Chapter 3 Current State and Issues of the Electroplating Industry and IDB Electroplating Center

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3.1 Current State and Issues of the Electroplating Industry

3.1.1 Current state of the electroplating industry

A field survey was conducted of 21 electroplating units. In Sri Lanka, there are approximately 80 electroplating units, of which 40 are classified as micro-cottage industry, and others are considered to have facilities and equipment to perform sufficient electroplating operations. The study team visited 21 units, around one half the total excluding micro-cottage industries. The study team was able to visit and observe units of varying sizes and types of operation, including more than one type of electroplating, allowing it to collect data and information sufficient to grasp a general picture of the electroplating industry and units in Sri Lanka. During the visit, a questionnaire survey was conducted at each unit, and major data obtained thereby are summarized in Table 3-1.

The units surveyed are classified by their process and enterprise size into the following three types:

Group 1: Units which have the electroplating process as part of an entire process line to manufacture their own products, and are located in the industrial areas. (Factory size is relatively large, and in Sri Lanka, they are classified as medium or large enterprises. Products include safety pins, farm sprayers, packaging materials, and metal furniture.)

Group 2: Units which manufacture ornaments or automotive and motorcycle parts, using the electroplating process. (Some of them are also operating parts dealers and/or repair shops, located outer city areas or rural areas.)

Group 3: Units which are specialized in electroplating on parts or ornaments on a contract basis for parts suppliers or manufacturers, located in commercial districts of urban areas. (Very small size, generally categorized as platers or plating shops.)

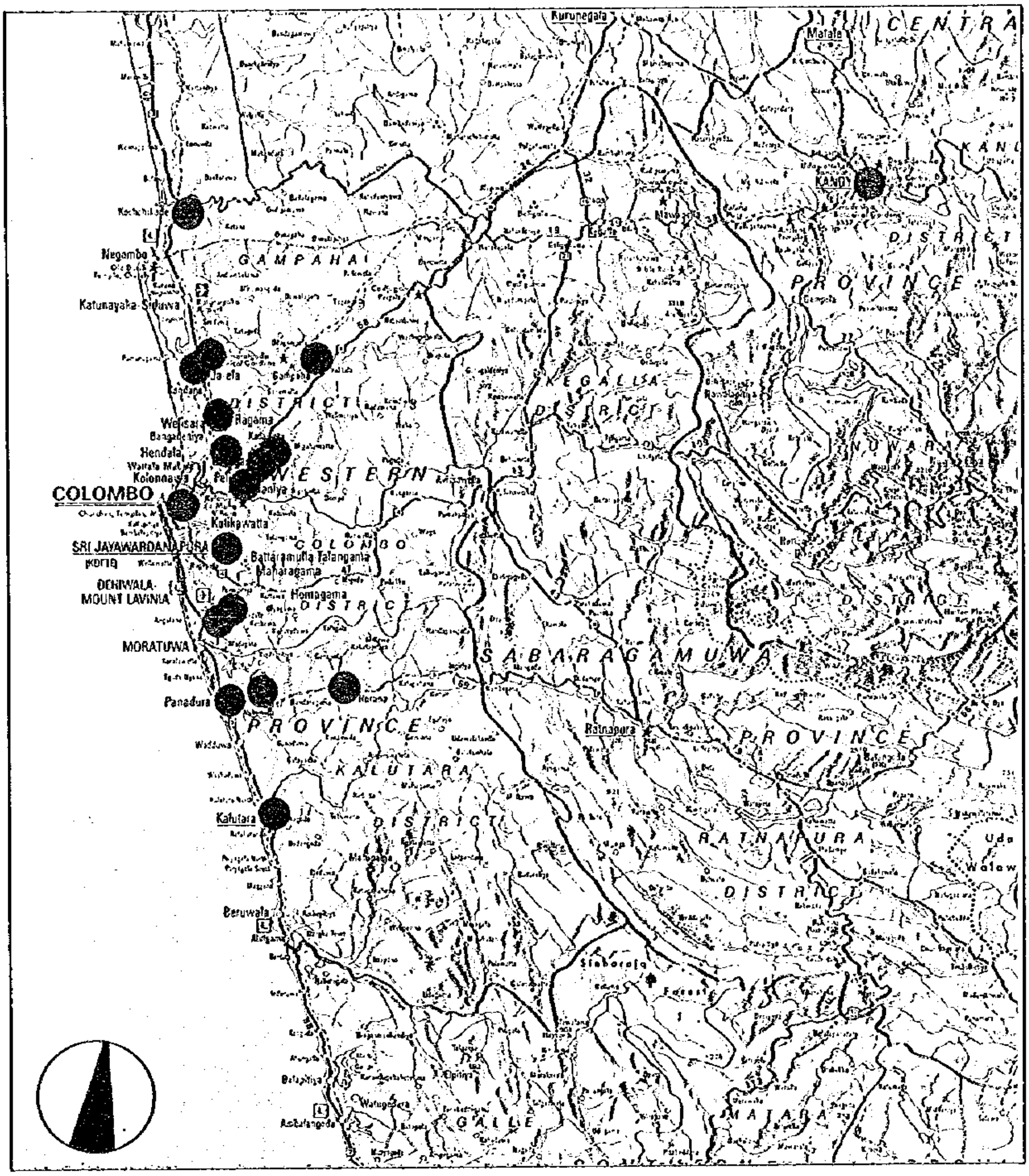
Note that any of the above units are small in size of electroplating operation, and 3-5 workers are engaged in the process including polishing.

Judging from the above, the electroplating industry in Sri Lanka has not reached at critical mass so as to be considered as an independent industry subsector. MID and IDB (under MID) that are responsible for industrial promotion recognize the above mentioned current state of the electroplating industry. They have a strong desire to foster and promote the electroplating industry in the belief that electroplating is essential for improving quality, performance, and international competitiveness of metalworking products made in the country.

Table 3-1 LIST OF ELECTROPLATING UNITS (Answer for Enquete)

No.	Name of Company	Place	Products	Establishment	Total Area (m^2)	Building Area (m^2)	Type of Business	Employee Total	Employee Electro-plating	Material	Kind of Electro-plating	Expansion Plan	Waste Water : CN	Waste Water :Cr+6	Waste Water Acid/alkali	Waste Water Volume (Liter/day)	Treatment Plan
1	M.E. Ferdinandis & Co (Pvt.) Ltd.	Kalutara	Safety Pin	1981	525	225	Integrated	50	1	Mild Steel	Ni-Cr	No	N.A.	N.A.	N.A.	900 Gallons/day	Own
2	City Cycle Industries	Panadura	Bicycle	1988	15,176	7,386	Integrated	500	Plaing (under planning)	Mild Steel	(Ni-Cr) (Zn-chromate)	Yes 1998			○	No	Own
3	D.S.Engineering Company	Panadura	Air Conditioner Parts	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
4	Agro Technica Ltd.	Ekala, Ja-Ela	Agricultural Machinery	1989	N.A.	N.A.	Integrated		4	Brass	Ni-Cr	for Hard Chrome			○	3,100	Own
5	Lloyd Industries	Delatura, Ja-Ela	Motor cycle parts	1986	35 purches	12 purches	Integrated		10	Carbon Steel	Cu-Ni-Cr Zn	Yes	○		○	100	Own
6	Metro Industries	Kochchikade	Bolts/Nuts	1967	33,904sq.ft.	18,094sq.ft.	Integrated	76	2	Carbon Steel	Cu-Ni-Cr Zn	No	○	○	○	50~70	Own
7	E.Francis Perera & Company Ltd.	Kandy	Ornaments	1939	1,600	2,400	Integrated	52		Bronze Brass Silver	Cu-Ni-Cr, Ni-Cr,Zn, Au,Ag,	Yes 1997	○	○	○	2,000	No Plan
8	Varna Ltd.	Ratmalana	Packaging Bag (Printing Roll)	1965	25,000	4,000	Rotogravure Printing	160	12	Carbon Steel	Cu-Ni-Cr	Yes			○	10,000	Own Collective
9	Sasico Enterprises	Ratmalana	(no enquete requested)				Plating only										
10	Sirima Industries	Horana	Electrical Parts	1978	5,000sq.ft.	1,200sq.ft.	Integrated	15	4	Carbon Steel, Bronze,Copper, Aluminum	Zn	Yes 1997	○	○	○	200	Own
11	Duro Metal Industries	Colombo 10		1977	1,600sq.ft.	1,600sq.ft.	Plating only		7	Carbon Steel, Bronze,Copper,	Cu-Ni-Cr	No	○	○	○	200	Own
12	New Lanka Electroplaters	Colombo 6		1962	750sq.ft.	500sq.ft.	Plating only		5	Carbon Steel, Bronze,Copper,	Cu-Ni-Cr, Ni-Cr,Ag,	No	○	○	○	150	Own
13	Auto Crafts	Colombo 6	Ornaments, Building Materials	1960	5,000	2,000	Integrated	35		Copper, Nickel,Brass,	Cu-Ni-Cr	Yes 1997	○		○	100	Collective
14	Flexport (Pvt.) Ltd.	Nugegoda		1980	1.5 acre	10,000sq.ft.	Integrated	70		Copper,Bronz, Silver,Brass,	Cu-Ni-Cr, Ni-Cr, Ag,Au,	Yes 1997				N.A.	Own, Collective
15	The City Trading Company	Colombo 11		1948	200sq.ft.	100sq.ft.	Integrated		5	Carbon Steel, Bronze,Copper, Aluminum	Cu-Ni-Cr, Ni-Cr, Oxidising,	No			(Waxy)	50	Collective
16	Kithusiri Metal Industries	Mahabage	Ornaments	1967	2,400sq.ft.	2,400sq.ft.	Integrated		4	Copper, Bronze,	Ni-Cr, Zn	Yes 1997	○	○	○	1,000	Collective
17	Metalray	Kandana		1971	16(1/2) purches	10 purches	Plating only		4	Carbon Steel, Bronze,Copper,	Cu-Ni-Cr, Ni-Cr,		○	○	○	?	Collective
18	Alumex (Pvt.) Ltd.	Sapugaskanda, Makola	Aluminum Sash	1988	26,315	2,187	Integrated	142	23	Aluminum Extrusions	Anodising	No			○	290,000	Collective
19	St. Theresa Industries	Sapugaskanda	Bolts (Electrical Parts)	1987	2.5 acre	2,000sq.ft.	Integrated	60			Hot Galvanizing	Yes 1997			○	?	Collective
20	Weliketiya Brass Founders	Kelaniya	Auto Parts Ornaments	1983	6,000sq.ft.	3,000sq.ft.	Integrated	25	12	Carbon Steel, Bronze,Brass, Aluminum,	Cu-Ni-Cr, Ni-Cr, Oxidising,	yes 1996	○	○	○	100	Own
21	Central Industries	Gampaha	Motorcycle Parts	1976	2,500sq.ft.	5,000sq.ft.	Integrated		2	Carbon Steel, Copper,	Cu-Ni-Cr	Yes 1997	○	○	○	200	Own

N.A. : no answer



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LOCATION MAP OF THE ELECTROPLATING UNITS VISITED BY THE STUDY TEAM

(Four units in Colombo city are expressed by one point)

3.1.2 Major issues related to the electroplating industry

(1) Major issues related to all industry in Sri Lanka

Major problems facing the electroplating industry, including those heard from government authorities and organizations, and electroplating units during the study team's visit, are summarized as follows. These are considered to be issues facing all industries in the country.

1) The free trade system attracts products of good quality from foreign countries. Although similar products are locally made, they are inferior in quality and performance compared to foreign products which flow into country in large quantities and impede the improvement of local products.

2) As a wide range of products are freely imported from foreign countries, many of them are not locally produced (or the absence of local products results in dependence upon imported products).

3) The small scale of the market, among other factors, prevents certain foreign products from being imported, i.e., chemicals and women's accessories. They are being imported in small quantities, are high priced and sold out quickly.

4) Domestic customers are not concerned about quality and performance of local products. Partially related to the problem in (1) above, what the market expects most from local products is a "cheap price," not quality or performance.

5) Heavy tax burdens discourage production activity. The income tax and the turnover tax amount to a combined total of more than 50%, varying with company size and other factors, and the national security levy (4.5%) has created less-favorable conditions for business activity.

6) In the questionnaire survey, the study team asked reasons why enterprises had their own electroplating capabilities as part of the manufacturing process or why they did not use outside processors. Many respondents cited the delay in delivery by outside processors, low technology levels, and sufficient internal capability.

