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MELTING AND GRANULATING OF CONTAMINATED STEEL SCRAP

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ABSTRACT

Increasing quantities of radioactively contaminated and activated metallic residues can be expected to be treated and disposed off due to decommissioning of nuclear installations and site remediation.

In view of the high disposal costs and the anticipated long intermediate storage time maximum volume reduction of radioactive waste is one of the key-notes.

For more than 10 years Siempelkamp's CARLA melting plant in Krefeld has successfully demonstrated the recycling of slightly radioactively contaminated scrap. Re-use has been represented by manufacture of high-quality waste containers and shielding equipment made of ductile cast iron.

In the last few years a supplementary recycling path has been developed in order to involve the potential of scrap with high chromium and/or nickel content. The process is based on a special granulating technique and the substitution of the hematite (iron ore) portion of heavy concrete shieldings.

For official attestation of the granule concrete shieldings all necessary tests for type A/IP II container approval have been successfully performed according to the IAEA requirements. Furthermore, different versions of such containers have been qualified for their usage in German repositories.

INTRODUCTION

During the last decade melting technology has been developed and commercially established as an adequate safe method for recycling of low-level radioactive scrap saving costly storage volume and reducing consumption of raw metal. The method is based mainly on a separation effect of the radiologically dominant nuclides during the melting process at roughly 1500°C, which leads to a significant transfer of these radionuclides into the process waste such as slag and filter dust representing only a few percent of the overall mass. The treated metal can be normally re-used by manufacturing of waste containers and shielding equipment (recycling portion approx. 30 wt.-%).

As high chromium and/or nickel contents of the scrap reduces material toughness by degenerating the material structure a supplementary recycling path has been developed based on a special granulating technique (Fig. 1). The generated granules are used as substitute for hematite in the production process of heavy concrete for shieldings.

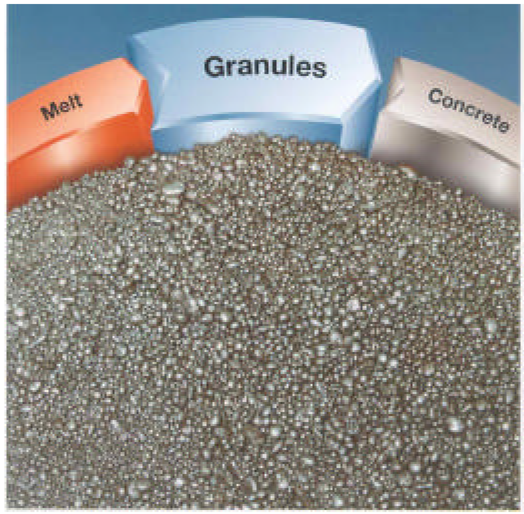

Fig. 1: The general process chain for manufacturing of granulate concrete shieldings

Extensive R & D work since the early nineties together with research institutions as well as concrete experts and manufacturers led in the last few years to a new technology for producing heavy concrete shieldings and waste containers with remarkable material characteristics.

THE PROCESS

The temperature of the melt in the melting furnace amounts to approx. 1700°C where high-grade steel is used as the initial material; when using a carbonized material this amounts to approx. 1550°C.

The liquid iron is passed from the furnace to a ladle and then poured into a 20m² water basin after ladle treatment (Fig. 2). The pouring stream is thereby broken up by means of a lateral water jet (Fig. 3). Small iron droplets are formed which solidify and cool off in the water basin.

