diecasts consist of an outer steel jacket with trunnion for handling with a sintered refractory crucible liner. The crucible liner is manufactured foundry-compliant and is thermo-mechanically very stable. Thus the diecasts can be used as a permanent mould for a longer period which contributes to minimizing secondary waste (Fig. 3).



Fig. 3: Casting to 1 t ingots

After this the ingots are pulled out of the diecast and are cleaned of any possible remaining slag particles in the blasting cabin. Although the ingots are processed free of loose surface

contamination, all ingots will be radiologically measured before releasing them from the controlled area for outdoor storage.

The iron ingots have an average weight of 1,000 kg (Fig. 3) with an extremely hard surface due to the quick solidification. No specified quality of the iron ingots can be achieved. These iron ingots meet the requirements of passive safety which will be discussed later in this paper. The metal ingots are stored on the ingot storage yard in identified batches until a decision is taken about the further recycling path in agreement with the customer.

Other casting methods can be implemented at the specific request of the customer.

RECYCLING PRODUCTS

The customer-specific solutions developed by the cooperation between GNS and Siempelkamp cover all stages in the field of nuclear waste management from first concept drafts up to final waste disposal. This service extends to all kinds of radioactive waste generated during the operation and decommissioning of nuclear facilities.

MOSAIK® Cask for Transport und Storage

For this purpose various types of MOSAIK® casks (Fig. 4), which are made of cast iron with spherical graphite nodules of GGG 40 quality, are developed and manufactured. Slightly contaminated metal scrap can also be used as recycling material for the production of these nodules. Given the fact that different kinds of waste have to be accommodated, several types of casks were designed with different volumes, wall thicknesses, lid systems and, if necessary, supplementary lead shielding in the walls and filter systems, thus assuring the versatility of the MOSAIK® concept., Special MOSAIK® casks are approved as Type B or IP2 packaging for transport in accordance with ADR. [2]

Cast Iron Container Type VI

This cast iron container (Fig. 4) is a square container made of cast iron with spherical graphite nodules which is used as packaging for radioactive waste from water-conditioning installations in nuclear facilities requiring a higher shielding. The maximum possible load is approximately 1,600 kg to meet the max. allowed weight of a Konrad packaging of 20 t.

The cylindrical and graded lid design of the container dispenses with connectors which are facilitating charging procedure. This container is coated with a layer which can be decontaminated easily. Handling of the container is realized by cross-beams at the integrated ISO corners. The cast iron container Type VI is approved as incident-proof packaging of waste containers class II and is thus suitable for final disposal in the German Konrad mine.



Fig. 4: MOSAIK[®] and Cast Iron Container

More than 5,500 casks manufactured from Ductile Cast Iron (DCI) in cylindrical or cubic form licensed for the German ILW Konrad repository have been manufactured with a recycled metal content of between 15 % and 25 %.

BALANCES

Since 1989 approximately 15,000 t of metallic waste from German nuclear power plants has been melted within the cooperation between GNS and SNT. 2,500 t of the melting products have been released for general re-use. 11,500 t have been recycled for manufacturing casks within the nuclear industry. The average amount of radioactive residues resulting from the melting process is approximately 5 % related to the mass of the melted metal (Fig. 5).

All kinds of ferrous metals like iron, mild steel, stainless steel and zinc-coated steel are being melted. Most surface coatings can be catered for without causing any negative effect on the procedure. Besides the large quantity of iron and steel processed to date, a large amount of non-ferrous metals have been successfully recycled by melting. The high added value which can be achieved by the recycling and release of non-ferrous metals onto the raw material market after successful decontamination by melting makes this path an economical approach for every disposal project [1].

The wide spectrum of treatment and recycling options which can be offered for radioactive metals are shown in Fig. 5. Recycling metals in the material cycle, be it in the form of new products for nuclear technology or as secondary raw material after release, is the primary task. Of course, all of this can only work when cooperating with strong partners, such as GNS Gesellschaft für Nuklear-Service mbH, who use most of the recycling components as construction material for packaging of radioactive waste. A successful melting and recycling procedure facilitates a maximum reduction of volume and costs with regard to storage in final repositories. Generally, of the original 100 % metal scrap, approx. 5 % remains as radioactive waste in the form of secondary waste which must be stored in a final repository. 95 % of the original quantity can be recycled insofar as the described options are applicable. The quantity of secondary waste depends exclusively on the material and is subject to fluctuation. The following assignment of the waste types can be regarded as the statistical average from operation up to the present.

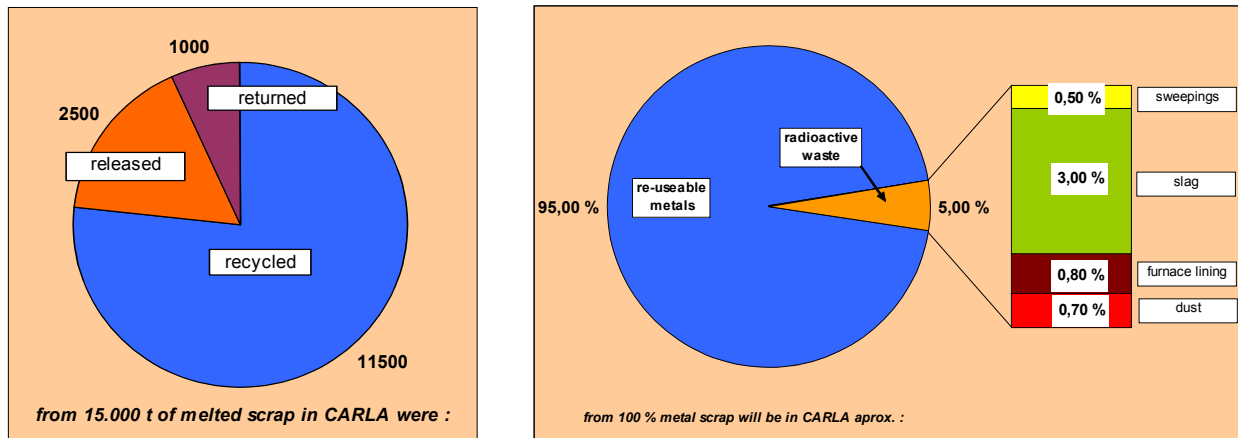


Fig. 5: Material and Waste Balance

RELEASE

Besides the use of metal ingots for the production of new components for nuclear cycles, release and the later use as secondary raw material plays an important role in our recycling concept. Engineering-wise the melting procedure is by far the optimum solution. A homogenous liquid melt can be very easily and representatively sampled by a single sample. Approx. 3,000 kg metal melt can be qualified by using a so-called “coin” sample. The sampling and measuring effort required for other methods of the same quality are much higher. Additionally the “coin” samples can be retained and drawn on at any time for control purposes by authorities, experts or even the customer. The quality blend resulting from the procedure with regard to material analysis, geometry and mass of the ingots (approx. 1,000 kg) as well as the hard surface finish are passive safety features which exclude any other use after release other than melting again together with other scrap. Besides active measures such as, for example, corresponding declarations of obligation by the customer, precisely these passive aspects point favourably to the ingot as the preferred release object for metals.

As a last internal control step, the application of a large scale detector has proved of value for checking the marketability of the ingots.

Currently, 2,500 t of ingots are being released for GNS.

CONCLUSION

Thousands of cubic metres of final disposal capacity have been saved. The highest level of efficiency and safety by combining general surface decontamination by blasting and nuclide specific decontamination by melting associated with the typical effects of homogenization. An established process - nationally and internationally recognized. Excellent connection between economy and ecology.

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