WASTE TREATMENT PRACTICES IN THE ELECTROLESS NICKEL INDUSTRY

By

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ABSTRACT

In the fall and winter of 1994 a survey was conducted to establish what the electroless nickel industry presently is doing to treat its different waste streams and the cost of this treatment. A detailed questionnaire was sent to 350 electroless nickel facilities requesting their assistance in establishing the state of waste treatment in the industry. The seven different waste streams surveyed were:

- The rinse water from rinsing the parts after plating,
- The spent electroless nickel bath,
- The spent nitric acid passivation solution,
- The plating and nitric acid solutions lost during transfer of the bath,
- The rinse water from rinsing the tank after transfer and after passivation,
- The spent stripping solution used to remove defective coatings, and
- The vapor, mist and air rising from the surface of the tank.

This paper describes the results of this survey and summarizes the waste treatment practices and costs in the electroless nickel industry today.

SURVEY

Each of the 350 facilities was asked to describe what it did for waste treatment for a *typical* tank rather than for the entire facility. To try to make it easier for the respondents to complete, a *typical* tank was defined as the one that they were most familiar with and was easiest to describe. This could be the tank that they use every day, their largest one, or perhaps the tank that they have had the longest. They were asked to respond to as many questions as possible, even if they did not know the answers to all of them. Multiple choice and yes or no questions were used extensively.

Seventy-three facilities returned the survey. This is equal to a 20 percent response, and confirms the interest of the industry in this subject. Since there are about twelve hundred electroless nickel facilities in the United States and Canada, the response also equals 6 percent of the industry. Thus, the results should be statistically significant.

Of the 73 responses, 18 were captive facilities of manufacturing companies or government agencies. This portion is 25 percent of the total, which is similar to the general portion of captive facilities in the industry. The remainder were commercial job shops. Two of the responses were from Canadian companies.

TYPICAL PLATING TANK

The size of the plating tanks reported for the survey ranged from 10 to 3000 gallons. The geometric mean of the 73 responses was 200 gallons. Thirty-nine of the respondents plated high phosphorus baths in their tank, 42 plated medium phosphorus baths, ten plated low phosphorus baths, and three reported that they used PTFE composite solutions. Many respondents reported using more than one type of solution in the same tank.

[NOTE: Because of the extreme variation in many responses, an average (arithmetic mean) did not appear to give a good representation of the data. For that reason, a geometric mean is used to describe the data in this paper.]

POST PLATING RINSE

The post plating rinse can be the largest volume of waste from an electroless nickel tank, although it usually contains only a small amount of nickel.

Most of the 73 respondents to this section of the questionnaire use flowing rinses after their plating tank. Only 15 percent of the facilities use still rinses, compared to 58 percent who use flowing rinses and 19 percent who use a combination of still and flowing rinses. Two respondents reported using only spray rinses after plating. In addition, 32 percent reported that their rinses were of a counterflow design. Eight percent of the shops use hot rinses after plating.

The number of rinses used was almost equally divided between those using a single rinse (49 percent) and those with more than one (51 percent). The minimum number of rinses reported was one and the maximum was four. The mean number was 1½.

The amount of water discharged from the line was much more diverse. The minimum and maximum quantities ranged from zero to 170,000 gallons per day. [It was obvious with some responses that the question had been misunderstood and that the shop's total discharge had been reported. However, the geometric mean was effective in eliminating these responses.] The mean discharge, however, was 560 gallons per day. This discharge was equivalent to almost three times the plating tanks' volume.

Of the four respondents who reported zero discharge, two were routing all of their waste to evaporators, either for recycling or disposal. The third uses ion exchange to recycle their water. The fourth returns all of their rinse water to the plating tank.

The nickel content of the rinse water also showed a wide variety. It varied from 0.1 to 5000 ppm, with a mean value of about 4.8 ppm. The highest concentrations were for those facilities where the water was recycled through evaporation or ion exchange. Also, as one would expect, the nickel content of the water tended to be lower for those facilities with high discharge rates.

