WASTE ARISING FROM DISMANTLING OPERATIONS : MELTING CONTAMINATED SCRAP IRON

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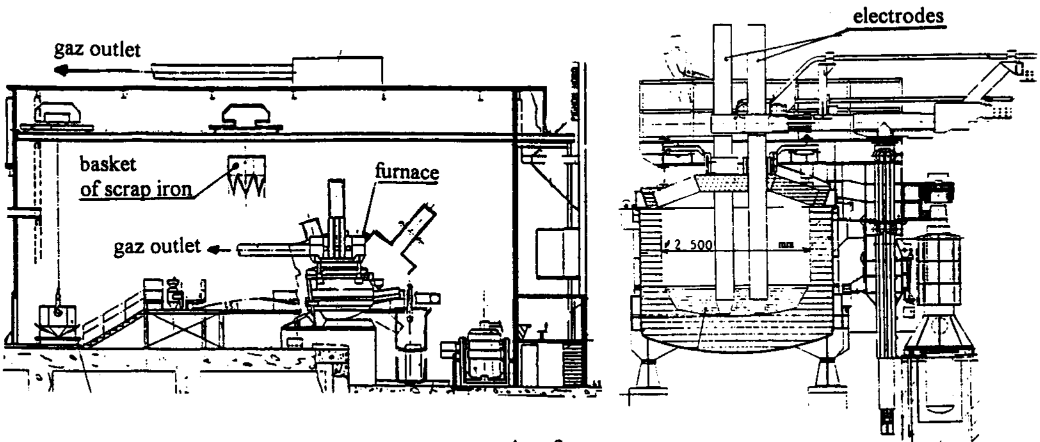
INTRODUCTION

The « Institut de Protection et de Sûreté Nucléaire » (IPSN) assessed the safety of melting operations for contaminated scrap iron which are carried out in an arc furnace with a capacity of 15 tonnes, located at Marcoule. The « Unité de Démantèlement des Installations Nucléaires » (Unit for Nuclear Installations Dismantling) of the CEA « Direction du Cycle du Combustible » (Fuel Cycle Direction), is responsible for operating this furnace.

To day, more than 5,000 tonnes of radioactive iron have been melted, of which 4,000 tonnes resulted from the dismantling of the coolant systems (CO_2) and the auxiliary equipment of the G2 and G3 reactors. Initially, the iron was cast into 25 kg ingots and into 4 tonne blocks which were placed in interim storage in the G2 and G3 facilities. Then, the scrap iron was made directly into either biological shielding or into cast iron containers for packaging highly radioactive waste.

The radioactive spectrum of scrap iron from dismantling of the G2 and G3 reactors was composed of ^{60}Co (95%) and ^{137}Cs.



Arc furnace

DESIGN OF THE FOUNDRY : LIMITING THE RISKS

The maximum allowable level of radioactivity for materials to be melted was set so that the permissible limits regarding radiological conditions at work for personnel, gaseous discharges into the environment and removal of waste, could be respected.

IPSN took particular care to verify that the dose rates in areas where personnel would be permanently present always remained less than 2.5 μGy/h and that the maximum atmospheric contamination level in the melting room always remained less than 80 times the Derived Air Concentration Limit relating to the radiological elements present.

The arc furnace has a cup which enables very large pieces of scrap iron to be melted. This reduces the amount of cutting, dismantling and handling during preparation of the scrap iron in the foundry. This helps to reduce the overall doses and also helps to reduce the risk of dispersal of radioactive materials during these operations.

This is due to the fact that sections of the pipe-work from the coolant systems of the G2 and G3 reactors, which were 1,200 and 1,600 mm in diameter, could be put directly into the furnace cup which has an inside diameter of 2,500 millimetres. It was not necessary to cut these pipes into small pieces, as would have been the case with an induction furnace which has a much smaller capacity.

To limit the ionising radiation exposures of the workers in the foundry, the majority of the operations are carried out remotely from a control room. The presence of operators in the melting room next to the furnace is limited to rake out slag and to control temperature, i.e. to four workers for 20 minutes per heat.

In order to prevent dispersal of radioactive materials in the foundry rooms, the room containing the furnace is maintained at lower pressure by means of a ventilation system. This ventilation system is also designed to capture the gases and aerosols produced by melting, as close to their emission as possible.

These gases and aerosols (400 kg per heat) are removed at three places : directly from the furnace, from the room immediately above the furnace and from the casting area. The extraction network of this ventilation system, removing around 40,000 m^3/h, is equipped with gas cooling devices and three filtration stages. These are a bag filter, a high efficiency filter that can be unclogged, and a final very high efficiency filter.

Around 99% of the dust emitted is removed by the ventilation system and most of it is captured by the bag filter. The dust which is dispersed in the melting room is removed during the weekly cleaning of the room.

After IPSN had assessed the experience gained from one year of operation and the radiological reports, the maximum limit of radioactivity for the material to be melted was increased, for example, for cobalt from 250 Bq/g to 400 Bq/g.