7) Internal turmoil resulted in a sharp decline in production and sales compared to a year earlier. As a result of the armed conflict between Tamil extremists and the government forces in the northern region, product sales in the region dropped sharply, having serious impact on business activities throughout the country.

8) Most enterprises, while realizing the need for environmental protection, believe that they do not need to invest expensive pollution control equipment as their environmental discharge is very small.

(2) Major issues related to the electroplating industry

Among the above problems those relevant to the electroplating industry are as follows:

1) The market does not have much concern about product quality and performance, discouraging the improvement of electroplating work.

2) The potential market for electroplating is small in the number and type of metalworking products, and most of manufacturers have their own electroplating process due to the absence of reliable outside processors.

3) The current financial condition does not justify the industry to invest in pollution control equipment which does not generate profits. Concessionary loans and other incentives may be one solution.

3.2 Current State and Issues of the Electroplating Units

3.2.1 Current state of the electroplating units

(1) Overview

An investigation of 21 units was performed (among them 17 were processing plating units), which were chosen by IDB. Some units are carrying out the plating work for the parts of their products in their own manufacturing facilities and the others are exclusively doing the plating ordered from outside. As previously mentioned, Sri Lanka has about 80 plating units including home industries or something of a similar type. Since many units of variable sorts and scales were investigated, we think it is sufficient to understand the current state of the electroplating units in Sri Lanka.

1) Sort of plating and waste water

In terms of the kind of platings, copper, nickel and chromium plating were the main ones. Relatively little zinc was present. Gold and silver amounted only to a little.

Table 3-2 KINDS OF PLATING AND WASTE WATER

Kinds of plating or waste water	Number of units	Remarks
Kinds of plating		
Copper plating	12	Acidic copper plating 1 Copper cyanide plating 11
Nickel plating	15	Mainly dull nickel plating
Zinc plating	4	Cyanide bath in all units (Non-cyanide baths are not used)
Chromium plating	11	Mainly for ornaments, partly for industrial (hard) chromium plating
Kinds of waste water		
Cyanide waste water	15	
Chromium waste water	16	Chromium plating 11 Chromate treatment 5

2) Market and operation situation

The plating products currently produced in Sri Lanka are mainly motorcycle and automobile repair parts except the safety pin, parts for agricultural spraying equipment, metallic parts for furniture, etc. and for the domestic market only. The operation rate is very low. During our visit, only 7 units were in operation and the other 10 units were not in operation, which may be due to the present economic conditions more or less. The ordered amount was not enough to operate for a whole day; therefore, many units are operating two or three half days per week.

3) Technical level and quality

The technical level for plating is not sufficient. The fundamental technology for plating such as plating bath control, current density calculation, etc. are not yet completely understood. The plating work depends on worker's experience, and there are no detail working instructions. No interest regarding working environment and layout for the equipment are taken.

The quality level of the products is low, and the inspection is only for appearance with nothing given to plating thickness and corrosion resistance. As the quality consciousness in the market is low with only interest in appearance and price and few requirements for quality, motivation regarding process improvement is weak.

4) Environmental issues

Regarding environmental issues, they have a better understanding of the necessity of waste water treatment; however, only 3 units have obtained an environmental protection license. The investment incentive for waste water treatment is low and nobody has any interest in reducing the waste water load. It can say that nobody knows the regulated limits for waste water and almost no one has the knowledge to reduce waste water load and the waste water treatment technology. At present, since there is no actual damage and no regulatory control and an investment for waste water treatment does not create any profit, almost no unit has any real interest regarding this. Though 3 units have waste water treatment facilities, they are in no way sufficient as treatment facilities.

(2) Plating technology

1) Base materials and polishing

The materials mostly used are steel machine parts and copper alloy (bronze, brass).

Many units have more than 2 sets of polishing machines and the base material polishing before plating and finish polishing after plating is carried out. A certain plating unit manufacturing decorative parts has 12 sets of machines. There are almost no dust collectors in the polishing room and work environment conservation is almost out of the question.

2) Pretreatment

As the pretreatment process prior to plating, some units apply an immersion degreasing using an alkali degreasing solution purchased on the market, but many other units use light oil to clean machining oil. No unit uses the electrolytic degreasing. Generally, there seems to be no concerned about pretreatment.

3) DC power supply

As the DC power supply, a rectifier is normally used. Some units use the rectifying element itself that is immersed in insulation oil and left as it is exposed without any protection. Meanwhile, some old units use the DC motor generators. Those kinds of generators are not generally used today, because of the DC waveform and noise problems.

4) Plating tank

Many units use a wooden tank, FRP tank, round form tub or empty can of chemicals for the plating tank. In some cases, plating is carried out by putting chromic acid in a drum. The shape of many plating tanks are narrow and lanky, with few units using angular tanks. There is PVC (polyvinyl chloride) lining type of tanks to a limited extent, but some PVCs have been observed to crack.

As the capacity of plating tanks is comparatively large compared with size of the plating parts, many units decrease the solution quantity.

5) Rack

Only one unit is using racks. In general, any companies have no interest in them. All units plate in a way so as to tie parts with hard drawn, bare and thin copper wire and to hang them in a bath. Therefore, the position of parts or direction to the anode is not fixed. Moreover, thin copper wires result in overheating and run hot, because the over current exceeds the electric capacity of the copper wires.

6) Plating bath

As chemicals for plating, chromic acid and boric acid, etc. are the single substances and copper cyanide is as mixed salts purchased from plating chemical suppliers. Though a brightener is added to bright nickel plating bath, other plating baths use no additional agents. Generally, users do not seem to have sufficient knowledge as regards the bath composition.

Each of the units has very little understanding of the plating bath control and does not periodically analyze the baths. Some units rely on chemical suppliers to analyze chemicals once a month or once several months. Requests are only for pH tests and/or specific gravity tests. Others depend on experience without any analysis.

The results of plating bath analysis which were sampled during the first field survey are shown in Table 3-3.

Table 3-3 ANALYTICAL RESULTS OF ELECTROPLATING BATH

Bath, Item / Unit	Copper			Nickel				Zinc				Chromium			
	CuCN g/l	F-KCN g/l	pH	$NiSO_4 \cdot 6H_2O$ g/l	$NiCl_2 \cdot 6H_2O$ g/l	H_3BO_3 g/l	pH	$Zn(CN)_2$ g/l	T-NaCN g/l	NaOH g/l	T-NaCN /Zn	CrO_3 g/l	Cr^{3+} g/l	H_2SO_4 g/l	CrO_3 /H_2SO_4
A	-	-	-	77.8	86.1	13.7	4.42	-	-	-	-	-	-	-	-
B	-	-	-	192.7	47.5	20.6	5.18	-	-	-	-	-	-	-	-
C	13.2	3.8	10.4	241.6	65.3	-	4.57	30.0	93.3	93.9	5.58	-	-	-	-
D	-	-	-	-	-	-	-	65.9	54.0	23.3	1.47	-	-	-	-
E	44.3	-	10.2	35.4	18.1	-	6.57	-	-	-	-	132.7	0.9	2.59	51.2
F	-	-	-	29.1	39.3	1.6	5.48	-	-	-	-	-	-	-	-
G	-	-	-	79.4	15.9	-	5.41	-	-	-	-	-	-	-	-
H	-	-	-	-	-	-	-	44.2	43.7	58.6	1.78	-	-	-	-
I	37.0	1.9	9.92	22.0	29.0	36.4	6.15	-	-	-	-	-	-	-	-
J	3.9	0.5	10.0	0.0	64.6	24.7	6.15	-	-	-	-	240.0	0.7	0.50	480.0
K	-	-	-	43.1	64.3	33.3	5.50	-	-	-	-	-	-	-	-
L	29.1	1.9	9.78	77.4	67.3	39.5	5.79	-	-	-	-	-	-	-	-
M	54.4	2.7	10.1	35.1	45.8	37.1	5.46	-	-	-	-	-	-	-	-
N	-	-	-	-	-	-	-	100.1	51.1	120.0	0.92	-	-	-	-
O	59.3	2.6	10.0	121.4	57.2	39.5	5.63	84.8	98.2	34.5	2.08	Bright 210.3	-	0.91	231.0
												Hard 254.6	-	1.07	238.0

Generally, concentrations of plating baths are low. It seems they have no sufficient knowledge what bath composition is necessary for containment and only depend on the addition of mixed salts (copper cyanide bath) at any time that are purchased on the market.

All units do not control bath temperatures, the current densities corresponding to plating products and plating time settings, and also, do not measure the current density and cathode surface area. Moreover, they do not properly control the electrode arrangement and numbers.

Activated carbon filtering, dummy plating and pH measurement are almost never carried out. Filters are not used (even if filters are provided, they do not function properly); therefore, the plating baths are very dusty, containing something foreign matter with very contaminated material.

7) Rinsing and drying

Only one unit carries out multi-stage counter flow rinsing, the others are flow rinsing with only one tank. Many of them rinse with static water in buckets or pour the parts with water on the floor directly from a hose. Recovering of plating solution or circulating use of rinsing water are not done at all.

The drying method is a natural one. Heat drying is not carried out.

8) Inspection of plating products

It is said that no unit determines any plating thickness. The inspections are carried out only for appearance and not for plating thickness. Of course, no test for corrosion resistance and adhesion is carried out. As quality consciousness in the domestic market is low, they have no interest in improving product inspection and quality control.

9) Dull nickel plating

Regarding the conditions of nickel plating in Sri Lanka, almost all units make dull nickel platings and after plating they polish them. Even if they have a bright nickel bath , they do not use it and produce dull nickel plating. As dull nickel plating is being done at room temperature and a quantity of parts to be plated is small, a drag out of the solution is also small, causing the quantity of solution to have almost no change.

10) Quality of plated products in Sri Lanka

The quality investigation have been performed for samples which were carried back at the first field survey, for the purpose of grasping an outline of the quality situation regarding plated products in Sri Lanka. The test items were appearance inspection, plating thickness test, adhesion test and a corrosion resistance test (neutral salt spray test only). These results are shown in Table 3-4. The evaluation criteria for appearance inspection, adhesion test and corrosion resistance test are in accordance with that shown in Table 3-5.

At the appearance inspection, only six out of 21 samples were judged as being of the class A, nine samples were of the class C accounting for about half all of them, and furthermore, some samples had already began to rust. The quality evaluation was influenced by market demand, but was at a low level in general. Since the appearance indicates the results of all factors required for plating technology, it is desirable to make an effort to improve plating technology, together with the idea of providing and keeping a limit sample for plating appearance at each unit.

Though the plating thickness is usually determined between the parties concerned, the evaluation here is made by comparison with general technical level.

(a) The copper plating thickness is extremely thin, and they come under the category of flash copper plating or strike copper plating and can not be said to be a copper plating layer.
(b) The nickel plating thickness is barely 10 μm for only two out of ten samples, two samples being 3 μm mark with the others being less. In nickel plating, the plating thickness differs according to usage, and by decoration plating it is at 5~20 μm (determined between the concerned parties) generally.
(c) The chromium plating thickness is about 0.1 μm for seven out of nine samples with two samples being more than 0.25 μm.

As described above, the plating thickness of the Cu-Ni-Cr plating samples is extremely thin even if they are decorative plating, and it is difficult to say that they are quality plating.

(d) The zinc plating thickness is more than 10 μm for six out of nine samples. The zinc plating is performed to prevent corrosion, since the surface coating layer is dissolved into the solution during chromate treatment applied after zinc plating, therfore, it is necessary to pay close attention to plating thickness.

An adhesion test was carried out using the heat cycle method. The test results are relatively good and it is estimated that the samples of class B and C are caused by improper pretreatment.

During the corrosion resistance test, four out of 21 samples were class A and 14 samples were class C. Rust was observed on the class C samples at a relatively early stage. The workmanship of the products can be seen in the test results.

As described above, the general quality of the plating products in Sri Lanka is low compared with the international level.

