NICKEL PLATING OF SPENT FUEL ELEMENT TRANSPORTATION AND STORAGE CONTAINERS

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Abstract

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For economic reasons, the stainless steel used for nuclear transport and storage containers has been replaced by a significantly less expensive, but almost equally suitable material – spheroidal graphite cast iron. Because of the impossibility of sufficiently decontaminating raw cast iron surfaces, a suitable coating had to be developed. Steel lining, epoxy painting and soft nickel plating are known possibilities. If both the requirements made on such a coating and the economics are considered, soft nickel seems to be the most attractive solution. The paper describes the process of soft nickel plating which was developed by Von Roll, Switzerland, based on its proprietary "Toraxier-Process" – in co-operation with GNS (Gesellschaft für Nuklear-Service mbH, Essen). Soft nickel plating has been successfully applied to more than 30 Castor containers.

1. INTRODUCTION

Because of the high mechanical requirements on fuel element containers, these casks were originally made of stainless steel. The transportation and dry storage of spent nuclear fuel elements has now become a 'normal business' and economic considerations have become increasingly important. The search for a less expensive material which would, of course, have to meet mechanical and safety requirements, has been a natural consequence. Simple and substantial decontaminability was another requirement on the containers to allow for multiple usage.

After evaluating several possibilities a classical solution was found, namely, the replacement of the expensive stainless steel by cast iron plus a surface coating.

Ordinary cast iron would of course be too brittle. Spheroidal graphite cast iron (GGG 40), however, is a ductile material with mechanical properties similar to steel but significantly less expensive [1].

Raw cast iron surfaces, however, are rough and virtually impossible to decontaminate. Certain parts of the containers – especially their inner surfaces – have therefore to be coated with a suitable material. Specific requirements on this coating include:

- high adhesive and mechanical strength to withstand mechanical forces and thermal stresses to which the container may be exposed, together with high ductility
- high leaktightness with respect to helium penetration
- high chemical/corrosion resistance
- high resistance to mechanical abrasion
- ease of decontamination; smooth surface
- irradiation resistance with respect to all the above-mentioned qualities.

2. ALTERNATIVE COATINGS

The following coating possibilities are known:

(a) Stainless steel lining
(b) Epoxy painting
(c) Soft nickel plating.

Stainless steel liners are expensive. Actually they are not real 'coatings'. The connection between the basic container material – the cast iron – and the liner could never be as tight and close as in the case of alternatives (b) and (c). Experiments, performed by EIR, Würenlingen, have demonstrated that as far as decontaminability is concerned steel is only comparable to epoxy and nickel coating if its surface is mechanically polished [2].

Epoxy painting is cheap. However, the above-mentioned EIR tests showed that the epoxy surface had suffered substantially after an irradiation exposure of 3.1×10^6 Gy (3.1×10^8 rad). Therefore this type of coating fails on irradiation resistance.

3. NICKEL COATING

Electrolytically deposited nickel layers are generally highly suitable for the application discussed in this paper. However, the usual electrolytic nickel coating processes are rather inadequate with respect to the coating thickness. In practice, pores and other inhomogeneities frequently occur, as well as unequal distributions of the nickel, if the layer is thicker than a few tenths of a millimetre. Hydrogen embrittlement of the basic material may also occur as a severe problem in electrolytic processes.

TABLE I. PHYSICAL AND MECHANICAL QUALITIES OF SOFT AND HARD NICKEL (TORAXIER-PROCESS)

Quality	Soft nickel	Hard nickel
Density (g/cm^3)	8.9	8.9
Melting point (°C)	1450	1450
Coefficient of thermal expansion (10^{-6}/°C)	14–17	12–15
Electrical resistivity at 20°C ($\mu\Omega \cdot cm$)	7.4–7.8	8.6–12.4
Hardness (HV)	200–250	550–600
Tensile strength (N/mm^2)	400–500	1200–1400
Extension (%)	25–30	2–4

Von Roll has developed a proprietary process for the electrolytical deposition of nickel layers up to 10 mm of thickness or even more, known as 'Toraxier-Process'. Based on specific electrolyte compositions, process parameters and equipment design, highly uniform, homogeneous and thick nickel layers of reproducible qualities are deposited. Hydrogen inclusions are prevented and the nickel coating is therefore virtually free of pores.

In Table I several important physical and mechanical qualities of soft and hard nickel as produced by the Toraxier-Process are listed.

For the coating of spheroidal graphite cast iron containers, layers of a certain type of soft nickel are used, mainly because of the high ductility of the material. However, Table I gives an indication of the wide variety of mechanical and physical qualities of nickel coatings which can also be produced by the Toraxier-Process depending on process parameters.

Soft nickel platings are highly resistant to most neutral and alkaline media, to atmospheric corrosion and high temperature oxidation. Corrosion resistance to acid media is less favourable.