Forty-four percent of the respondents reported spray rinsing the parts over the plating tank to reduce the amount of nickel dragged out. Twenty-four percent of the respondents also pumped part of their rinse water back to the plating tank to reduce the amount that they discharged. Of these, however, only one reported using this water to spray rinse the parts.

Treatment of the rinse water also varied among the respondents. While 54 percent of them sent the water to their conventional treatment system for disposal, 21 percent did not treat the water at all, and 25 percent had a separate treatment system. In addition, two of the facilities used ion exchange to polish the effluent from their conventional system. One facility that does not treat their rinse water, does adjust its pH before discharge.

The separate systems ranged from simple to complex, from NaOH precipitation to reverse osmosis, as shown in the following table.

Number	Percent	Method
1	5	NaOH precipitation
3	16	Sulfide or carbamate precipitation
1	5	High pH chelate break
8	42	Ion exchange
3	16	Evaporation
2	11	Electrowinning
1	5	Reverse osmosis

The two respondents who use electrowinning, then send its effluent to their conventional treatment systems.

The cost of the different treatment methods was also quite variable. Overall, the costs ranged from $0.001 to $4.00 per gallon with a mean of $0.024 per gallon. The cost for those treating in their conventional system only was between $0.001 and $0.15, with a mean cost of $0.009. Ion exchange and evaporation ranged from $0.01 to $0.30 and $0.09 to $4.00 respectively, with means of $0.055 and $0.52 respectively. Only one respondent each reported costs for carbamate treatment, NaOH precipitation, high pH chelate break treatment and electrowinning. These were $0.06, $0.001, $0.002 and $7.00 respectively.

SPENT ELECTROLESS NICKEL BATHS

The spent electroless nickel bath is often the most difficult solution for platers to treat, because it contains large amounts of nickel, complexers and salts.

The biggest surprise of this survey was the number of facilities that successfully treat their spent electroless nickel solutions in their conventional treatment system. Six different shops, ranging from medium sized job shops to very large manufacturing plants, treat their baths using only standard lime precipitation. This represents 8 percent of the total responses. All reported that the electroless nickel bath did not cause any problems with the treatment of other waste streams. All reported a nickel content of less than 5 ppm in their effluent and that they discharged directly to their sewer connection. One of the six, however, also treated the bath with hypochlorite to oxidize organic acids. Only two of the respondents reported their cost for treating their spent baths. These were $0.002 and $0.50 per gallon. The respondent who reported a cost of $0.002 per gallon is a very large manufacturing facility, who reported the same cost for treating all of their solutions.

The remaining facilities, either have the bath hauled away for disposal or treat it in a separate system as shown in the following table.

Number	Percent	Method
15	22	Hauled off for disposal
45	67	Treated separately
7	11	Treated separately or hauled off

Eight of these respondents reported that spent baths have or would cause problems with their conventional treatment system.

Offsite Disposal

Of the seven who either treat the bath or have it hauled away, the decision of which method to use seems to be based on workload and time available. Four facilities, however, did report that it was less expensive for them to send the solutions offsite rather than to treat them. One facility also commented that they use a disposal service "when plate out does not work well".

Of the solutions being hauled away, 26 percent is sent to a hazardous landfill, 39 percent goes to a recycling facility, and 35 percent is sent to another disposal service. Of the latter, one respondent reported that their spent baths were disposed of by deep well injection. Another reported that they returned their baths to their supplier. Two facilities evaporated their baths before shipment to reduce their volumes.

The cost of offsite disposal ranged from \$0.75 to \$8.50 per gallon, with a mean cost of \$1.89 per gallon. None of the different methods appeared to be less or more expensive than the others.

Electroless Plateout

Of those treating their spent baths in separate systems, 35 or two thirds of the facilities use electroless plateout on large surface areas. Fourteen of these facilities reported that they discharge the treated bath directly to their sewer without additional treatment and with nickel contents varying from less than 5 to 50 ppm. The mean nickel content of the discharge was about 8 ppm.