Table 3-4 LIST OF EVALUATION RESULTS FOR QUALITY OF PLATING SAMPLE IN SRI LANKA

※ Judgment criteria are according to attached Table 3-5

Unit No.	Sample No.	Appearance inspection	Test of plating thickness accordance with JIS H 8501 X-ray Spectrometric Method		Adhesion test accordance with JIS H 8504		Corrosion resistance test accordance with JIS H 8502 Concentration of sodium chloride : 40～60g/L pH : 6.5～7.2 Temperature in the atomizing chamber :35±2℃ Duration of testing : 24Hr		Quality condition before and after the test
			Base metal	(Plating metal) Plating thickness (μm)	Heat test *1	Thermal shock test *2	Neutral salt spray test	Comment	
1	(1)	A	Fe-Cu	(Cu) 0.29, 0.53 - (Ni) 1.30, 1.66	A	A	B	· Partially changed to weak purple color and spotty red rust occurred	· Red rust occurred before test already inner surface of press fit. assumed due to poor covering of plating · Cu and Ni plating of wire was very thin
	(2)	B	Fe	(Ni) 1.86, 2.10	A	A	C	· Red rust occurred on inner surface	
2	(1)	C	Fe	(Zn) 10.0, 21.5	C	C	C	· White rust occurred · 30% of total area discolored to black	· Discolored to black already before test, showing insufficient chromate treatment
	(2)	C	Fe	(Cu) 0.05, 0.06 - (Ni) 6.7, 10.1 - (Cr) 0.06, 0.09	A	A	C	· Red rust occurred on 70% of total area	· There were many scratches on base metal surface and red rust occurred before test already
3	(1)	C	Fe(nut)	(Zn) 28.8, 40.3	A	A	C	· White rust occurred and discolored dark gray partially	· Chromate color tone of outer surface was good before test, but thread part of inner surface was gray and partially occurred red rust · Rust of inner surface progressed by test with increasing speed
	(2)	B	Fe	(Zn) 31.7, 45.5	C	C	C	· White rust occurred and discolored dark gray entirely	· Thin plating thickness and lack of brightness · Surface discolored remarkably by adhesion and corrosion test
4	(1)	B	Cu	(Ag) 0.09, 0.14	B	B	C	· Discolored to brass (Exposure of base metal?)	· Plating thickness was very thin and could not ascertain chromate treatment from surface condition
5	(1)	C	Fe	(Zn) ①1.42, 6.00 ② 0.29, 1.49 ③ 0.34, 1.32	A	A	C	· Red rust occurred and entire surface discolored to dark gray	· Partial corrosion occurred strongly before test. Occurrence and progress of rust was remarkable both in and out side
6	(1)	C	Fe	(Cu) 0.39, 1.13 - (Ni) 7.2, 10.6 - (Cr) 0.08, 0.17	A	A	C	· Red rust occurred on 30% of total area · Red rust occurred on entire inner surface	· Discolored to weak yellow entirely at adhesion test
7	(1)	A	Brass	(Ni) 1.02, 2.91	A	A	B	· Rust and discoloration not occurred	· Concentrate red rust occurrence and there was big difference of finishing condition between surface and back side
	(2)	C	Fe	(Cu) 0.02, 0.07 - (Ni) 2.11, 2.89 - (Cr) 0.08, 0.11	A	A	C	· Red rust occurred on 20% of total area	· Not occurred new rust and discoloration and kept good condition under plating coat
8	(1)	C	Brass	(Ni) 1.26, 1.96 - (Cr) 0.28, 0.35	A	A	A	· There was rust before test but not progressed	· Not occurred new rust and discoloration and kept good condition under plating coat
	(2)	B	Cu	(Au) 0.01, 0.03	A	A	B	· Not occurred rust but discolored to copper or brass entirely	· It is assumed to form Au-Cu alloy due to thin plating and absence of under plating
	(3)	A	Brass	(Au) 0.11, 0.34	A	A	C	· Not occurred rust but discolored to copper or brass entirely	· It is assumed to discolored by diffusion of Zn in base metal due to lack of under plating
9	(1)	B	Brass	(Ni) 2.71, 3.41 - (Cr) 0.35, 0.40	A	A	A	· Rust and discoloration not occurred	· Not occurred defects by test though uneven base metal
10	(1)	A	Fe	(Zn) 8.29, 15.6	A	A	C	· White rust occurred and discolored to dark gray entirely	· Plating thickness was enough, and showed good appearance of chromate (bright?) before test
11	(1)	C	Fe	(Cu) 0.88, 1.52 - (Ni) 3.11, 3.62 - (Cr) 0.04, 0.06	A	A	C	· Red rust occurred edge part and cylinder inner surface of product · Not occurred rust on outer surface	· Rust occurred already on inner part of cylinder before test (poor covering of plating)
12	(1)	C	Brass	(Ni) 0.15, 0.18 - (Cr) 0.06, 0.12	A	A	A	· Rust and discoloration not occurred	· There was big difference of finished appearance of surface and back side (due to polishing), but new defects not occurred by test
13	(1)	A	Cu	(Ni) 9.11, 13.6 - (Cr) 0.02, 0.04	A	A	A	· Weak discoloration partially	
14	(1)	A	Fe	(Zn) ① 11.3, 12.5 ② 21.2, 23.5	A	A	C	· White rust occurred and discolored to dark gray · Chromate color faded (gray)	· There was considerable discoloration to black at end periphery of product · Plating thickness was enough, and showed good appearance before test
	(2)	B	Fe	(Cu) 0.34, 0.45 - (Ni) 0.99, 2.36 - (Cr) 0.06, 0.19	A	A	C	· Red rust occurred on 10% of total area (especially bend corner)	· There was defects like pitting, assumed by unevenness of base metal or lack of removal of buffing medium

*1: Cu-Ni-Cv 300±5℃ ----- Cooling in room temperature
Zn Au 200±5℃ ----- Cooling in room temperature

*2: Cu-Ni-Cv 250±5℃ ----- Putting in water at ordinary temperature
Zn, Au 150±5℃ ----- Putting in water at ordinary temperature

Table 3-5 CRITERIA FOR QUALITY EVALUATION OF PLATING SAMPLE IN SRI LANKA

Judgment rank	Appearance	Adhesion		Corrosion resistance
		Heat test	Thermal shock test	Neutral salt spray test
A	Not be recognized harmful defects practically for actual use such as exposure of base metal, peeling, blister, stain, pit, roughness, fog, burning, unevenness of brightness color tone, flatness etc.	Not be recognized peeling and blister	Not be recognized peeling and blister	Not be recognized surface change practically compared to before test, like occurrence of red rust, white rust as well as discoloration
B	Not be recognized serious harmful defects for actual use such as exposure of base metal, peeling, blister etc.	Not be recognized peeling and blister even recognized surface change like discoloration	Not be recognized peeling and blister even recognized surface change like discoloration	Not be recognized occurrence of red rust or white rust, but recognized some change compared to before test, like discoloration
C	Be recognized serious harmful defects for actual use such as exposure of base metal, peeling, blister etc.	Be recognized peeling and blister strongly	Be recognized peeling and blister strongly	Be recognized serious defects of red rust, white rust, discoloration etc., compared to before test.
Comment	Finishing plating condition of surface and back side is strongly differ due to effective surface (with and without buffing). Therefore evaluation is performed considering this matter.	Since thermal shock test was carried out in succession of heat test, evaluation is performed considering that thermal stress was added already. That is, evaluation points are whether peeling and blister progressed compared to the condition after heat test, or newly occurred.		For sample having rust before test already, evaluation points are whether that rust progressed or new rust occurred on good plating surface.

(3) Waste water treatment

1) Environmental protection license

The plating units are noted as a high polluting industry and have to obtain a license for environmental protection issued by CEA. In the case where the conditions do not meet the environmental requirements, it is prohibited to discharge the waste water which could cause pollution.

The plating units have to apply CEA for a license and CEA investigates the unit based on the application and issue a license with the necessary requirements according to the investigation results, if any.

Three companies among the surveyed units have obtained licenses and have renewed it annually. However, two of them are not carrying out the waste water treatment and no analysis of the waste water is made by CEA for these three units. It is assumed that CEA has issued the license taking into consideration the facts that they are the most prominent units and the environmental influence seems rather small, because the scale of the contamination caused by the polluting chemicals can be estimated according to the volume of the applied chemicals.

2) Sort of waste water

15 units among the 17 units investigated are discharging cyanide water and 16 units are discharging chromium water. Waste water is classified into the concentrated waste water in the case in which the plating solution is replaced either wholly or partially because of some accident and the semi-concentrated waste water recovered from the drag out solution and the rinsing water.

There are no discharge of the concentrated waste water. Since the semi-concentrated waste water is brought into water rinsing process with no recovery of the plating solution, main part of waste water from plating unit is discharged during the rinsing process.

3) Rinsing method, waste water volume

Only one unit is carrying out multi-stage counter flow rinsing. The other units carry out the flow rinsing using a tank or rinse the parts with static water in a small-size bucket and replace the water periodically. Many units pour the parts with water directly from a hose on the floor and have no tank for this purpose. Even the collection of a sample for waste water analysis is not possible for these types of units.

The volume of the discharged water could not be measured because the plating work was not performed continuously, the working situation was not stable and no plating work was carried out in some units on the day of the survey or only a few units did carry out the plating work. The units did not keep precise records and the oral explanations were also different. According to the reports of the companies, the discharged water was very small in volume compared with the volume of the other industries that have contamination, as indicated in Table 3-6.

Table 3-6 WASTE WATER VOLUME

Waste water volume(L/Day)	Number of companies
Less than 100	7
101 to 1,000	8
More than 1,000	2

4) Waste water treatment

Among the units investigated, 3 units provide the so-called treatment tanks and are carrying out neutralization treatment periodically. However, they install a tank in midway in the waste water duct and added chemicals periodically, which is insufficient as regards treatment equipment .

A plating company uses alkaline waste water from the plating process for rinsing of the acid waste water from other processes. The waste water indicated the neutrality at the investigation. However, because both processes are not always operated at the same time and it is possible that one of the processes is not in operation, and thus, the regulated limitation can easily be exceeded. The treatment for the mixed waste water is adequate.

Other units discharge water without treatment directly to the drain or many of them allow the water to penetrate into the soil.

Table 3-7 shows the analytical results of the waste water from units (including the Electroplating Center).

The analytical results of samples of waste water are only for reference because the samples are waste water during the situation where plating work was not operated under a proper conditions in many units. Even in the units operating in the table, plating work was carried out only partially. It is considered that the analytical results may indicate a much higher value according to the operating conditions. It is difficult to estimate the average concentration from the analytical results, but the actual situation of waste water can be roughly obtained if the results are viewed taking the above-mentioned points into consideration.

Table 3-7 ANALYTICAL RESULTS OF WASTE WATER (mg/L, exept pH)

Unit	Total CN	Cu	Ni	Zn	Total Cr	pH	Remark
A			10.8		6.2	8.0	Operating
B				27.6	0.32	6.5	Not in operation
C		40.6	57.2	344	32.8		Operating
D	65.0	19.4		24.8	0.12	5.8	Operating
E	54.5	14.6	0.66		0.02		Not in operation
F		ND	0.12		*ND		Not in operation
G	0.64	0.44	1.03				Not in operation
H	75	3.91	244	0.72	*ND	5.9/7.6	Not in operation

*ND : Not detected

: Over the general standards in Sri Lanka

The waste water of units C, E, F and G in the table was untreated and the water of C was static rinsing water prior to dilution. These are naturally far beyond the environmental regulations. A, B, D and H stating that the water has been treated intermittently, but the waste water of all units except for E and F, where no work was performed on that occasion are far beyond the regulated limits uniformly.

Incidentally, the general discharge level of waste water and the recommended limit for waste water from the surface treatment process for the inland are a total of CN: 0.2 and 1.0 ppm, Cu: 3.0 and 1.0ppm, Ni: 3.0 and 1.0 ppm, Zn: 5.0 and 1.5 ppm and the Cr value of the general discharge level is a total of Cr:0.1 ppm and the recommended limit for the waste water from the surface treatment process is Cr^{3+} 1.0 ppm, respectively.

As shown in the above analytical results, most of the units discharge waste water containing high levels of contamination far beyond the regulated limit specified by CEA, but it seems that the occurrence of visible accidents by harmful substances have not be observed, because the volume of the discharged waste water is extremely small and the discharged water is mixed with a great deal of water from other sources in the drain or the groundwater in the nearby area where the waste water has penetrated into the soil, but is not drawn from a well.

