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**ELECTRODEPOSITION OF NICKEL ONTO
STEEL USING A SOLUBLE MOBILE ANODE**

G. S. Petit
R. R. Wright

APRIL 1978

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**OAK RIDGE GASEOUS DIFFUSION PLANT
OAK RIDGE, TENNESSEE**

*prepared for the U.S. DEPARTMENT OF ENERGY under
U.S. GOVERNMENT Contract W-7405 eng 26*

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ELECTRODEPOSITION OF NICKEL ONTO STEEL
USING A SOLUBLE MOBILE ANODE

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K-25 Technical Services Division

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Oak Ridge Gaseous Diffusion Plant
Union Carbide Corporation
Oak Ridge, Tennessee

Prepared for the U.S. Department of Energy
under U.S. Government Contract W-7405 eng 26

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ABSTRACT

During the Cascade Improvement Program (CIP), a number of component parts that have been in service for many years will be reused. Many of these parts will have exposed steel from loss of nickel plate or mechanical damage. A good method is needed to patch small areas of exposed steel with electroplated nickel to inhibit the corrosive attack of uranium hexafluoride (UF_6) on the steel.

A method to patch bare plate steel with nickel, using a mobile soluble anode, has been developed by the K-25 Technical Services Division. This report describes the method and presents test results of coupons plated by the method.

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ELECTRODEPOSITION OF NICKEL ONTO STEEL USING A SOLUBLE MOBILE ANODE

INTRODUCTION

A number of component parts which have been in service for many years will be reused during the Cascade Improvement Program (CIP). Many of these parts will have exposed steel from loss of nickel plate or mechanical damage during removal and reinstallation in the plants. A good method is needed to patch small areas of exposed steel with electroplated nickel to inhibit the corrosive attack of uranium hexafluoride (UF_6) on the steel. This technique should also be useful to repair voids in the nickel plate; such as high-porosity areas and plating contact areas on new component parts before installing in the cascade.

It is also necessary to demonstrate that this technique gives good bond of nickel to the steel substrate, that the deposit is low in stress, is ductile, meets the hardness requirements, and is capable of withstanding exposures of UF_6 for 20 to 25 yr. After demonstration of these capabilities, the method must be approved before acceptance as a general procedure for plant usage.

This report describes a method developed by the Plant Support Section, Special Services Department of the K-25 Technical Services Division. The method uses a soluble mobile anode which is constantly supplied with fresh nickel plating solution from a reservoir. Coupons have been plated by this method and tested. The plating method, equipment setup, and test results are presented.

SUMMARY

A method has been developed to patch bare plate areas of steel with nickel. The method uses a mobile soluble anode and electroplates nickel onto steel. The equipment can be used in the field or in the shops to patch areas of exposed steel on parts designated for reuse in the plant.

Coupons were prepared for accelerated corrosion testing and metallurgical examination. This report describes the method and presents the test results. Additional tests will be required before certification for routine plant usage can be effected.

EXPERIMENTAL

TEST APPARATUS

The test apparatus includes the following:

1. dc power supply.
2. Plastic magnetic pump.
3. PVC (Tygon) tubing.
4. Constant-temperature bath.
5. Portable soluble (nickel) anode.
6. Nickel plating solution.

ANODE DESIGN AND EQUIPMENT REQUIREMENTS

The first requirement was to design a portable anode which would allow the nickel plating solution to flow through the anode and onto the surface to be plated. The anode must also be an active (or soluble) anode with a supply of nickel chips (sulfur-depolarized nickel chips from the International Nickel Company, Inc. (INCO)* were used), Figure 1. The complete unit must contain a reservoir of plating solution maintained at plating temperature by a constant-temperature water bath, an all-plastic magnetic pump is required to flow the solution from the reservoir to the anode using PVC tubing for mobility of the anode. A rectifier to supply direct current (dc) for plating and, where possible, a return of the plating solution to the reservoir for reuse. The rectifier positive (+) lead is connected to the anode and the negative (-) lead is connected to the part to be plated (cathode), Figure 2.

SELECTION OF NICKEL PLATING BATH

The nickel sulfamate bath was selected, since it has better throwing power than the watts-type bath, and the nickel deposited from the sulfamate bath is lower in stress. The bath composition and plating conditions were varied to establish the optimum conditions for plating at low- and high-current density (CD). The condition used for low- and high-CD plating are presented in Table 1.

Table 1

NICKEL SULFAMATE BATH COMPOSITION AND PLATING
CONDITIONS USED WITH MOBILE ANODE

Bath Composition	Low CD ^(a)	High CD ^(a)
	40 to 100 ASF, g/liter	100 to 200 ASF, g/liter
Ni(H ₂ NSO ₃) ₂ ·6H ₂ O	425	800
NiCl ₂ ·6H ₂ O	6	30
H ₃ BO ₃	30	30
Sodium lauryl sulfate	2	2
Plating Conditions		
pH ^(b)	3	1.2
temperature, °C	55-60	60-65
(a) CD based on anode area.		
(b) pH adjusted with sulfamic acid.		

*Reference to a company or product name does not imply approval or recommendation of the product by Union Carbide Corporation or the U.S. Department of Energy to the exclusion of others that may meet specifications.