The remaining 21 respondents, however, had to or choose to send the bath on for further treatment. Approximately one half returned the bath to their conventional system as shown in the following table.

Number	Percent	Method
12	57	Returned to conventional system
5	24	Polished with carbamate
2	9	Polished with ion exchange
1	5	Treated with permanganate
1	5	Treated with hypochlorite

The nickel content of the solutions returned to the conventional systems varied from 1 to 150 ppm, with a mean value of about 14 ppm.

Of those polishing with carbamate, two can directly discharge the remaining solution containing less than 5 ppm nickel. Two others returned it to their conventional system with nickel contents between 5 and 50 ppm. The fifth respondent plated the bath out and then polished with carbamate to 5 to 10 ppm nickel. They then treated the solution with hypochlorite, permanganate, peroxide, and lime in their conventional system.

Two respondents plated their baths to nickel contents of 50 to 100 ppm, and then polished with ion exchange. Two others treated the solution with either hypochlorite or permanganate to oxidize the organic acids and discharged at 5 to 10 ppm. One of these facilities evaporates the plated out liquid for offsite disposal.

The cost of treating a spent bath by electroless plateout ranged from $0.33 to $15.00 per gallon, with a mean cost of $1.20 per gallon. The reported costs for those who directly discharge after plateout versus those who send the solution on for further treatment were not significantly different. The mean costs were $1.15 and $1.24 per gallon respectively.

Other Separate Systems

Of the 17 other respondents with other separate systems for treating their baths, most precipitated them either with caustic soda or sulfur compounds, as shown in the following table.

Number	Percent	Method
6	35	NaOH precipitation
4	23	Sulfide or carbamate precipitation
1	6	NaOH and $CaCl_2$ precipitation
2	12	Proprietary additive for precipitation
1	6	Vacuum evaporation, then recycle
1	6	Electrodialysis, then recycle
2	12	Other, not described

Seven respondents used NaOH to precipitate the nickel from the bath. One of these also added $CaCl_2$ to reduce the solution's phosphate content. Only one of these facilities could then discharge directly to the sewer. Five of the others returned the effluent to their conventional system, and one polished it with ion exchange. The nickel content of the treated solutions ranged from less than 5 ppm to 10 ppm, with a mean value of about 5.3 ppm. The cost of this treatment varied from $0.74 to $2.00 per gallon with a mean cost of $1.14 per gallon.

The four respondents using carbamate or Na_2S to precipitate the nickel from the spent bath were all able to discharge the remaining liquid to their sewer. The nickel content of the treated solutions ranged from less than 5 ppm to 10 ppm, with a mean value of about 5.5 ppm. The cost of this treatment varied from $0.06 to $1.50 per gallon with a mean cost of $0.30 per gallon.

Two respondents use proprietary additives, which they obtained from their electroless nickel supplier, to treat their spent baths. They were also able to discharge the remaining solution to their sewer without additional treatment. The nickel content of the effluent from both facilities was less than 5 ppm. One respondent reported their cost to be $0.74 per gallon.

One facility uses vacuum evaporation to recover the water from the bath (which is commingled with all of the other wastes in the facility) and has the effluent recycled. This facility has no sewer connection and discharges no waste. The cost for treating all of the facility's wastes is $0.09 per gallon.

One facility uses electrodialysis to reduce the nickel content of the solution to about 3000 ppm and then evaporates the effluent before shipping it offsite for disposal. The cost of this treatment was not reported.

Phosphates

Only eight respondents, or 11 percent of the total, specifically reported treating their spent bath solutions to reduce their phosphate content, although 13 respondents reported that they had a discharge limit for phosphates. Conversely, 38 respondents, or 52 percent, reported that they did not have a limit for phosphates. The locales limiting the amount of phosphate that could be discharged were random and spread across the country. In one case, two shops, one with and one without discharge limits, were only a few miles apart, but in different municipalities, both of whose POTW's discharge to the same body of water. Seven respondents reported their phosphate discharge limits. These limits are shown in the following table.