5) Knowledge regarding to waste water treatment

Almost none of the plating units have sufficient knowledge regarding waste water treatment. According to the investigation of desire for the waste water treatment plan, most of the plating units indicate a desire to carrying out waste water treatment on their own premises, and not under the joint control in an industrial complex or in a centralized treatment system recovering waste water collected by tank trucks. The reason why they prefer to have their own treatment system than a joint or centralized system is thought due to lack of knowledge regarding the treatment method for plating waste water, and it must be considered that they know little or nothing about the investment funds needed to install waste water treatment facilities or the method of centralized treatment as well as the expense they must bear. It is not easy to calculate the investment funds and the expense for treatment. However, first of all it is necessary to educate them so that they have a certain level of knowledge regarding the method of waste water treatment .

3.2.2 Issues of the electroplating units

Given the current situation of electroplating units, major issues facing them are summarized as follows:

1) Electroplating technology

(a) There is the lack of quality concern in the market, which is interested only in appearance and price, discouraging quality improvement.

(b) There is the lack of knowledge on basic electroplating techniques; including the proper setting of current density and control of plating bath.

(c) Plating bath is not analyzed on a periodical basis and its concentration is generally low. Plating bath is contaminated because no filter is used.

(d) Bare copper wires are used to hang products in a plating solution. Only one unit uses plating racks, and most of them do not feel the need for use of plating racks.

(e) Pretreatment is not sufficient to ensure high plating quality, in particular electrolytic degreasing is not done.

(f) Dull nickel plating followed by polishing is the widely accepted plating process, and bright nickel plating is rarely made.

(g) Most units wash plated products by sprinkling water by bucket or hose, discharging the plating solution freely without recycling.

(h) Plated products are inspected for external appearance only, and no other tests such as thickness and corrosion resistance are conducted.

2) Waste water treatment

(a) While the electroplating industry is designated as a high-polluting industry and is required to obtain environmental protection license. However, a few units actually obtain the license.

(b) While most unit owners feel the need for proper waste water treatment, there is the apparent lack of knowledge on effluent standards and treatment technology. As treatment facilities do not produce any profits, they do not feel the pressing need for investment.

(c) No efforts are made to reduce waste water in the rinsing process that is a direct source of waste water, such as reduction of the plating solution to be discharged into the rinsing tank by recovery of the solution, and reduction of water consumption for rinsing. No separation into cyanide- and chromium-based waste water is performed.

(d) Most units do not treat waste water in any manner. Treatment carried out in a few units is not done properly. At present, waste water is diluted with waste water from other sources or penetrates into the ground. In future, there is a high risk of serious environmental pollution, such as health damage by toxic substances contained in waste water and contamination of ground water by waste water which saturate soil.

3) Recommended areas of improvement

(a) Improvement of rinsing process and work

Recovery of plating solution, multi-stage rinsing, and classification of waste water by type

(b) Implementation of systematic waste water treatment

Installation of treatment facilities or connectivity to centralized treatment system

(c) Improvement of plating process and work

Proper setting of current density, use of plating racks, filtering and air agitating, and proper control of concentration and temperature of plating bath

(d) Improvement of pretreatment process and work

Dipping degreasing and electrolytic degreasing

(e) Implementation of quality control based on product inspection

Measurement of thickness, corrosion test, and management and utilization of collected measurement data

In addition, general areas of improvement are listed as follows:

- To raise awareness and understanding of electroplating and waste water treatment technologies,
- To improve working environment (in particular, dusty environment should be avoided in plating shops), and
- To provide training for workers (proper work procedures and practices of field workers constitute the first step of quality improvement).

3.2.3 Related matters for plating technology and waste water treatment

The related matters for the present conditions and problems of plating units regarding plating technology as well as waste water treatment are described here. Furthermore, the technical contents concerning plating technology and waste water treatment are attached at the end of this paper as a supplement. We believe it will be helpful for understanding the plating technology and fundamental technology of waste water treatment together with following related matter.

(1) Pretreatment process

The process to remove oil stained during machining, pressing, bending and welding, etc. and the polishing dust of base metal polishing so as to make surface clean is called degreasing.

If degreasing and rinsing is not sufficient, it could cause electroplated coatings to peel off due to poor adhesion with the base metal. Especially, since bright nickel plating is harder and more brittle than pure nickel, it is necessary to clean the surface to obtain the best adhesion. There are 3 steps in degreasing, namely, predegreasing, boiled degreasing and electrolytic degreasing.

Predegreasing: This is a preliminary process to remove any heavy oil or polishing agent. This is sufficient for pretreatment of the painting surface, but boiled degreasing and electrolytic degreasing are necessary for plating.

Boiled degreasing (alkali degreasing): Removes the oil adhering to the parts due to saponification, emulsification and swelling of the fixed grease, by means of immersion into a hot bath composed of sodium hydroxide, sodium silicate, sodium phosphate, sodium carbonate and a surface activator.

Electrolytic degreasing : Removes the buff-dregs, oil, scales due to hardening and rust fixed on rough surface which can not be removed by the immersion degreasing process. This is necessary to improve the adhesion of the plated coating.

(2) Plating process

1) Plating bath

The basic bath compositions of copper, nickel, chromium, zinc and chromate treatment are common worldwide. Concentration, brightener and other additional agents are specially selected according to each factor .

2) Current density

There are the appropriate current densities corresponding to each plating bath, and the total current value should be calculated based on the total surface area to be plated. The plating is controlled not by voltage but by current. When the quantity of the parts is changed, the current value should be changed also due to the change in the surface area.

3) Elimination of impurities

Plating bath should not contain any impurities. If bright nickel bath contains chromic acid, plating is impossible. If it contains zinc and copper, the brightness is lost and becomes a lead color. To eliminate the above, dummy plating is necessary. The organic substance is absorbed and eliminated by an activated carbon. When the plating solution is made fresh, filtering using an activated carbon and dummy plating is necessary.

4) Racks

Racks are important jigs for conducting current normally, so as to distribute current uniformly over the plating parts and make the same current density between adjacent parts, namely, to make a uniform plating thickness.

Racks should be made so that the plating current can flow as calculated in order to obtain the best plating. The cross section must have a sufficient area to allow sufficient current for conductor. As for the materials, copper, titanium, phosphor bronze wire and steel wire are used, with the surface being insulated.

Generally, racks are designed and manufactured internally so as to fit the parts or ordered from the specialized companies in racks.

5) Filtering and agitation

The plating solutions of copper cyanide, zinc cyanide, silver and gold should be transparent in the plating bath. The nickel plating and copper sulfate baths can not be seen down to the bottom due to their color, but they should not be muddy. For this purpose a filter is installed and the plating solution is circulated and filtered day and night in some units even if plating work is not being carried out.

Air agitation is essential because of preventing pitting and obtaining high current due to agitation of the plating solution. It is desirable to keep an electrode pitch of more than 30 cm to allow the current to flow uniformly (except for industrial chromium plating).

It is necessary to fix the parts using racks for agitation. Furthermore, plating bath should be kept clean so that impurities or dust do not adhere to the parts due to diffusion resulting from agitation.

(3) Rinsing

If the water rinsing is not sufficient, problems could occur such as staining of the plating, uneven deposition, defective adhesion and pinholes. Furthermore, since the rinsing have close relationship with the waste water treatment, variable trials are carried out to improve the water rinsing effect with less water.

1) Reduction of drag-out quantity and recovering of the plating solution

If the reduction of the drag-out amount of the plating solution and recovery and reuse of the solution are achieved, it is not only able to reduce the amount of the chemicals to be used but also able to reduce the drag-out amount of chemicals into rinsing process. Thus, the quantity of the rinsing water can be reduced and consequently the quantity of the waste water can be reduced.

To reduce the drag-out amount of the chemicals, it is necessary to study dripping time, shaking off of the stagnant solution, air blowing and rinsing by spraying. A recovering tank shall be provided to recover and reuse of the chemicals.

2) Multi-stage counter flow rinsing

At present, the parts from several plating baths are rinsed in only one water rinsing tank.

It is able to reduce the water required for water rinsing by applying a multi-stage counter flow rinsing system (2 or 3 stages). Two or three rinsing tanks should be used on each line of all plating systems.

For example, the parts after chromium plating are put into the first water rinsing tank with racks having the chromium plating solution being rinsed. The racks are rinsed again in the second tank, in this stage there still remains a considerable amount of plating solution and the essential rinse can be carried out in the third tank.

Therefore, first two tanks are called the recovering tanks, and are used for supplying water when the chromium plating solution level drops due to evaporation, and the second tank is used for supplying the first tank.

This system is same for the drag-out of solution for nickel plating (the plating solution which puts on the parts and the rack, taken out from the plating bath), and the recovering tank is used to supply water when the solution level drops due to evaporation or drag out.

Therefore, the recovering tank must be used with PVC lining or made from the thick PVC plate both for nickel and chromium.

Further, there are a single tank, double tank, and triple tank (some of them is separated in the inside of tank) available as the type of water rinsing tank. The integral construction of plural water rinsing tanks is called a cascade type or multi-stage water rinsing.

There are multi-stage batch rinsing and multi-stage counter flow rinsing systems, multi-stage counter flow rinsing is generally adopted.

Multi-stage batch rinsing: Water in the initial rinsing tank is disposed based on the control result of contamination of the water in the final rinsing stage. Rinsing water is transferred to the next tank one by one and the fresh water is poured into the final tank when it has become empty. It is difficult to control of contamination of the water in the final rinsing stage.

Multi-stage counter flow rinsing: Rinsing water is poured in the final tank continuously, and water overflowing from the initial tank is sent to the treatment process.

Only dipping of the parts into water is not sufficient regarding rinsing. The parts are swung and shaken in water or air agitation from the bottom of rinsing tank is carried out. The spray rinsing is effective to improve rinsing efficiency.

3) Separation of waste water

Cyanide waste water and chromium waste water should be treated separately due to the difference in the treatment method; therefore, it is essential to separate the waste water for treatment.

Even if the centralized treatment is utilized, it is necessary to separate the waste water according to the composition in each unit.

The waste water overflowing from the rinsing tank should not be disposed directly onto the floor, and it is necessary to separate to the cyanide, chromium, acid/alkali or alkali/cyanide, acid/chromium water by piping and transfer them into the proper receiving tanks.

Improvement of the equipment lay-out to shorten the transportation distance and arrangement of the drip boards between the tanks is necessary, so as to prevent the chemicals from dropping on the floor during transportation of the parts from the plating bath to the rinsing tank. It is also needed to arrange the barriers on the workshop floor to separate the working area into cyanide and chromium groups, so that the mixing of the waste water of both groups on the floor can be prevented. A pump pit should be provided in each area to transfer the collected water by pumping up into the holding tanks.

(4) Products inspection

Main inspection items for plating product are usually appearance inspection, plating thickness inspection, and test of adhesion and corrosion resistance. There are several methods for each inspection item, and the most popular methods at units are as follows.

- Test method for plating thickness

Coulometric method: Dissolve a small certain area of plating as an anode by constant current electrolysis, and measure the thickness applying that the required time to remove the coating is proportional to the thickness.

Fluorescent X-ray specrometric method: Perform a specific fluorescent X-ray of the chemical element of the composed substances by an irradiate exciting X-ray on the specimen, and determine the thickness from its characteristics. It will be able to determine the coating thickness using a non-destructive and non-contact way.

- Test method for corrosion resistance

Neutral salt spray test method: Investigate the corrosion resistance in the sodium chloride mist atmosphere using salt spray test equipment. Evaluation is made by comparing the corroded condition of the specimen with a standard figure.

- Test method for adhesion

Thermal test method: Investigate the adhesion of plating by heating of the specimen

Thermal shock test method: Investigate the adhesion of plating by a thermal shock of the specimen

The evaluation is made by visual observation for both methods. When peeling off or blistering of the electroplated coatings is observed , then judge for defective adhesion.

(5) Bright nickel plating

1) Bright nickel plating is the start point of plating technology.

The bright nickel plating has been already industrialized together with the bright copper plating in 1953 with the foundation of the epoch-making development of plating technology. Before that, dull nickel plating had to be polished, not only needing a lot of manpower but polishing reduces the electroplated coatings; therefore, quality problems such as plating thickness and corrosion resistance occurred. On the contrary, the bright nickel plating did not have such problems because there was no need for polishing after plating. Furthermore, the bright nickel plating could do the work with high current density by raising the temperature in the plating bath and applying air agitation, that is, high-speed plating, and then productivity could be enhansed. In this case, the plating solution of the recovery tanks could be returned, because the solution in the plating bath decreases due to vaporization in the heating.