The main radiation risk in the foundry relates to the complete loss of filtration which could lead to a release of contaminated gases and aerosols by the stack, which could reach 2.7 GBq. However, this accidental condition would have no significant effect on the environment.

REDUCING THE VOLUME OF WASTE

In order to reduce the total volume of dust generated by melting and captured by the bag filter, the dust is returned to the furnace to be melted. Experience has shown that this recycling system does not significantly increase the quantity of dust produced by each melting operation. The number of times it can be recycled is, of course, limited, owing to the increase in radioactivity of the resulting dust.

As regards slag, tests showed that its final volume cannot be significantly reduced by recycling, so it is not.

Melting enables the initial volume of metallic waste to be reduced by around a factor of 10. Furthermore, recycling scrap iron in the nuclear field avoids to use new materials (not contaminated) and, therefore, to increase the final volume of wastes.

FOUNDRY OPERATION REPORT

Radioactive elements are mainly emitted when the scrap iron melts, and not when it is put into the furnace. As this melting phase always occurs when the furnace is closed, and the gases are removed directly from the furnace cup, the dispersal of radioactive materials in the melting room is relatively low. It must be noted that scrap iron is loaded four to eight times during each melting operation.

During melting, the behaviour of each radioactive element depends on its metallurgical properties and on the physical and chemical conditions under which melting is carried out. Therefore, some radioactive elements are systematically lost from the melting bath as aerosols, such as caesium, or as gases, such as tritium. Others are found in varying proportions in the slag and dust. Others, such as cobalt, remain almost totally in the cast iron.

The behaviour of certain radioactive elements such as uranium can vary, depending on the characteristics of the melting bath. Indeed, in the case of reducing conditions (when carbon is added at the beginning of melting), a large proportion of uranium remains in the cast iron. However, during oxidizing melting (without adding carbon), a large proportion of this radioactive element is found in the slag (70%) and in the dust (30%). Moreover, the addition of oxidizing products during melting increases the amount of uranium recovered in the dust. It is therefore possible to extract the uranium from the cast iron produced by melting.

Experience has shown that radioactive elements remaining in the cast iron, mainly cobalt 60, are uniformly distributed in the material.

Since the foundry started operating in 1992, and until the end of 1995, the total exposure of the foundry personnel was 35 man-mSv. This dose equivalent was shared between around 20 to 25 workers and represented, in comparison, less than 6% of the collective dose equivalent received during all the partial dismantling operations of the G2 and G3 reactors. Finally, the radiological cost per tonne of scrap iron melted in this furnace was on average of 7×10^{-3} man-mSv/t.

OPERATING INCIDENTS

Since the foundry began operation, three significant incidents occurred.

1. Simultaneously loading, for test, sections of pipes and 25 kg bags of manganese compounds into the furnace led to high pressure in the furnace which was channelled towards the top through the sections of pipe, thus lifting a melting room ceiling slab. However, no dispersal of contamination was revealed in the hall outside the melting room. The incident was most likely due to the bags being damp. The adding of manganese is given up.

2. 2.5 tonnes of steel tubes with concrete still adhering to them were put in the furnace which already contained 10 tonnes of molten steel, resulting in a violent reaction. Several slabs of the melting room ceiling were lifted. In this second incident, only the external part of the melting room ceiling was slightly contaminated around the damaged area. This incident was caused by the presence of concrete. The adding of concrete is prohibited.

3. Following one melting operation, a fire was revealed in the bag filter of the gas extraction network. Around 40% of the bags were partially burned. The two other filters placed further down the network were smokelogged, which lead to an increase in their pressure loss and to their deterioration. The quantity of radioactivity released through the stack was less than 540 kBq of ^{137}Cs. This incident was due to the introduction of reactive metals (magnesium, zinc, zirconium, ...). The checking of absence of reactive metals is enhanced.

CONCLUSION

The operating experience of the foundry shows that the risks of dispersal of radioactive material and of exposure to ionising radiation are properly controlled and that the main difficulty lies in acquiring a sufficient knowledge of the chemical composition of the scrap iron so as to avoid introducing materials which could lead to violent reactions during melting. In addition, in comparison with conventional steelworks, the effects of violent reactions are accentuated by the small size of the melting room.

Notwithstanding these incidents, it appears that melting radioactive scrap iron in an arc furnace can be carried out in satisfactorily safe conditions providing their radioactivity and above all, their physical and chemical compositions are known. Setting up a quality assurance programme for the reception of scrap iron at the foundry, systematic analysis of test pieces and rigorous visual monitoring enable the properties of the materials for melting to be better discerned, and thus avoid the presence of materials which could lead to violent reactions during melting of the scrap iron.

Recycling steel in the nuclear industry in the form of biological shielding, containers or other semi-finished products, appears to be an economically viable solution and poses few radiation risks. The mean radioactivity per unit of mass of recycled steel in the plant is about 10 Bq/g.

At last, melting contaminated steel reduces its contamination level and concentrates the radioactive elements into a significantly reduced volume with a better confinement.

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