Location	Phosphorus Limit
NY	1.5 ppm
IN	10 ppm
MI	10 ppm or 2½ lb/day
MD	11 ppm
WI	12 ppm or 40 lb/day
IN	200 ppm
WI	60 lb/month

Of the seven facilities treating for phosphates, four used lime or $CaCl_2$ to precipitate it. Three of these facilities also added peroxide, hypochlorite and/or permanganate. The three remaining shops used only permanganate or peroxide to reduce the amount of phosphate. Even after this treatment, however, two respondents could not discharge the treated solution and have to have it hauled away. Three other facilities reported that they treated the bath to oxidize its organic acids (but not to treat for phosphates) either with hypochlorite or permanganate.

Nine respondents reported the phosphate content of their effluent; four were facilities that treated the bath to remove phosphates and five did not. The phosphate content of the effluent from shops that treat for it ranged from 1 to 20 ppm, with a mean value of 5.6 ppm. The content of the discharge from shops that do not treat ranged from 1 to 1500 ppm, with a mean value of 41 ppm.

SPENT NITRIC ACID SOLUTIONS

The spent nitric acid solutions used to clean and passivate electroless nickel plating tanks are very strong acid solutions containing large quantities of nickel, but are usually easier to treat than are electroless nickel plating solutions.

Of the 72 respondents to this section of the questionnaire, four did not treat spent nitric acid solutions. Two facilities used PVC bag liners in their tanks, which were thrown away rather than stripped. Another uses the acid to neutralize alkaline waste. The fourth is a very small installation with 10 gallon plating tanks, which does not treat the small amount of spent acid that they generate.

The remaining facilities handle their acid in many different ways, as shown by the following table.

Number	Percent	Method
14	21	Treated in a conventional system
1	1	Treated conventionally or hauled off
29	43	Treated separately
6	9	Treated separately or hauled off
18	26	Hauled off for disposal

Conventional Systems

Fifteen respondents simply send the spent acid to their conventional treatment system, where it is neutralized and precipitated with lime. None of these facilities reported that any additional treatment was required. All reported that their effluent contained less than 5 ppm nickel. The cost of treating the spent acid in these systems ranged from $0.0002 to $3.75 per gallon, with a mean cost of $0.22 per gallon.

Separate Systems

The largest number of the facilities reported that they had a separate system for treating their spent stripping acid. The techniques used were similar to those reported for dealing with spent plating baths as shown in the following table.

Number	Percent	Method
24	67	Precipitation with NaOH, KOH or $NaCO_3$

7	19	Carbamate precipitation
2	6	Precipitation with lime
2	6	Evaporation, then recycle
1	3	Electrodialysis, then recycle

In addition, three facilities reported adding the spent acid to their electroless nickel baths before treatment by electroless plateout.

Of the twenty-six facilities treating their spent acid by precipitation with hydroxides or carbonates, only five reported needing additional treatment (other than filtration and pH adjustment). Two facilities returned the treated solution to their conventional treatment system and one each polished by sulfide precipitation, iron precipitation and ion exchange. The nickel content of the effluent ranged from less than 5 to 50 ppm, with a mean value of about 6.3 ppm for all facilities. For those polishing afterwards, the effluent's nickel content was only reduced to a mean value of about 5.5 ppm. The cost of precipitation ranged from $0.10 to $2.60 per gallon, with a mean cost of $0.69 per gallon.

Seven respondents treated their spent nitric acid by carbamate precipitation. None of these facilities required additional treatment and all discharged directly to their sewer. The nickel content of the effluent was less than 5 to 10 ppm, with a mean value of about 5.4 ppm. The cost of this treatment varied from $0.06 to $20.00 per gallon with a mean cost of $0.71 per gallon.

The two facilities that evaporate their spent nitric solutions both reported that the nickel content of their effluent was less than 5 ppm. Their costs were $0.09 and $0.44 per gallon. No information on effectiveness or cost was provided on the facility using electrodialysis.