As mentioned above, since the bright nickel plating could reduce manpower regarding polishing and achieve improvement in quality and productivity, it has been wide-spread as a fundamental technique for plating technology together with the progress of the brightener as well as improvement in the plating process such as heating of the plating bath, air agitation, circulate-filtering, etc. It is a basic condition to master all processes and operations of the equipment for the bright nickel plating bath to carry out zinc plating, precious metal plating like gold and silver. Furthermore, this technique is fundamental also for advanced plating of hard chromium plating, plating on plastics and electroless plating.

When the corrosion resistance is a more important factor than the appearance like for automobiles or bicycles, the superior corrosion resistance can be obtained by duplex or triple nickel plating applying semi-bright nickel together with bright nickel plating, and also applying porous chromium plating or micro-cracked chromium plating in addition.

An example of working process for nickel-chromium plating is shown in Figure 3-1.

2) Bright nickel plating works

In the case of bright nickel plating, when maintaining a suitable current density and a uniform current distribution, so long as the brightness under the same plating condition is maintained, same plating thickness can be obtained even if any number of parts are plated. Furthermore, it also shows the metallic impurities in the deposit such as copper, zinc, etc. are not more than the allowable limit.

In the bright nickel bath plural brighteners are added, therefore, control of the plating bath and plating work is necessary. It is necessary to provide a filter and a blower for each bath. The use of racks is also essential.

Sometimes abnormalities occur during daily work such as poor brightness or pitting. In that case, it is able to overcome this quickly by carrying out the Hull cell test at the site better than by analyzing the impurities of very small quantities. When dark-gray plating occurs on the test piece at a low current density location at the beginning of plating or applying the Hull cell test, the dummy plating (carrying out the dummy plating to the copper or iron sheet of accordion pleats form as cathodes) should be carried out to remove any impurities such as copper or zinc in the nickel bath.

3) Elimination of buff finishing

So long as the bright nickel is plated completely, the delicate surface roughness is made smooth by the leveling effect provided in the plating bath; therefore, a buff finishing is not carried out. The plating thickness can be guaranteed, because the deposited electroplated coating is not polished..

As the polishing work generates an abrasion noise from emery buff and the noise from the abrasion machine or cyclone collector, working condition is not very good. Also, buff polishing is a source of dust. It is, therefore, better to separate it from the plating unit to prevent dust. The elimination of buff finishing after plating by performing bright nickel plating prevents such problems.

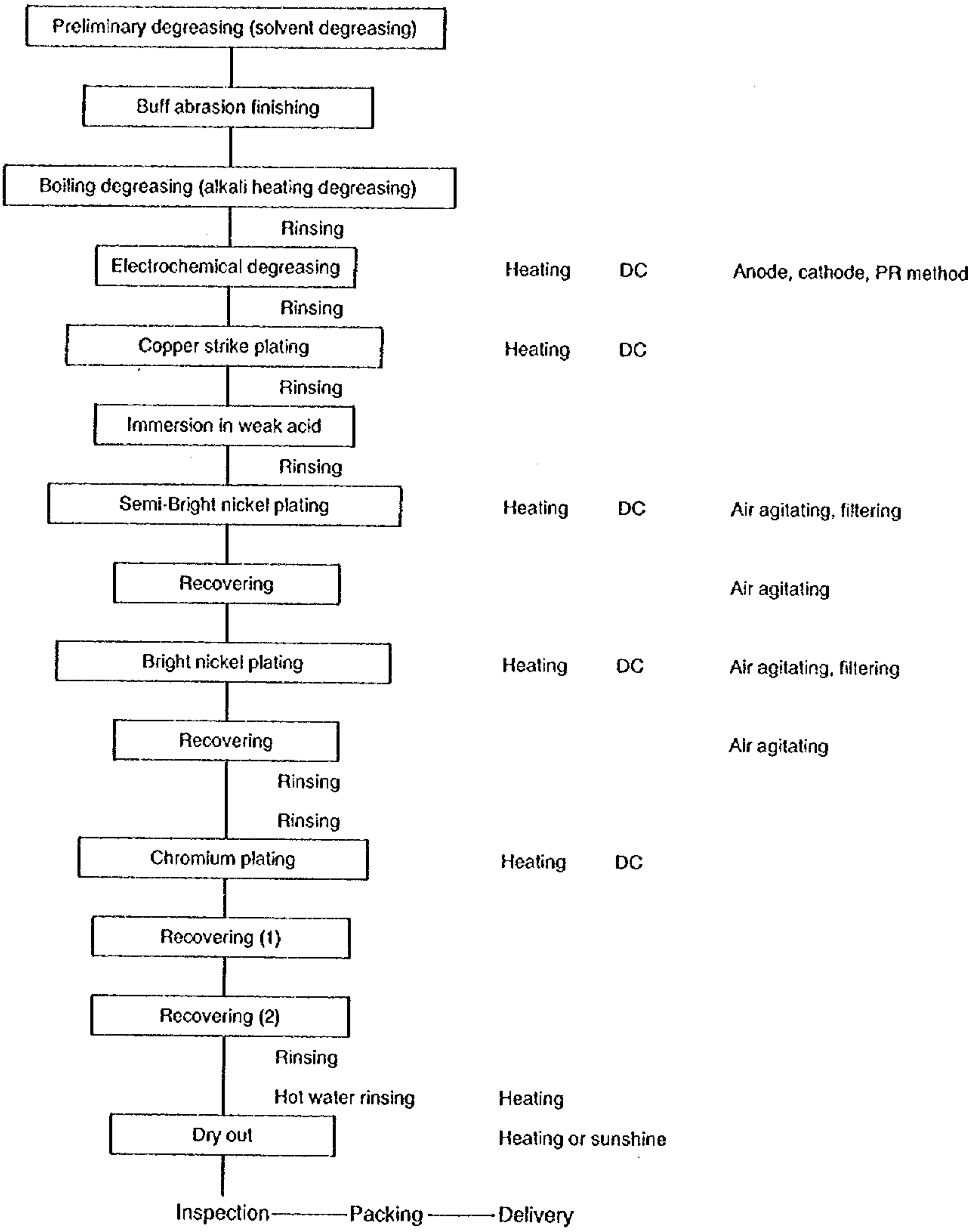


Figure 3-1 WORKING PROCESS OF NICKEL-CHROMIUM PLATING

(6) Waste water treatment

1) Waste water treatment

The penetration of untreated waste water including harmful substances seeping into the soil causes underground water pollution due to the accumulation of harmful substances in the soil. In the method of dilution of waste water, an immense water volume is necessary to regulate waste water. For example, if a concentration of Cr^{6+} in the recovery solution in the process of chromium plating is 12gr/L, it must be diluted 120,000 times to reach the regulated limit 0.1ppm of the waste water, meaning that the dilution is impracticable.

The treatment for plating is different according to the harmful substance composition. The cyanide and chromium waste water should be separated and be treated by different chemicals. The mixture of 3 kinds of waste water of cyanide, chromium and acid/ alkali should be avoided.

2) Continuous treatment and batch treatment

The batch treatment is more suitable than the continuous treatment for units in which the plating work is carried out intermittently with a small waste water volume. The batch system is appropriate to cases of a cyanide concentration of more than 300ppm, a Cr^{6+} concentration of more than 200ppm and a waste water volume of less than 6～10 m^3 per day.

The flow sheet of continuous system is shown in Figure 3-2 and batch system is shown in Figure 3-3.

In the batch system, the waste water is held in the holding tank, and is treated in the reaction tank for every batch and discharged after treatment. Motor driven stirring equipment is provided in the reaction tank, and the quantity of chemicals is controlled using a portable measuring instrument (pH ORP), to discharge the waste water conforming to the regulated limit. To allow for easy injection of the chemicals, an injector is installed.

In the continuous system, the waste water which flows into the treatment tank is treated continuously by the continuous injection of chemicals, the concentration of waste water should be continuously checked. When the operation rate is high and the waste water volume is large, the continuous system is suitable, because a big tank is necessary for the batch system.

At present, the treatment carried out in Sri Lanka is performed with a intermittent injection of the chemicals once or twice per day into the waste water discharged continuously during the plating work and no holding tank and treatment tank are provided. Accordingly, untreated waste water is discharged during the time when no chemicals are injected. The waste water regulation can not be kept in such a treatment manner even if the treatment is carried out.