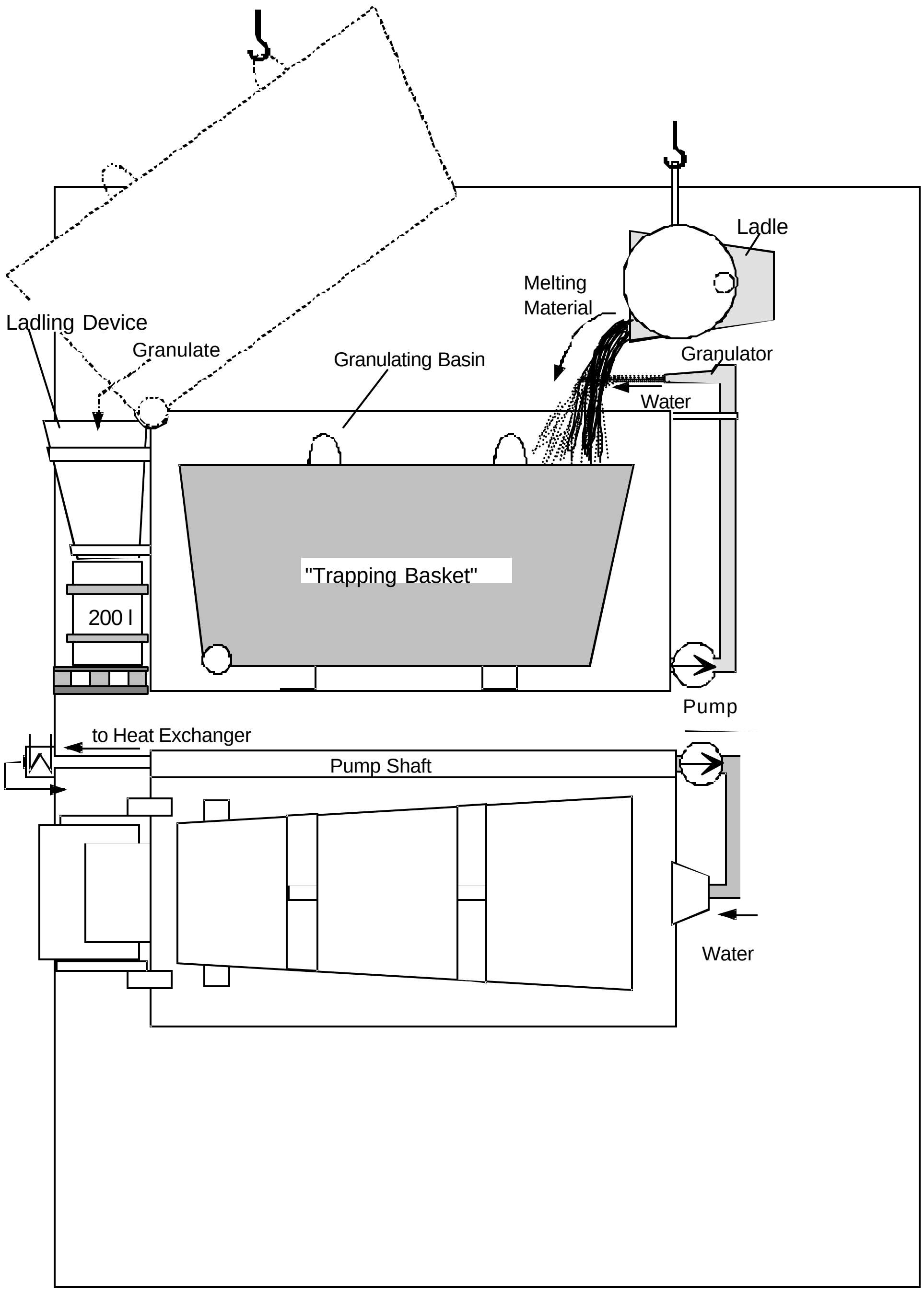

Fig. 2: Basic drawing of a granulator station

Fig. 3: Granules production in Siempelkamp's CARLA plant

Shape and size of the granulate are, amongst others, influenced by parameters such as melting additives, pouring speed, melt temperature, water temperature and pressure as well as diameter of the water jet. Highest uniform shielding efficiency of the shielding equipment to be produced is realized by using spherical, massive granules with diameters between 1 mm and 8 mm (Fig. 4).

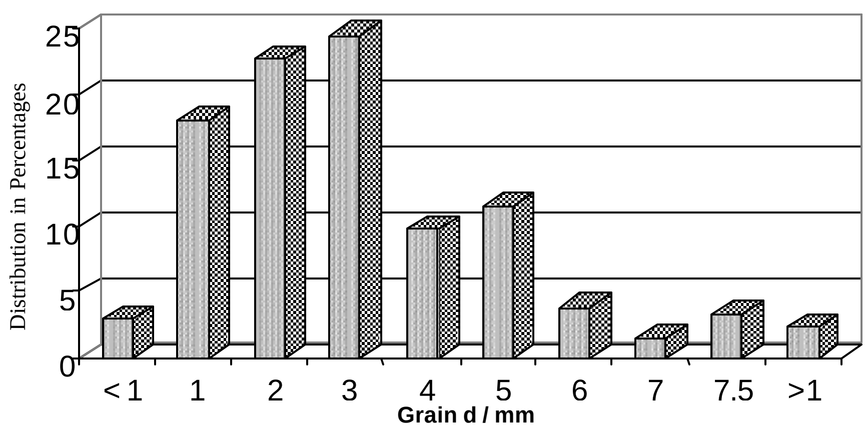

Fig. 4: Typical screening analysis of the granules production

The production capacity of Siempelkamp's CARLA plant is roughly 2-3 Mg of granules per hour. Final drying of the granules minimizes corrosion and agglomeration effects especially in case of longer storage periods before subsequent production steps.