Offsite Disposal

Eighteen facilities have their nitric acid solution hauled off for disposal or recycling. In addition, six of those with separate treatment systems and one with a conventional system sometimes send their waste acid offsite for disposal. Of those who use both methods, the decision of which to use again seems to be based on workload. One facility commented that they use a disposal service "when waste treating is busy".

Of the 25 facilities where solutions are being hauled away, 14 percent went to a hazardous landfill, 50 percent to a recycling service and 36 percent to another disposal service. Of the latter, two respondents reported that their spent nitric solutions were disposed of by deep well injection. The cost of offsite disposal ranged from zero (for one Canadian facility) to $8.50 per gallon, with a mean cost of $2.62 per gallon.

TRANSFER LOSSES

Each time an electroless nickel bath or nitric passivation solution is transferred from the plating tank to another tank or holding tank, a small volume is usually lost. This amount of solution must be waste treated and replaced. The volume of these losses depends upon the frequency with which the bath is transferred, operator method and tank design.

The transfer practices of the 72 respondents to this part of the questionnaire were quite varied. The frequency of transfer ranged from once daily to once yearly. This is summarized in the following table.

Number	Percent	Frequency
14	19	Daily
12	17	Every two days
6	8	Every 3 to 5 days
20	28	Weekly
3	4	Every 1 to 2 weeks
11	15	More than 2 weeks

Four respondents reported that the frequency of their transfers "depends on work load". In addition, two of the facilities do not transfer the bath in the traditional sense. They use PVC bag lined tanks. After the bath is removed and the bag replaced, the bath is returned to the tank without stripping it. The mean period of transfer was 5 days.

One half the respondents transfers the electroless nickel bath to a second (twin) tank. The other half transfers to a holding tank. After stripping the tank, however, only 9 percent of the shops transfer the nitric acid passivation solution to a second plating tank. All of the others transfer it to a holding tank.

Forty-two respondents use a standard 30 percent nitric acid solution to strip the electroless nickel tank. The strength of the acid used by the remaining facilities varied from 5 percent to concentrated acid. The mean strength of the acid used by these shops was 43 percent.

Sixty-six respondents estimated that their bath and nitric acid losses during transfer ranged from zero to 30 gallons and zero to 75 gallons respectively. As a function of the plating tank volume, however, both bath and nitric acid losses ranged from zero to 10 percent. Those facilities reporting no losses were those with very careful transfer practices, which usually resulted in longer times required to transfer the solution. Those with higher losses were typically those with smaller tanks and without special transfer practices. The mean volume of bath and nitric acid lost was 1.1 gallons, which was equal to 0.55 percent of the plating tank volume.

Many respondents use the filtration pump on their tank to transfer the solution. Most facilities, however, use a second, dedicated transfer pump as shown in the following table.

Number	Percent	Transfer With
25	36	Filter pump only
33	48	Second transfer pump
10	15	Both filter and transfer pump
1	1	Bucket

Thirty respondents reported that they collect the solutions left in the tank after transfer in a bucket, and then pour it into the twin tank or storage tank. Six others use wet/dry vacuums to collect the leftover solutions. Five respondents rinse their tanks with water while transferring to reduce their losses. The use of buckets after transferring reduces mean bath loss to 0.18 percent. Using a vacuum to collect the remaining solution further reduces it to 0.07 percent. Even rinsing while transferring seems to provide some advantage with a mean loss of 0.12 percent.

Three respondents use gravity to help transfer their nitric acid. These facilities have their storage tanks installed below the plating tanks. This reduced their acid loss to only 0.06 percent.

Four respondents specifically listed sloped bottom plating tanks as an aid to better draining and to reduce transfer losses. This design, however, does not seem to significantly improve the effectiveness of their transfer practices. Their mean lost was 0.47 percent. The remaining 27 respondents do not attempt to reduce their losses. They simply drain whatever is left in their tank to their waste treatment system.

The amount of time needed to transfer the bath or nitric acid solutions varied greatly among the different facilities. The minimum time reported was five minutes for a 100 gallon tank. The maximum time reported was 120 minutes for a 750 gallon tank. The mean period was 29 minutes. As a function of the plating tanks volume, the transfer time ranged from 0.5 to 100 minutes per 100 gallons, with a mean time of 13 minutes per 100 gallons.