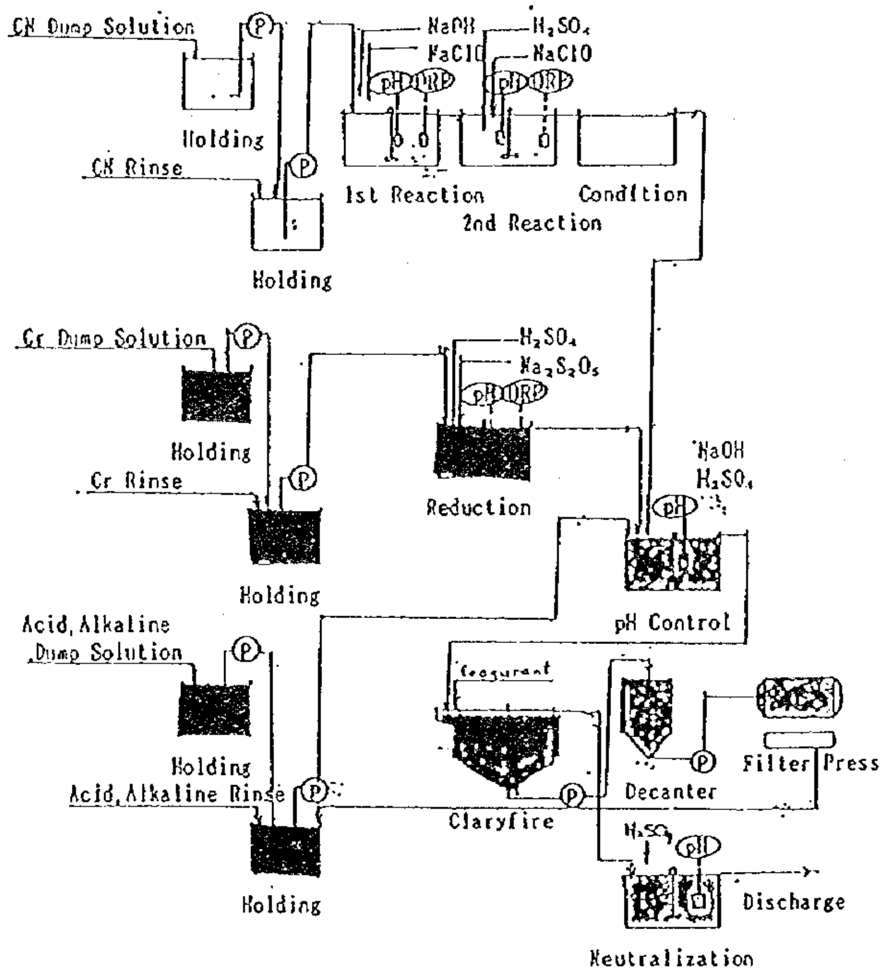


Figure 3-2 FLOW SHEET OF CONTINUOUS TREATMENT

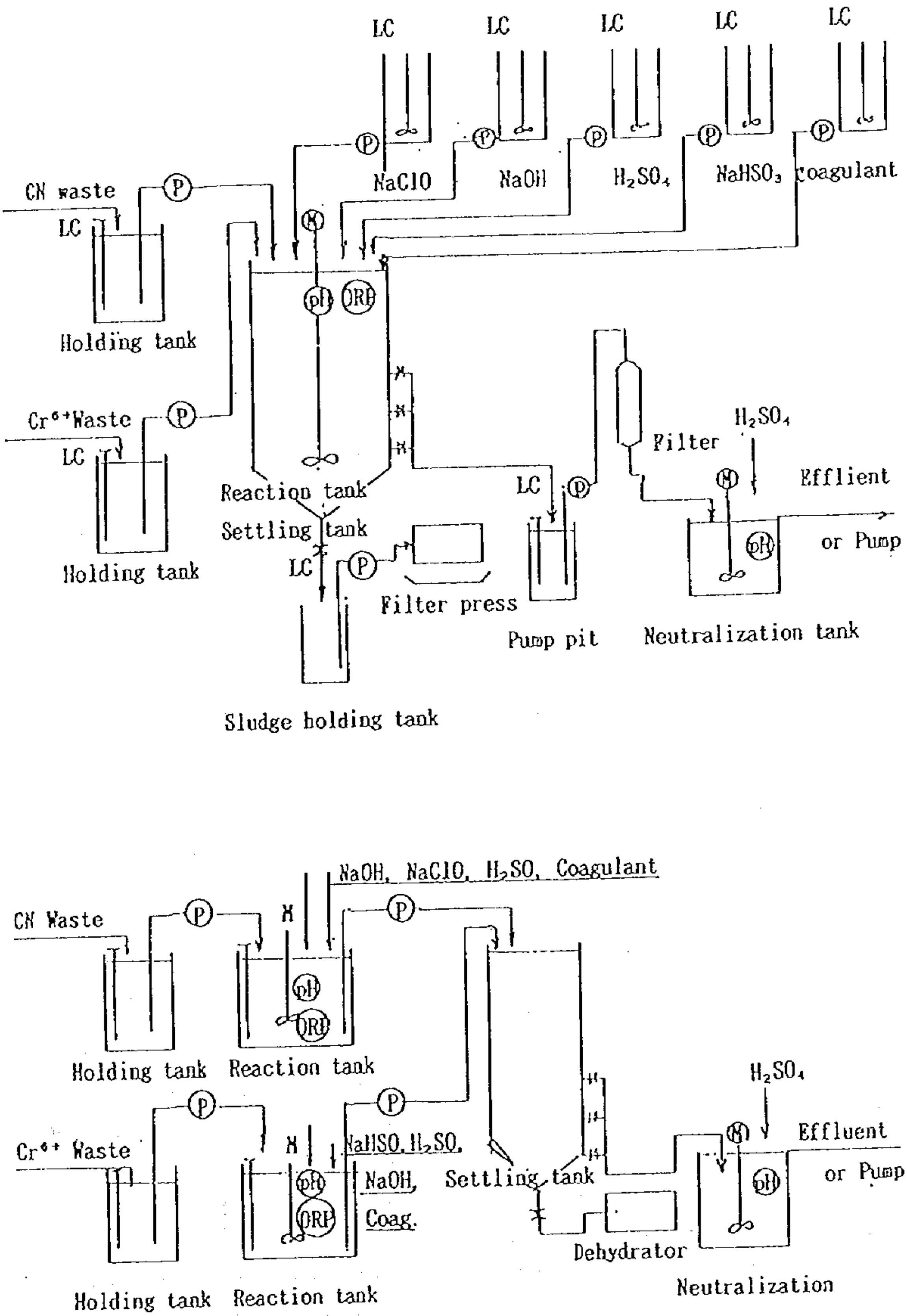


Figure 3-3 FLOW SHEET OF BATCH TREATMENT

(7) Installation planning of waste water treatment facilities

The following are installation planning for waste water treatment .

- Treatment facilities will be installed in individual units.
- Industrial complex will be arranged and communal treatment will be carried out.
- Waste water is collected from individual units, for example, with tank trucks and centralized treatment will be carried out.
- The exchange absorption of the harmful substances will be carried out by using ion-exchange resin in individual units and the regeneration treatment will be centralized performed.

In principle, it is desirable to have the treatment facilities located in the premise of each unit.

Units lager than medium-size ones should have the own treatment facilities and should carry out their own treatment.

In case of small-size units, it seems better to treat the waste water in a centralized treatment plant than to have their own treatment facilities from the viewpoint of investment funds regarding treatment facilities, installation space and treatment techniques. The method to move to an industrial complex and to carry out joint treatment there is not simple for small-size units, because there are many difficult problems for individual units not only to solve the pollution treatment, but to bear the moving expenses and maintain the existing customers. As far centralized treatment it is not necessary to move the unit and there is only the problem of limited waste water treatment, it is more practical as the treatment planning for existing units than to move the industrial complex.

1) Installation planning of equipment for individual units

As described in sub-clause (6) Waste water treatment, select the batch system or continuous system considering the operating situation of the plating equipment and the waste water volume. Even though any system is selected, it is necessary to make effort to reduce the volume of waste water and the concentration of the chemicals in waste water by taking measures against the sources described in sub-clause (3) Rinsing process, prior or simultaneously to installation of the waste water treatment facilities. When the water volume is reduced, the batch system can be applied.

There is the way that to select a unit who is cooperative in promoting the popularization of the waste water treatment in the industry as the model unit, and perform here in-process improvement, installation and operation of the treatment equipment. Then, open the industry to actual equipment and operate as well as hold the workshop to spread the techniques on a much wider basis. It is recommended that the Electroplating Center will undertake the technical leadership and support the model unit from planning to operation. It is a possibility to select the Electroplating Center as a model unit, but the present waste water volume there is 400 L/day. It has been assumed that the waste water volume will increase to 400 L/day of acid, 400 L/day of chromic acid, 700 L/day of alkali/cyanide, total 1.5m^3/day when the plating amount is increased in future. However, it ought to decrease by recovery of the chemicals and the measure of saving water in the rinsing process. Therefore, it will not be needed to operate the unit every day due to the small waste water volume. It is necessary to improve the waste water treatment facilities in the Electroplating Center, but it does not make sense unless the model plant is operated daily (improvement of the waste water treatment system in the Electroplating Center is described in chapter 6). It is necessary to study in advance to avoid that the model plant does not perform its duties due to a shortage in the waste water volume even though the equipment is installed. It is better to select a model unit which can keep constant plating work volume daily and the waste water volume which is needed to operate more than once per day.

2) Communal treatment in industrial complex

This is a method to gather plating units in an industrial complex, establish a cooperative association and treat together waste water from all units. It would be more cost saving to install a joint treatment equipment than install it in individual units. However, since there are problems such as the moving expenses to the complex, the maintenance of a customer due to movement, it is difficult to consider only a solution to the pollution treatment.

The establishment of a complex may not be successful if its objective is only for the communal treatment of waste water. It is essential to achieve the merits of establishing a complex and cooperate association in the management aspect of an enterprise. For example, if there is a consensus about the following policies, it does make sense to establish a complex.

- Segregating the sort of plating work of units in a complex
- Joint purchasing of material
- Unification of the plating charge
- Unification of the fund system
- Collection of the welfare facilities
- Technical training system

To succeed in communal treatment of waste water, the following conditions are essential and it is required that each unit which joins a complex is not based on the idea only to perform waste water treatment easier but to pay more attention to the waste water treatment so as not to cause any inconvenience to the other association members and to maintain a joint system .

- To have a strong leadership company as a complex member
- To keep the responsibility of each unit regarding its own waste water
- To calculate accurately and reasonably the basis of the expenses for waste water treatment to be shared.

For reference, the actual results in Japan are as follows. There are 734 companies doing independent plating work in Tokyo and only two industrial complexes are using the communal treatment method. In Chiba Prefecture, two complexes were established, but one of them was closed due to financial difficulties, and the cooperative association was dissolved. The complex is now operated by the leading company who took over some ex-members of the association.

Judging from the present situation of small-size companies in Sri Lanka, it may be impossible to move the units (plating workshops) from the present location to an complex as regards funding and business activities.

3) Centralized treatment

This is the method to transport the waste water from the units to a centralized treatment plant by tank trucks and treat the waste water there, in the event that the volume of waste water of each unit is extremely small. This method is suitable for small-size units where no engineer for the treatment technology is available, no funds for treatment equipment are provided and no space to install the equipment exists.

Each unit has to hold waste water separated as regards cyanide and chromium in the holding tanks, so that the centralized treatment can be carried out more economically. Furthermore, the transportation charge from a unit to a treatment plant as well as the treatment fees have to be borne.

The centralized treatment plant is the same as an industrial complex plant, however, since each unit does not move, there is no difficulties like in the case of a complex. There are merits such as no need of funds and operational control for the treatment equipment which are required for individually installed equipment.

In the case of carrying out centralized treatment, it is essential to investigate the number of the companies utilizing the plant, the volume of the water to be treated, the treatment method, the location of the plant, the body to establish and operate the equipment, the body to make technical guidance, the transportation method of the waste water, the cost of transportation and treatment, and the disposal of the generated sludge. The determination of the treatment charge is connected closely to the volume to be treated, and some arrangement, for example, a compensation system, needs to be investigated, so that the operation costs of the plant are guaranteed.

In Thailand, there are results to carry out centralized treatment of plating waste water (including surface treatment industries) in the city of Bangkok (refer to 5.1.2). Since there are many small-size plating units in Sri Lanka whose waste water is mostly less than 1 m^3/day, centralized treatment is worth investigating as a practical method. The installed location should be determined considering transportation, because the plating units are distributed over a wide area. However, there is an idea to establish plants step by step splitting up the north and south regions. The governmental aid for the investment for equipment may be also needed. It is recommended that the establishment and operation of plants will be realized under the technical guidance of the Electroplating Center.

4) Centralized regeneration by ion-exchange resin

This is a method utilizing the principles in which a large volume of the dilute waste water is concentrated into a small volume of concentrated solution by ion-exchange resins. There are two methods: One is to adsorb all ions in waste water to resins and recycle the water; and the other is to adsorb the metals (salt) only and recycle the metals.

When waste water flows through ion-exchange resin column, cations such as Cu^+ and Ni^{2+} and the anion such as CN^- and CrO_4^{2-} are absorbed in the respective resins and they are removed from the waste water. When the resins are saturated with such ions, the ions are liquated by acid or alkali and a concentrated solution is obtained as the liquated solution. Since the liquation process and treatment of the concentrated solution needs a special technique, the resin is made as a portable resin column and centralized regeneration and centralized treatment of liquated solution are performed by collecting the saturated resin columns. The plating units lease the resin column from the manufacturer and use it by connecting it with the piping for waste water. When the resin is saturated, a new column is connected and the saturated one is returned to the manufacturer.

For recovery of the metallic salt, the waste water containing nickel or chromium is poured through the resin column and the metallic ion is absorbed in resin. The manufacturer recovers nickel salt or chromic acid salt from the adsorbed and saturated resins and recycles them as material of nickel or chromic acid. However, if recovered metal amount is small, it is impossible to be used as material.

Even in the case in which the recovered metals can not be utilized, it is possible to reduce the volume of the waste water by using ion-exchange resin, and then, the equipment for the waste water treatment can be miniaturized and the installation space can be saved.

In the case of Hong Kong, where the installation space for the treatment equipment is limited, it is recommended to condense the waste water by ion-exchange resin. In the case of Bangkok where the centralized treatment is carried out, there is a plan to arrange ion-exchange resin for every unit and condense the waste water there, so that the waste water volume to be transported can be reduced.

(8) Low-polluting chemicals

To realize the pollution-control measures economically, it is necessary not only to find how to treat harmful materials, but also to minimize the volume of the harmful materials and chemicals difficult to treat.

The low concentrated plating solution, chromate solution, zinc plating solution with a low concentration of cyanide (moderate and low concentration), and a non-cyanide plating solution that does not contained cyanide at all have been developed and are used in some fields. As for the solution for the pretreatment, the treatment solution without chelate that is difficult to treat, a long duration solution that is easily separated from the degreasing solution and non-cyanide solution for electrolytic degreasing and stripping of nickel coating have been developed.

However, since these non-polluting chemicals (for example, in the case of a change over to a non-cyanide zinc plating bath) affect the different influence for an acidic bath and alkaline bath regarding throwing power, current efficiency, and the character of coating, it is necessary to apply these chemicals taking the character, use and purpose into consideration.

3.3 Current State and Major Issues related to IDB Electroplating Center

3.3.1 Current state of IDB Electroplating Center

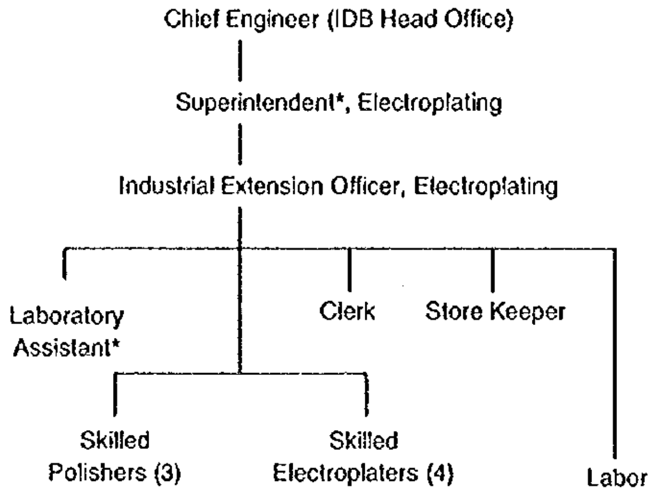
(1) Overview

The center belongs to the Engineering Division, one of IDB's twelve divisions. It was established around ten years ago to transfer electroplating and waste water treatment technologies to small- and medium-sized platers and provide practical training for the purpose of improving electroplating technology in the country. It was financed by the World Bank as one of the second projects to support the fostering of SMIs and growth of employment and export opportunities in Sri Lanka.