The concrete for the manufacturing of heavy concrete shieldings is a special mixture of the granules with concrete additives. The most important parameter during the process is a well defined water content of the concrete to guarantee homogeneous material properties. Following the mixing step the material is filled into permanent moulds for the hardening process, which are already removed within a one hour period. Fig. 5 shows the view into a typical granule concrete shielding container gained by this procedure.

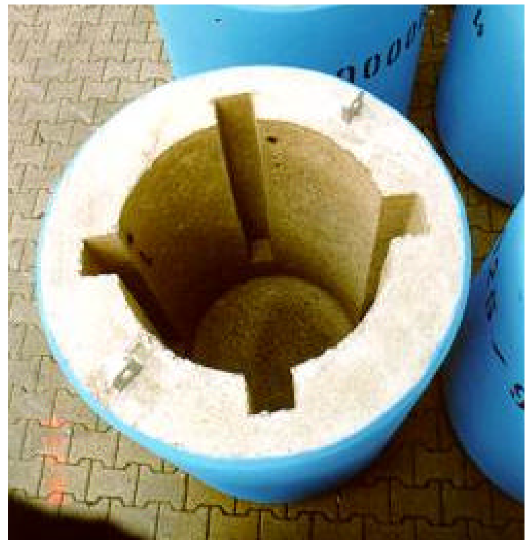

Fig. 5: View into a granule concrete shielding container for 200 l drums

MAIN CHARACTERISTICS OF THE GRANULATE

In general, as in other manufacturing processes, the quality of the product is obviously strongly dependent on the quality of the input material and the qualification of the work force.

In addition, some special characteristics can be emphasized for the granule concrete: Fig. 6 demonstrates the specific shielding effects of iron granule concrete with a density of ρ =3.5 kg/dm³ and normal concrete with ρ = 2.4 kg/dm³ depending on the wall thickness. Compared with normal concrete, the shielding effect of granule concrete therefore is higher by more than 45 %. The mentioned reference density of 3.5 kg/dm³ is achieved with an approx. 55 weight-% proportion of iron granulate. A value up to 4 kg/dm³ can be adjusted, which cannot be realized with the usual additive hematite.

A further advantage of the granule concrete is the significantly higher compressive strength of approx. 65 N/mm².

The homogenity in the shielding is guaranteed by the production procedure and has been manifested on several containers by means of radiography tests using a Co 60 test source inserted.