Nineteen respondents estimated the cost of their transfer losses. These costs ranged from $3.00 to $400.00 per transfer for bath losses and $0.15 to $300.00 per transfer for nitric acid losses. The mean costs were $16.80 and $3.70 per transfer. The cost of waste treating these losses was estimated by 22 respondents at between $0.001 and $30.00 per gallon, with a mean cost of $0.08 per gallon.

TRANSFER RINSES

After each transfer of plating solution or nitric acid, the tank should be rinsed. This rinse water becomes contaminated with nickel and may need to be treated.

Sixty-six facilities responded to this part of the questionnaire. They reported that the volume of rinse water discharged after each transfer varied from zero to 1200 gallons, with a mean volume of 28 gallons. As a function of the plating tanks volume, The amount of rinse water discharged ranged from zero to 290 percent. The mean volume was 13 percent of the tanks' capacity. One half the respondents reported the nickel content of their transfer rinse water. It varied from 0.08 to 1250 ppm. The mean nickel content was 12 ppm.

Sixteen of the facilities do not treat the transfer rinses and instead discharge it directly to their sewer. Two-thirds of the remaining respondents drain the rinses to their conventional treatment system. One facility polishes the conventional system's effluent with ion exchange. One respondent captures all of the rinse water and adds it back to the bath or nitric to avoid having to treat it. One respondent reported that they did not rinse after transfer.

The remaining 17 respondents used dedicated treatment systems for these rinses, as shown in the following table.

Number	Percent	Method
6	35	Precipitation with NaOH or lime
2	12	Carbamate precipitation
4	23	Ion exchange
3	18	Evaporation
2	12	Other, not described

The cost of treating the rinse varied from \$0.002 to \$7.00 per gallon with a mean cost of \$0.08 per gallon. For those facilities using only their conventional system for treatment the mean cost was only \$0.04 per gallon. For the respondents with hydroxide or carbamate precipitation or evaporation the mean costs were \$0.70, \$0.06 and \$0.55 per gallon respectively.

SPENT STRIPPING SOLUTIONS

Most commonly, either nitric acid or proprietary alkaline strippers are used to remove defective electroless nickel deposits. These can be easy or very difficult to treat. Alkaline strippers in particular are a problem for waste treatment because of the very strong complexers that they contain.

This was especially evident from the responses of the 69 facilities that answered this section of the questionnaire. The types of strippers used by the respondents are summarized in the following table.

Number	Percent	Type of Stripper
40	58	Alkaline
24	35	Concentrated nitric acid
24	35	Diluted nitric acid
3	4	Nitric/sulfuric or sulfuric/peroxide acids

The diluted nitric acid included solutions with concentrations ranging from 12½ percent to 50 percent. These solutions are most commonly used to strip electroless nickel coatings from aluminum or stainless steel substrates. Concentrated nitric acid is used for steel, and alkaline strippers are used for steel and copper substrates.

These different strippers were treated by many different methods, although there were some common factors. Many shops use more than one method depending upon the type of stripper. These methods are summarized in the following table.

Number	Percent	Method
1	1	Not treated
12	17	Treated in a conventional system
26	37	Treated in a separate system
35	50	Hauled away for disposal

One respondent is a very small installation that does not treat the small amount of diluted nitric acid that they generate.

Conventional Systems

Twelve of the respondents treat all of their strippers in their conventional system. Five of these were treating alkaline strippers, three were treating concentrated nitric, four were treating diluted nitric, and the last was treating another unnamed stripper. All of them reported that it caused no problems with the effectiveness of their conventional treatment system. Some of these were very large facilities with high flow rates, but some were only medium size job shops. All discharged the effluent from their system directly to the sewer with no additional treatment. The nickel content of the discharge from these systems was less than 5 ppm. One respondent reported that the phosphate content of their effluent was 5 ppm after their alkaline stripper was treated with lime. Another respondent also added hypochlorite when treating alkaline strippers.