DWG. NO. G-77-674
(U)

Figure 1
MOBILE SOLUBLE ANODE

DWG. NO. G-77-675
(U)

Figure 2
MOBILE ANODE PLATING APPARATUS

SAMPLE PREPARATION

The sample coupons were 2.5 x 6 x 0.5 in. A516 steel. The coupons were degreased in methyl chloroform, dipped in hydrochloric acid (HCl), rinsed, polished in an ammonium acid fluoride (NH_4HF)-hydrogen peroxide (H_2O_2) solution (3 wt % NH_4HF - 6 vol % H_2O_2), rinsed, then dipped in a sodium dichromate ($\text{Na}_2\text{Cr}_2\text{O}_7$)-sodium hydroxide (NaOH) solution (5 wt % $\text{Na}_2\text{Cr}_2\text{O}_7$ -5 wt % NaOH) at 65°C, rinsed in cold water, and air dried.

An area 2 x 3.75 in. was masked off on both sides of the coupons and the masking was air dried overnight. The coupons were activated in HCl and rinsed, and the unmasked area was plated with 3×10^{-3} in. of nickel from a nickel sulfamate bath. The coupons were then water rinsed and air dried.

NICKEL PLATING WITH THE MOBILE ANODE

The masking was removed from one area at a time to expose the bare steel. After removal of the masking, the area was degreased with methyl chloroform, activated with HCl, and rinsed. The part was *not allowed to dry* before the start of plating.

The coupon was connected to the negative lead of the rectifier, the pump was activated to flow the preheated nickel solution (65°C) through the anode and onto the part. The rectifier, preset at 4V, was turned on to start the plating. The anode was continuously moved over the area to be plated. The anode was kept between 1/32 to 3/16 in. from the part being plated. The rectifier was adjusted to the desired current density (200 ASF) and plating continued until the target plate thickness was reached.

The coupons prepared for testing were plated with the high-current density solution at pH 1.2 (Table 1) and 200 ASF.

TEST RESULTS

Two of the coupons were exposed to an accelerated corrosion test which is equivalent to 30 yr of plant exposure to UF_6 . Visual examination of the exposed samples showed only slight darkening of the nickel and no evidence of corrosive attack on the steel or blistering of the nickel plate.

Figure 3 shows an exposed sample after cutting for metallurgical examination with an unexposed sample for comparison. The good adherence of the plate is evident, since no peeling of nickel occurred during the corrosion test and cutting of the sample. Figure 4 shows samples that were flame sprayed with nickel-aluminide coating (95.5 % Ni - 4.5 % Al). This photograph is included only to show the severity of the test and not to degrade the flame spray coating technique.

A photomicrograph of the polished cross section (missing area in Figure 3) shows a clean nickel-steel interface and no evidence of corrosion or separation of the plate, Figure 5.

Figure 3
SAMPLES PLATED WITH MOBILE ANODE
Cut Sample Exposed to Corrosion Test; Unexposed Sample for Comparison

Figure 4
SAMPLES FLAME SPRAY-COATED WITH
NICKEL-ALUMINIDE AFTER CORROSION TESTING

NEGATIVE NO. 17278

500X

Figure 5
NICKEL PLATED WITH MOBILE ANODE
SHOWS CLEAN INTERFACE AFTER CORROSION TESTING

The same cross section (Figure 5) was etched with sodium cyanide (NaCN) and ammonium persulfate $[(\text{NH}_4)_2\text{S}_2\text{O}_8]$ to examine the crystal structure of the nickel deposited with the mobile anode and for lamination, Figure 6a. A cross section of an area with test plate deposited on the conventional nickel plate was also etched to evaluate the bond between the two plates and to compare the crystal structure of the two types of nickel deposit, Figure 6b.

Figure 6a shows evidence a laminate structure of continual columnar crystal growth. Figure 6b shows the interface of the two deposits and the continuation of the same crystal structure as the conventional deposit.

HARDNESS

The nickel deposited using the mobile anode had a Vickers hardness of 196 HV₁₀₀ units. The hardness of nickel deposited by the conventional sulfamate bath was 213 HV₁₀₀ units.

DISCUSSION AND CONCLUSION

The test results obtained appear promising for use of the mobile anode method for *patch* plating nickel on parts to cover exposed steel. Additional tests and data will be needed before the process is certified for plant use on a routine basis. It has, however, been used occasionally in emergency situations. A flow discharge nozzle with about 2 ft² area of bare steel was plated using this method. Figure 7 shows the equipment used and the flow discharge nozzle.

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The authors wish to acknowledge the valuable assistance of J. L. Madix, Gaseous Diffusion Development Division, for performing the accelerated corrosion test and R. G. Vornehm, Special Services Department, for supervising the metallographic evaluation.

NEGATIVE NO. 17164

(A) NICKEL PLATED WITH MOBILE ANODE
SAME SAMPLE IN FIGURE 5 AFTER ETCHING.

500X

NEGATIVE NO. 17166

(B) GOOD BOND BETWEEN NICKEL LAYERS
PLATED BY THE TWO METHODS

500X

Figure 6

SAMPLES ETCHED WITH NaCN AND $(\text{NH}_4)_2\text{S}_2\text{O}_8$
TO EXPOSE CRYSTAL STRUCTURE

Figure 7
MOBILE ANODE PLATING EQUIPMENT USED TO
PATCH PLATE FLOW DISCHARGE NOZZLE

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