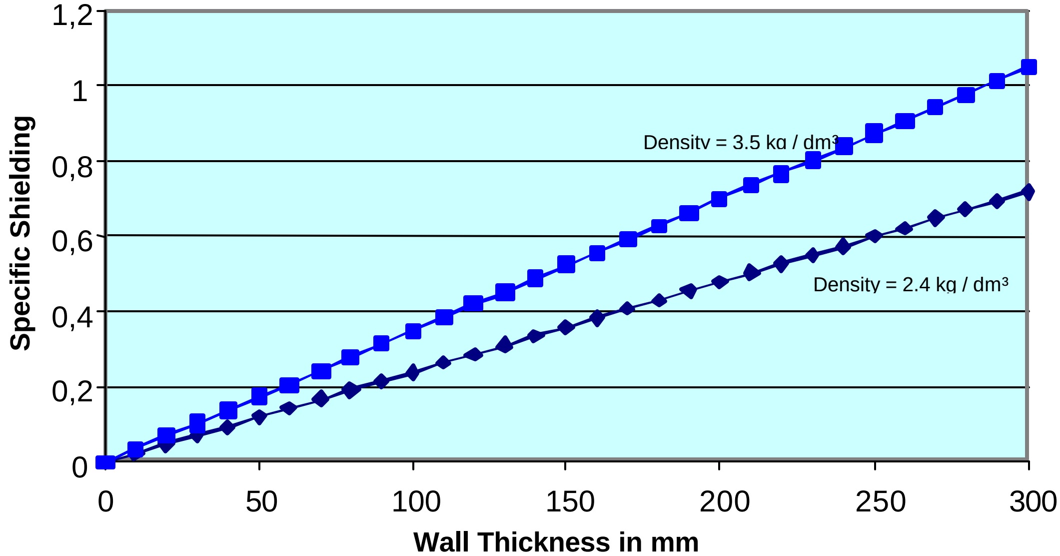

Fig. 6: Specific shielding in dependency of the m aterial density

THE QUALIFICATION

For official attestation of the different versions of granule concrete shielding containers all necessary tests for the so-called type IP-II as well as type A approval were performed stepwise from the beginning of 1997. An impression of a 0.8 m drop test according to the requirements for the German KONRAD repository is provided by Fig. 7. The component integrity was kept without any problems.

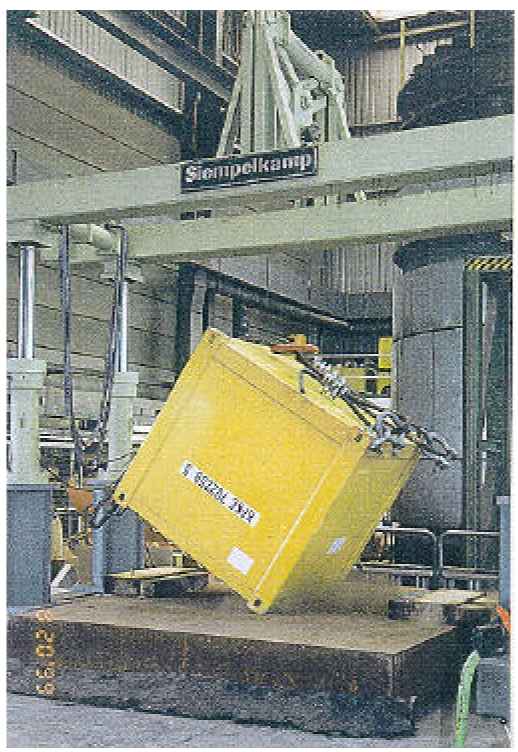

Fig. 7: 0.8 m drop test

Fig. 8: Stackability test for PSC-container

Fig. 8 shows a stackability test for a so-called PSC-container.

To get the approval for the German final depository Morsleben (ERAM) the thermal conductivity of the granule concrete had to be measured. Assuming the worst case the thermal conductivity was 1.6 W/Km, a value which is low enough concerning a minimal container wall thickness of 140 mm.

After successful tests the German authorities gave their approval to the various container versions described in more detail as follows.

THE PRODUCTS

A variety of containers made of different materials (e.g. nodular cast iron, steel, normal concrete, heavy concrete based on hematite or iron granulate) exists in Germany for securing radioactive waste. Containers for radioactive waste with negligible heat development are constructed in such a manner as to meet the requirements of German Transportation Law as well as e.g. compliant with the final storage conditions for the planned German final storage site, Schacht Konrad. The main criteria for planning are environmental influences as well as thermic and mechanical faults. For example, a container must be stackable six-fold, must resist a drop from 0.3 to 1.2 m and withstand fire damage of 800°C for one hour. Due to the load limitation average in final storage, the total permissible overall weight for cylindrical containers is limited to 4 Mg, for cubic containers the max. weight is limited to 20 Mg. The dimensions of the containers are adapted to the load limitation and laid down in the final storage conditions.

Within these general boundary conditions Siempelkamp is offering several types of heavy concrete shieldings with granulated recycled metal scrap (Fig. 9) as listed with their main characteristics in Table I.

Fig. 9: Siempelkamp heavy concrete shieldings with granulated recycled metal scrap

Table I: Overview on Siempelkamp's granule concrete containers

Container type	**GBA 200**	**GBA 400**	**GBC-Type IV**	**PSC-Type II**
Konrad storage classification	I	I	I *)	I
Transport classification	Type A	Type A	IP II	IP II
Dimensions [mm]				
Length	∅ 1,060	∅ 1,510	3,000	1,700
Width / Diameter	1,370	1,370	1,700	1,600
Height			1,400	1,700
Shielding thickness [mm]				
Concrete	100	100	200	80-220
Steel				10-100
Drum insertion	1 x 200 l	1 x 400 l	8 x 200 l	
Max. permitted weight [kg]	4,000	4,000	20,000	20,000
Weight empty [kg]	2,900	2,600	Ca.13,500	6,000 –14,000
Volume [m³]	1.2	1.34	7.14	4.7
net volume [m³]	0.325	0.54	3.18	1.4 – 2.7
Granulate re-use [kg]	ca.1,450	ca.1,300	ca.7,000	1,800 – 4,000

The cylindrical GBA type is used for containing a 200 l - drum or a 400 l - drum respectively, where the drum provides the tightness and the concrete shell serves for the fixation and the shielding effect.