Only three respondents reported their costs for treating strippers in their conventional system. These were $0.002 and $1.65 per gallon for alkaline strippers and $6.00 per gallon for concentrated nitric acid. The respondent who reported a cost of $0.002 per gallon is a very large manufacturing facility, who reported the same cost for treating all their solutions.

Separate Systems

Of the 22 facilities treating strippers in a separate system, most were neutralizing with hydroxide as shown in the following table.

Number	Percent	Method
12	54	Precipitation with NaOH or KOH
1	5	Precipitation with NaOH and $MgSO_4$
1	5	Precipitation with NaOH and bleach
1	5	Precipitation with lime
5	23	Precipitation with Na_2S or carbamate
2	9	Evaporation, then recycle

The twelve facilities treating with hydroxide only, handle all three types of strippers. The nickel content of the effluent from these systems range from less than 5 to 50 ppm, with a mean value of about 8.4 ppm. Two of these facilities (which reported nickel contents of less than 5 ppm and which treat both diluted nitric and alkaline strippers) can discharge their effluent directly after filtration and pH adjustment. In addition, one facility mixes the liquid remaining after treating with their chromic acid waste and evaporates it before offsite disposal.

The remaining eight facilities return the effluent from this treatment to their conventional system for further treatment. These facilities include all of those reporting nickel contents of more than 10 ppm after hydroxide precipitation. The mean nickel content of this discharge was about 9½ ppm. Two of these facilities also reported adding hypochlorite or peroxide to their conventional systems to help oxidize organics and phosphites. The cost of this type of treatment ranged from $0.83 to $3.00 per gallon, with a mean cost of $1.44 per gallon.

The three facilities treating with NaOH and $MgSO_4$, with NaOH and bleach or with lime, all treat both alkaline and nitric acid strippers. All can discharge directly without further treatment. With $MgSO_4$ and lime, the nickel content of their effluent is less than 5 ppm. With NaOH and bleach, the effluent contained 5 to 10 ppm nickel. The cost of treatment at this latter facility was $6.00 per gallon.

Five of the respondents use sulfides or carbamate to precipitate all three types of strippers. The nickel content of their effluent ranges from less than 5 ppm to 10 ppm, with a mean value of about 6 ppm. Two of these facilities can discharge the remaining solution without additional treatment. The other three, however, return it to their conventional system. One of these facilities also adds hypochlorite and permanganate to their conventional treatment systems to help oxidize organics and reduce phosphites. The cost of this type of treatment varied from $0.50 to $1.03 per gallon, with a mean cost of $0.64 per gallon.

Two facilities evaporate their strippers before shipping them offsite for recycling or disposal. One of these (who commingles and evaporates all of their waste) reported their cost to be $0.09 per gallon.

Of those treating their strippers in separate systems or having it hauled away for disposal, four reported that it would cause problems with their conventional treatment system. All these facilities were treating alkaline strippers.

Offsite Disposal

One half the respondents has all or part of their strippers hauled away for offsite disposal. Of these facilities, five reported that they treat their nitric acid solutions onsite, but send alkaline strippers offsite. The types of stripper being hauled away are shown in the following table.

Number	Percent	Type of Stripper
25	71	Alkaline
10	29	Concentrated nitric acid
5	14	Diluted nitric acid
1	3	Nitric/sulfuric acid mixture

Fifteen percent of these solutions went to a hazardous landfill, 50 percent to a recycling service and 35 percent to another disposal service.

The cost of offsite disposal of strippers varied from zero (for an alkaline stripper for one Canadian facility) to $13.50 per gallon, with a mean cost of $2.54 per gallon. Where disposal of the different types could be separated, the mean cost of hauling off alkaline cleaners was $2.37 per gallon. That for nitric acid solutions was $2.92 per gallon, and that of the mixtures was $3.06 per gallon.

Phosphates

As with spent plating baths, only eight respondents specifically reported treating their stripping solutions to reduce their phosphate content. One of these facilities was adding peroxide to their conventional treatment system, one permanganate, three hypochlorite, and four lime. Three of these facilities reported the phosphate content of their discharge, which was 1, 5 and 6 ppm.