Concerning decontaminability after significant irradiation exposure, the experimental investigations by EIR [2] already mentioned, where different decontaminating procedures were applied, led to the conclusion that electrolytically deposited nickel coatings were extremely favourable, as a result of their mirror-like surface and high corrosion resistance.

4. NICKEL COATING OF CASTOR CONTAINERS

The present status of nickel plating technology at Von Roll for nuclear transport and storage containers was – last but not least – achieved as a result of close

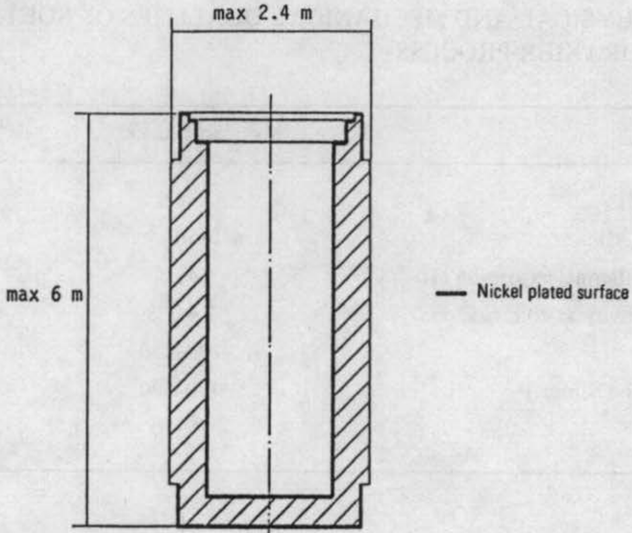
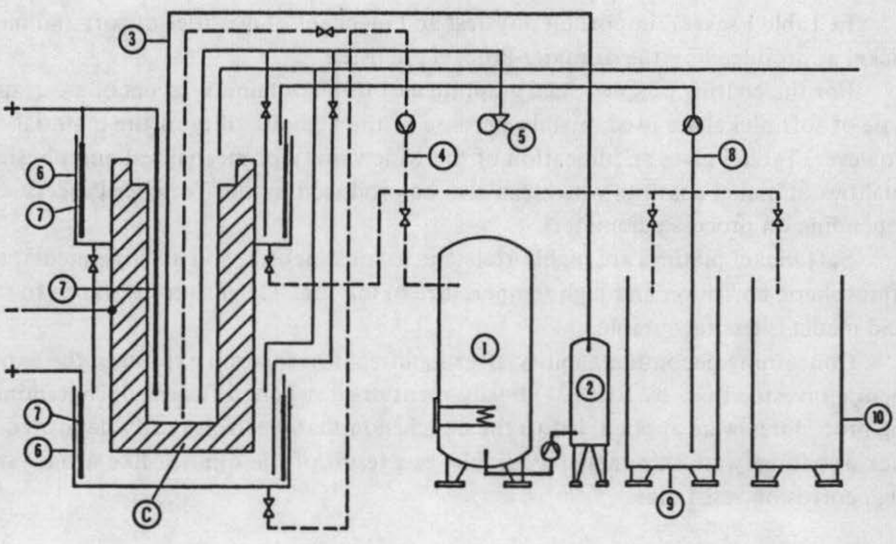


FIG. 1. Nickel plated surface of Castor container.



C. Castor container
1. Ni electrolyte tank
2. Filter and pump
3. Electrolyte flow line
4. Electrolyte return line
5. Compressed air supply
6. Electrolyte container
7. Ni anode

+/–. Electrolyte supply
8. H_2SO_4 flow line
9. H_2SO_4 tank
10. Wash water tank

FIG. 2. Flow chart of Von Roll's Castor container soft nickel plating plant.

co-operation with GNS. This co-operation included a jointly defined and discussed series of experiments concerning nickel plating of Castor containers.

Figure 1 shows schematically the surface areas of a container which are nickel plated; 25–30 m^2 per container are plated with a soft nickel layer of 1.5 mm.

Special equipment was installed at Von Roll's electroplating shop in Klus, Switzerland, to handle these containers, the weight of which varies between 55 and 105 t.

Figure 2 shows schematically the process of nickel plating of different parts of the surface of a container. The electrolyte is continuously cleaned and the process is highly automated.

5. OUTLOOK

Dry storage of irradiated fuel elements is considered a real alternative to storage in ponds. The storage containers also solve the transportation problem between nuclear power plant and intermediate storage facility.

Von Roll has up to now provided more than 30 Castor containers with soft nickel plating for EIR, Switzerland, for the Kernforschungsanlage Jülich and the nuclear power plants of Stade, Biblis and Würgassen in the Federal Republic of Germany as well as for the USA and the USSR

It is certainly reasonable to assume that the concept of dry storage of spent fuel elements in transport and storage containers made of spheroidal graphite cast iron plus soft nickel plating will continue to be applied. Economic reasons clearly favour this solution.

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