Eight 200 l - drums are contained by the cubic GBC type.

A special newly introduced version is represented by the so-called product steel container (Fig. 10) consisting of a sandwich steel shell with granulate as additional shielding material in between. Production of this container type is based on a licence granted by FZK. The most advantageous features of this version are given by the exclusion of chipping of concrete due to inappropriate handling as well as by the capability of surface decontamination.

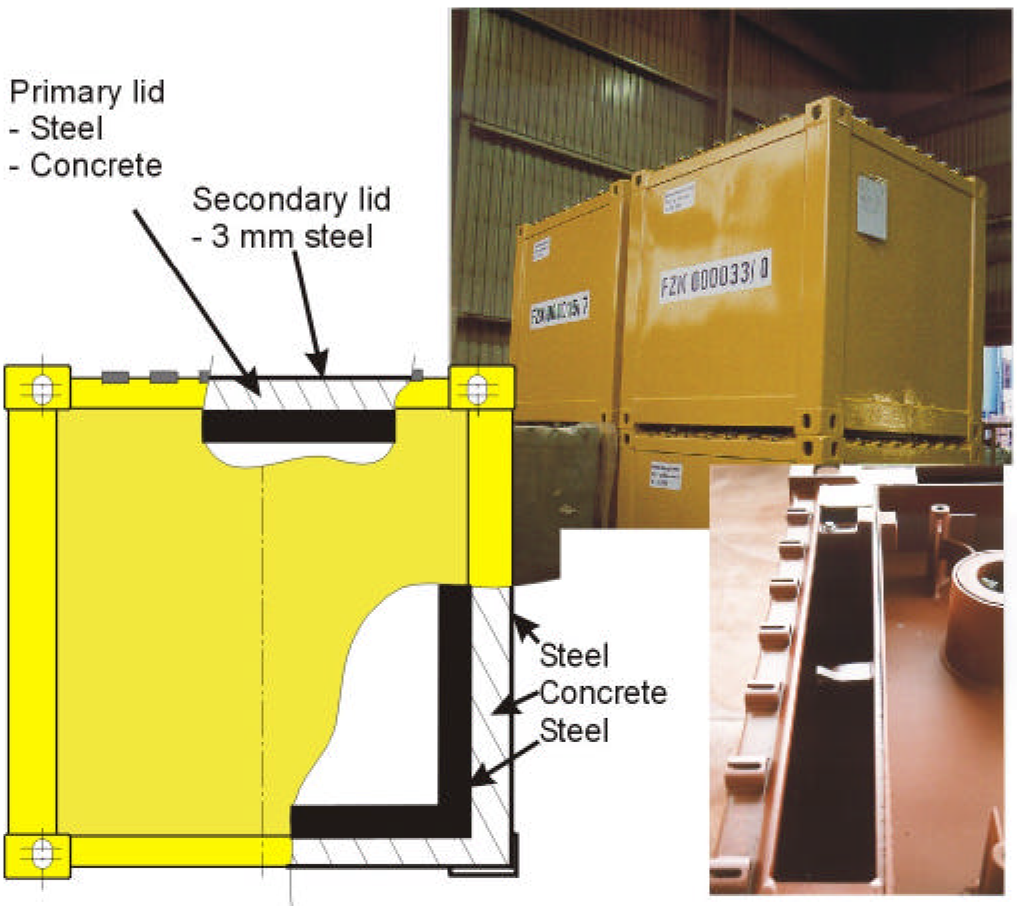

Fig. 10: Product steel container

Last but not least, it should be mentioned that this new technology found interest to be involved in the waste management activities for the Chernobyl area as well as to provide shielding elements to the sarcophagus work for the unit 4 of the Chernobyl NPP (Fig. 11).


Fig. 11: Unit 4 of the Chernobyl NPP

CONCLUSION

With the granulation technique an alternative recycling path for highly alloyed steel scrap has been developed and qualified for commercial application according to national (German) and international (IAEA) regulations.

Evidently, this technique could be also applicated for "ordinary" metal scrap providing an additional adequate sink for hazardous material.

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