The center is located within IDB facilities in Peliyagoda, northeast of and adjacent to Colombo, separate from IDB's head office in Moratuwa. In addition to the electroplating center, the facility accommodates Rubber Division's workshop and analytical laboratory. While providing education and training services related to electroplating technology, the center performs electroplating work on a contract basis by using its equipment, which revenues cover about one third of total expenditures required for the center's operation.

(2) Organization

The center is led by the chief engineer of Engineering Division and is staffed by 13 people; a superintendent, an industrial extension officer, a laboratory assistant, three polishers, four electroplaters, a clerk, a store keeper, and a labor. Of total, there are three technical staff (marked by * in Figure 3-4), with remaining staff being workers or office workers.



* : Technical Staff

Figure 3-4 ORGANIZATION STRUCTURE OF IDB ELECTROPLATING CENTER

(3) Equipment

The center has a polishing shop, an electroplating shop, a laboratory, store houses, and an office. Electroplating and waste water treatment facilities, installed at the time of construction of the center, are capable of performing a standard set of electroplating operations, including zinc plating, copper plating, nickel plating, chromium plating, and hard chromium plating. There are a "Bondal" tank to perform zincate treatment for plating on aluminum and a brass plating tank, which are not used. The tank for "Bondal" treatment do not have any solution. Compared to equipment owned by electroplating units visited for the field survey, however, the center's equipment is more diverse and larger in number. A plan view of the center is shown in Figure 3-5. Although some equipment needs repair or improvement, it is fully operational and there is no urgent need for replacement. In fact, there are many other areas which require improvement.

Polishing and electroplating equipment, waste water treatment equipment, and analytical instruments and laboratory equipment owned by the center are listed in Tables 3-8, 3-9, and 3-10. The existing analytical instruments and laboratory equipment do not cover all the work required at the center, and the center sometimes borrows required equipment from the Rubber Division that has a facility within the same site.

Figure 3-5 GROUND PLAN OF IDB ELECTROPLATING CENTER (REFER TO TABLE 3-8 to 3-10)

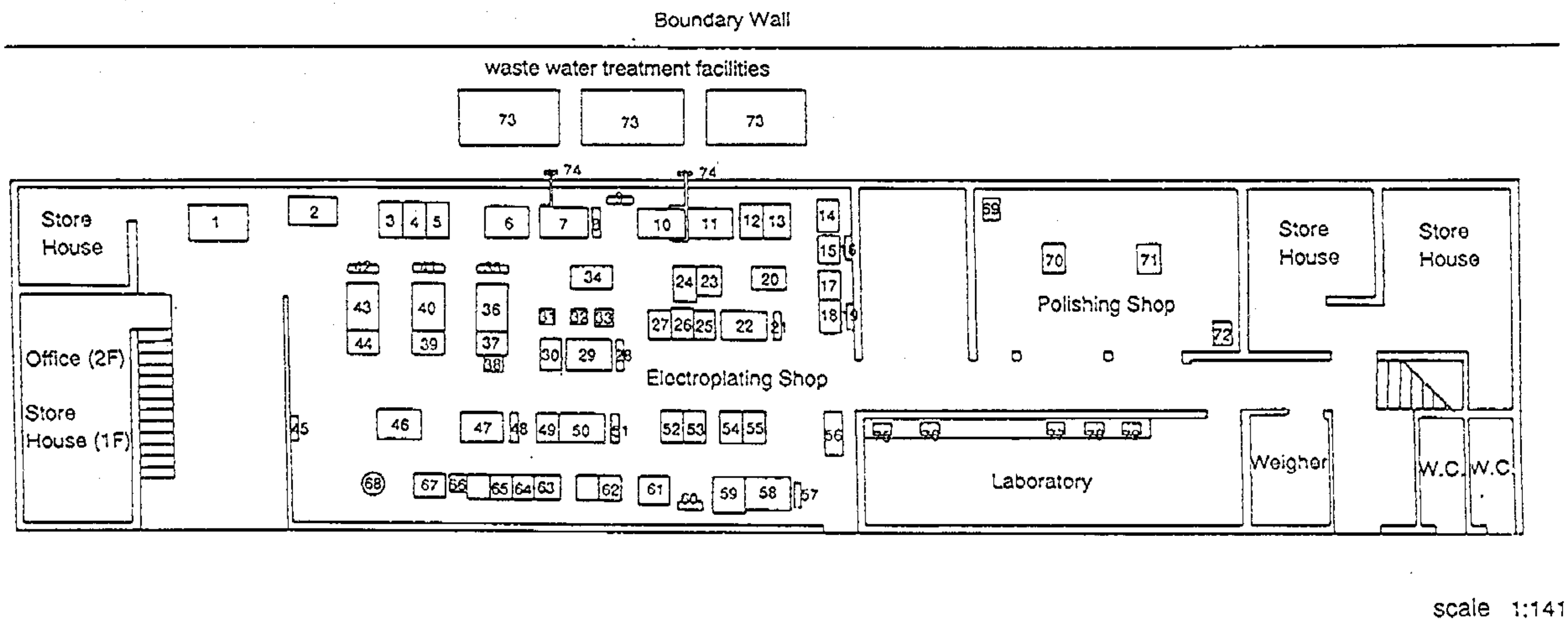


Table 3-8 ELECTROPLATING EQUIPMENT

1 M.C.B. Panel (920 x 1,600)
2 Rectifier (440 x 1,300)
3 Hot Water Rinsing (850 x 600)
4 Cool Water Rinsing (850 x 600)
5 Chrome Neutralizer (850 x 600)
6 Drag Out Tank (900 x 1,350)
7 Bright Chromium Plating (900 x 1,350)
8 Resistant Board (700 x 200)
9 Resistant Board (200 x 700)
10 Hard Chromium Plating (900 x 1,350)
11 Nickel Stripping (750 x 1,350)
12 Water Rinsing (850 x 600)
13 Neutralizer (850 x 600)
14 Water Rinsing (850 x 600)
15 Chromium Stripping (850 x 600)
16 Resistant Board (700 x 200)
17 Water Rinsing (480 x 480)
18 Nickel Stripping (850 x 600)
19 Resistant Board (700 x 200)
20 Minco Cleaner (620 x 910)
21 Resistant Board (700 x 200)
22 Cyanide Copper Plating (760 x 1,220)
23 Bondal Dipping (610 x 610)
24 Water Rinsing (550 x 700)
25 Water Rinsing (850 x 600)
26 Acid Dipping (850 x 600)
27 Water Rinsing (850 x 600)
28 Resistant Boord (700 x 200)
29 Acid Copper Plating (760 x 1,220)
30 Water Rinsing (850 x 600)
31 Filter (450 x 500)
32 Air Blower (400 x 400)
33 Filter (480 x 480)
34 Water Rinsing (600 x 850)
35 Resistant Board (200 x 700)
36 Bright Nickel Plating (1,220 x 760)
37 Water Rinsing (600 x 850)
38 Filter (450 x 500)
39 Water Rinsing (600 x 850)
40 Dull Nickel Plating (1,220 x 760)
41 Resistant Board (200 x 700)
42 Resistant Board (200 x 700)
43 Brass Plating Bath (1,220 x 760)
44 Water Rinsing (600 x 850)
45 Deionizer (650 x 200)
46 Water Rinsing (760 x 1,220)
47 Hot Metal Cleaning (760 x 1,220)
48 Resistant Board (700 x 200)
49 Water Rinsing (850 x 600)
50 Anodic Cleaner (760 x 1,220)
51 Resistant Board (700 x 200)
52 Cyanide Dipping (850 x 600)
53 Water Rinsing (850 x 600)
54 Water Rinsing (850 x 600)
55 Cyanide Dipping (850 x 600)
56 Barrel Polisher (1,500 x 600)
57 Resistant Board (700 x 200)
58 Zinc Plating (760 x 1,220)
59 Water Rinsing (1,050 x 880)
60 Resistant Board (200 x 700)
61 Zinc Plating Barrel (880 x 880)
62 Water Rinsing (610 x 1,220)
63 Nitric Acid Dipping (610 x 610)
64 Blue Passivation (610 x 610)
65 Water Rinsing (610 x 1,220)
66 Yellow Passivation (480 x 480)
67 Hot Water Rinsing (600 x 850)
68 Dryer (500 ϕ)

70 Polishing Machine (700 x 1,600)
71 Polishing Machine (700 x 1,600)

Table 3-9 WASTE WATER TREATMENT FACILITIES, AND OTHERS

69	Dust Collector (1,250 x 700)
72	Dust Collector (1,250 x 700)
73	Waste Water Treatment Tank (1,500 x 2,700) x 3
74	Exhaust System (250 ϕ Pipe)

Table 3-10 LABORATORY EQUIPMENT

75	Oven
76	Muffle Furnace
77	pH meter
78	Thickness Tester
79	Chemical Balance

(4) External service

The center's education and training activities related to electroplating technology are conducted through training courses which are described as follows.

A two-day training course was conducted three times in 1995, and once up to August 1996. The course is designed for people who will be engaged in electroplating work for the first time or do not have much experience. It is given for 10～15 students each time and a certificate of completion is issued. Three technical staff of the center serve as instructors. In the morning, lectures are given on introduction to electroplating, the handling of chemicals, plating procedures, and other basic knowledge. In the afternoon, trainees visit the center and observe polishing and plating operations carried out by skilled workers. Trainees do not engage in actual work. A general impression is that the contents of the course material are not entirely consistent with actual operations at the center.

Another course is a program teaching know-how for solving problems at the production site. In 1996, one program was held up to August. This programme is usually attended by 5-8 persons. No certificate is issued. The program appears to answer mostly basic questions raised by private electroplating units.

(5) Production activity (contract work)

The center, under IDB head office's basic policy, performs electroplating work on a contract basis from outside, which constitutes the center's revenue source. In 1995, it performed 70 - 80 electroplating jobs for around 30 customers per month, and earned 500,000 Rs. annually, which accounted for one third of the center's annual expenditures (1.5 million Rs.).

Although the center plans to add 2 rectifiers and some workers, the study team observed that the center can perform more work even at its current capacity. Without new investment or an increase in work force, productivity can be improved significantly by improving levels of technology and skills and standardizing work procedures for higher efficiency.

Despite the contribution to earn revenue by contract work, one should not forget that the center's major purpose is to improve electroplating technology and foster the industry. An emphasis on commercial business by competing with private electroplating units seems to be conflict with, or even adversely affect, the center's original function.

In Sri Lanka, labor unions are organized by trade and are closely associated with certain political parties they support, so that EPC must obtain approval of IDB's chairman for any change which affects working conditions, e.g., any change in the work management system. The approval usually takes time as the chairman has to make careful coordination to avoid any dispute by anticipating reaction of labor unions to the change.

(6) Current state of waste water treatment

The center's plating facility does not seem to be utilized well as most tanks are not in use. The amount of waste water discharged from the center is 400 liters/day. Waste water is discharged from the rinsing tanks through overflow pipes, and then is divided into alkali- or cyanide waste water and acid or chromium water, which are stored in 500 liter tanks. They are treated by chemicals once or twice per month. The treated waste water goes through neutralization tanks and is allowed to penetrate into the ground. Clearly the current intermittent treatment system has little effect on continuously discharged waste water as it is discharged without treatment while no chemical is put into the tanks.

Also, waste water does not flow smoothly from the rinsing tank to the treatment tank due to an insufficient pressure head.