VENTILATION

The vapor, mist and air rising from the surface of the electroless nickel solution may contain small quantities of entrained nickel. This vapor stream is often exhausted and sometimes scrubbed.

Of the 72 facilities who responded to this section of the questionnaire, 82 percent provide some type of exhaust for the vapor from the electroless nickel tank. Those tanks that were not exhausted ranged in size from 10 to 350 gallons. Their mean size was 130 gallons. Of the tanks that were exhausted, 46 percent of the facilities scrub the vapor and 54 percent do not.

Twenty-one respondents reported that their ventilation system was a legal requirement. Forty-five respondents reported that it was not. Of those facilities where ventilation is a requirement, eleven scrub the vapor, one has a demister, and nine only exhaust the vapor to the outside.

Only twelve respondents reported that they have a discharge limit for the air that they exhaust. Fifty-three respondents stated that they did not have a limit. Only six respondents, however, reported their discharge limit. These limits are shown in the following table.

Location	Exhaust Limit
IN	1 mg/m^3
OH	50 ppm
RI	0.45 kg/day
NY	0.025 lb/hour
KY	0.073 lb/hour
AZ	0.767 lb/hour

Eighty-nine percent of the 27 respondents who scrub their electroless nickel vapor also treat their scrubber solution. Eleven percent do not.

Of those that treat the scrubber solution, 17 return it to their conventional treatment system. Six facilities treat it in a separate system. Three of these use ion exchange, two use NaOH precipitation, and one facility uses carbamate precipitation. In addition, one facility adds the solution to their other electroless waste, where it is treated by NaOH precipitation. One facility ships the solution offsite for disposal.

Only three respondents reported their cost for having these solutions treated. These are $0.50 per gallon for 150 gal/day through their conventional system, $1.65 per gallon for treating 10 gal/day by carbamate precipitation, and $2.00 per gallon for offsite disposal.

CONCLUSION

The only fact that this survey confirmed conclusively was that there are many different ways to treat electroless nickel waste streams. Most of them seem to work to the satisfaction of their owners. There is also obviously a wide variation in the requirements and regulations to which the different shops must conform.

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BIOGRAPHICAL SKETCH

In Memory of Ron Duncan

Ron Duncan served as Vice President of Palm International, Inc., where he led the company's technical and educational initiatives. Prior to joining Palm, he was Director of Research at Elnic, Inc., focusing on electroless nickel formulation and materials research.

Before entering the metal finishing industry, Ron spent 12 years in the oil sector with Exxon and Caltex Petroleum Corporations, tackling materials and corrosion challenges. His work took him across the globe—including the United States, Middle East, Europe, South America, and Africa—where he developed a reputation for his deep expertise and practical problem-solving.

Ron held a BE in Mechanical and Metallurgical Engineering from Vanderbilt University. He was a Registered Professional Engineer and a certified Corrosion Specialist through NACE. A leader in technical standards, he chaired NACE task groups T-1G-19 and T-6A-53, contributing to authoritative reports on electroless nickel and other metallic coatings. He also served on the AESF's Electroless Committee.

Throughout his distinguished career, Ron authored more than fifty technical papers on corrosion, coatings, and electroless nickel. His work appeared in Materials Performance, Plating and Surface Finishing, Metals Progress, Products Finishing, and Finishers Management, as well as in numerous industry conferences. He was the principal author of the electroless nickel chapter in Volume 5 of the Metals Handbook and was honored with the AESF Gold Medal in 1996 for the best paper published in Plating and Surface Finishing.

Ron also directed the Electroless Nickel School, a comprehensive four-day seminar presented by Palm, which educated professionals in all aspects of electroless nickel technology.

Ron Duncan passed away on December 15, 2006. He is deeply missed by his family, colleagues, and the broader surface finishing community. His legacy of innovation, mentorship, and integrity continues to inspire all who had the privilege of working with him.