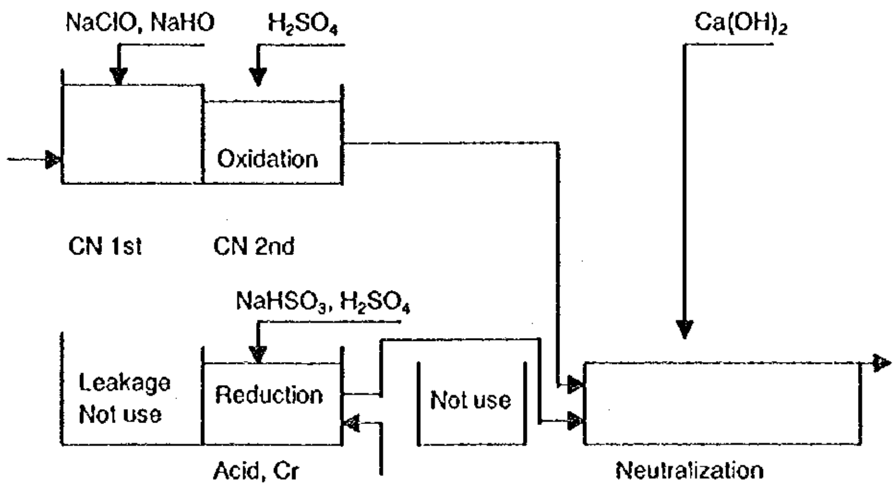


Figure 3-6 FLOW SHEET OF WASTE WATER TREATMENT IN THE PLATING CENTER

(7) Technology and skill levels

The center's three technical staff members received training (one in the U.K. and two in India) when they joined the center. However, interview with the acting superintendent and the laboratory assistant by the study team indicates that they lack both the ability to apply basic knowledge to actual work as well as field experience. The training course's textbook can be understood by the staff, but knowledge contained in it does not seem to be fully utilized in the center's field operations. The entire electroplating process, from polishing to waste water treatment, is not supported by necessary equipment including measuring instruments, and basic work rules such as procedures and presetting of work conditions have not been manifested as production technology and skills.

A number of problems can be pointed out. In the pretreatment process, no activation treatment is carried out. During the plating work, there is no rack suitable for applying electricity to a plated object, and instead a copper wire is used by bending it into an incorrect shape. Plated objects are not correctly arranged in the plating bath. Important parameters for plating bath, such as bath composition, concentration, temperature, and duration, are not controlled. Although the plating bath is analyzed every other week, available records are incomplete and do not appear to be used for control of bath. This has been confirmed by the fact that there was no time series data on variation of bath composition or control chart. The plating bath is not agitated by air, evidencing the lack of concern about distribution of chemical concentrations in the plating bath. Also, the plating bath is not circulated through filtering, resulting in gradual contamination. As a result of many undesirable practices, current density and voltage used during the plating work deviate from the range usually used.

Though quality standards are specified for plated products, no directions are given for quality standards, and quality inspection depends solely on visual inspection by workers. Physical characteristics such as plating thickness and peel strength are not measured at all. This is probably because good appearance alone is satisfactory to meet the market's requirements. The scope of electroplating work is limited to the repairing of automotive bumpers, the plating of reinforcing sheets for instrument panels, and the plating of bolts and nuts. At least, the study team did not observe any work requiring high quality.

The study team's findings are based on numerous observations made at the center and are not related to potential capability. In conclusion, technology levels of electroplating work at the center are more or less the same as those at private electroplating units.

(8) Production management

The electroplating center is geographically remote from IDB's head office and transportation access is limited. As a result, there is an apparent lack of communication between IDB headquarters and the electroplating center. The chief engineer of Engineering Division does not visit the center frequently.

The center's electroplating work seems to be performed by relying on field skills learned through experience, rather than knowledge of basic technology supported by scientific and engineering theories. Thus, there is virtually no modern production management at the center.

There are no work standards and manuals are not available. Instead, a handbook[1] and a textbook[2] furnished by chemical manufacturers are used.

No work instruction sheet is issued for a new job prior to the start of the work. The plating bath does not seem to be checked periodically. Plated products are visually inspected for appearance and quantity.

The result of the second field survey indicates that, although the superintendent of the electroplating center proposes to IDB's chairman a communication system under which work instructions to workers are specified in writing, it has not been put into practice as negotiations

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1) "The Canning Handbook" Surface Finishing Technology, W. Canning plc. Birmingham (1982)

2) K.E.Langford & J.E. Parker, "Analysis of Electroplating and Related Solutions", 4th Ed., Robert Draper Ltd. (1971)

with many parties are required.

Equipment is not sufficiently maintained. Bag filters in the polishing process do not work and are left intact. Ducts and pipes are damaged. Polishers wear masks to prevent dust inhalation, which is not a desirable practice. Ventilators in the plating process do not work. Since all of them have presumably operated at the initial stage, it is reasonable to conclude that they do not function properly due to poor maintenance or misuse.

Piping to the waste water treatment process is also damaged. However, some of these problems can be overcome by innovative efforts at field, e.g., the use of a drainage pump. The electroplating process, which uses large amounts of acid and alkaline substances, often uses polyvinyl chloride (PVC) for equipment and piping materials. PVC materials should be repaired by securing necessary staff with PVC welding skills and equipment.

Poor maintenance is evident in analytical instruments used at the laboratory. They are precision equipment requiring special care to keep them in good operating condition. A typical example is seen in the chemical balance, the basic analytical instrument, which could not be used throughout the duration of the field survey. This is unthinkable if analysis is to be performed periodically.

Then, during the second field survey, the study team confirmed that the chemical balance had been repaired and the analysis of electroplating bath was being conducted on a periodical and systematic basis, and the results were recorded. These improvements have been made in response to our advice as requested by the chief engineer during the first field survey.

Chemicals are classified according to the type of toxic or hazardous substance and are kept in a locked warehouse. Proper control of chemicals is very important for facilities handling cyanide compound. During the second field survey, books recording acceptance and requisition of chemicals, and inventories levels are identified.

Consumables for daily work are also kept in the warehouse.

3.3.2 Major issues

(1) The primary purpose of the center is to improve and disseminate electroplating and waste water treatment technologies in Sri Lanka. As the first step, the center must have necessary technologies as well as production management capabilities that enable the center to achieve

the purpose. The center is expected to produce skilled workers who can apply basic knowledge and technology to actual electroplating work and waste water treatment practice, and who can teach other workers.

(2) The center must be a model facility for electroplating and waste water treatment technologies in the country. Efforts should be started by retraining the center's workers to provide them with the ability to apply learned technology and skills to actual work including basic tasks.

(3) The center should not allow low quality requirements in the market to justify the lack of efforts and progress. It must develop the ability to improve and implement electroplating and waste water treatment technologies to make the industry ready for import substitution demand, effective pollution control, and compliance with future environmental standards. As the reliable provider of technical guidance, the center must serve as a model case for high-grade electroplating, high productivity, and complete pollution control measures.

(4) Production technology can be easily disseminated if it is standardized and drives the streamlining of everyday work. The center's electroplating work is very low in productivity, and if market potential is fully exploited, production can be boosted without adding manpower, and can bring in additional revenues. Nevertheless, one should not forget that the center's primary purpose is to diffuse technology required for the fostering of the electroplating industry, rather than making a successful business. In this sense, productivity improvement at the center should be considered as a model case for other units to follow.

(5) IDB's head office intends to adopt the 5S movement as one of initiatives for productivity improvement. It is recommended that the center initiate the move as the first step of putting production management into practice.

(6) There is an apparent lack of maintenance technology and practice which are essential for keeping production equipment in operation. Maintenance activity must start upon installation of equipment if it is to function as designed. If expensive equipment does not work properly due to poor maintenance, the center would fail to fulfill its role as the model plant, and there would be a waste of resources that would affect national interest.

(7) The center is mandated to provide technical guidance for electroplating operations. However, its current state fails to convince the study team, among others, that it has the ability (field-proven) to assume such a leadership role in electroplating and waste water treatment including production management.

(8) The center seemingly intends to build up communication networks with the electroplating industry and its participants. It is important for the industry's development to enable the center to provide technical support for organizing the industry's efforts.

3.3.3 Technical issues observed at the electroplating center

(1) Issues related to electroplating technology

1) The center's technology was introduced around ten years ago and is still based on the process consisting of dull nickel plating, polishing, and glossing. The bright nickel plating process was commercialized in 1953 and is widely used, in countries including Thailand, the Philippines, and Pakistan (the duplex nickel plating process of semi-bright and bright nickel plating is used in some facilities). The dull nickel plating/polishing process involves the partial removal of the deposited layer, not to mention the need for an additional (polishing) process.

2) Pretreatment before electroplating operation is rarely carried out. Polishing powder is applied to the objects to be plated for manual scrubbing. Smut is removed in the same manner. After the pretreatment, the objects are bundled by wire (copper) and are put into the plating process (although rust develops in some places).

3) Work is not performed according to the basic plating process. For instance, copper plating is done by scrubbing the objects manually and placing them in a plating bath (current density of $13A/dm^2$ x 3sec). Then, the deposits are scrubbed by polishing powder manually. No copper striking is performed.

In the bright nickel plating process, neither activation treatment before plating nor air agitation is carried out. Since no rack is used, the objects cannot be securely fixed.

4) Plating conditions are not specified, e.g., conditions for setting the value of current for zinc plating, while the voltage is too high (80A, 11-12V). When the coated objects are taken out in the course of plating, no adjustment of the current is made, and the induction wires (copper wires) become hot.

Plating time and temperature are not clearly specified. Work is not performed in anticipation of coating thickness.

5) Control of plating bath (composition and temperature of plating bath) is improper. Periodical analysis is not performed, and no control chart is prepared.

The plating solution is not filtered, e.g., slimes are seen on the surface of the zinc plating bath.

6) Recycling of the plating solution and reduction of rinsing water (counter-flow rinsing) are rarely performed.

7) There is a lack of concern about plating thickness. Plating area, current density, and plating time are not controlled.

For instance, wrong plating conditions were set: for dull nickel plating, 1.5～2A/dm^2, 30 minutes for target plating thickness of 20 μ m (theoretical thickness of 9.2～12.7 μ m); and for bright nickel plating, 2.5～3A/dm^2, 20～30 minutes for target plating thickness of 20 μ m (theoretical thickness of 10.2～18.4 μ m). Then, thickness of randomly selected samples was very thin, 0.99 μ m and 2.33 μ m respectively, evidencing the lack of control.

8) Objects are not securely fixed as no plating rack is used, so that air agitation cannot be carried out for nickel plating. If air is fed, it rises on the anode side and does not serve the intended purpose.

9) The lack of concern about plating thickness results in the lack of concern about uniformity. As no plating rack is used, objects are oriented in varying directions relative to electrodes, resulting in lack of uniformity in plating thickness. In chromium plating, some areas are not plated and the surroundings are burned.

It is important to recognize the importance of plating racks.

10) There is the lack of control on anodes which affects uniformity in plating thickness. Anodes need to be arranged in consideration of primary current distribution.

Basic education on plating thickness and uniform electro-deposition is required.

11) As for filtration, mentioned in 5), its importance can be understood clearly by carrying out air agitation for nickel plating. For copper and zinc plating, anode bags should be used with continuous filtration at a rate of 4～5 times/hour.

(2) Major issues related to waste water treatment

1) The current waste water treatment is not sufficient as the chemical agent is fed intermittently while waste waters flow into the treatment tank continuously.

In cyanide oxidization reaction process, NaClO, required for secondary reaction, is not added. On the other hand, reduction of Cr^{6+} seems to be monitored on the basis of the change in the solution's color. This is not reliable and should be replaced by use of pH and ORP meters.

No coagulant is added to the neutralization tank to accelerate settlement and separation of hydroxides of heavy metals.

2) A difference in fluid level between the rinsing tank and the treatment tank in the process is not large enough to ensure smooth flow. It is designed to allow waste waters flow to the tank from the lower part of the tank's side. Generally, the difference in fluid level should be utilized effectively to produce a sufficient pressure head.

Effluents are discharged from the neutralization tank through overflow pipes and are allowed to infiltrate into the ground. They should be discharged to sewerage through pipes.

Effluents after cyanide oxidization treatment leak through the piping in several locations on the way to the neutralization tank, and infiltrate into the ground. Quick repair is required for broken pipe.

3) The neutralization tank is too large to allow sufficient mixing after addition of the chemical agent. It is recommended to separate the neutralization tank from the settlement tank. In the neutralization tank, the chemical agent will be added, followed by mixing, to cause hydroxides of heavy metals to settle. In the settlement tank, a coagulant will be added, and with effluent flow being slowed down to allow sedimentation, and only the supernatant liquid will be discharged.

(3) Issues related to equipment

1) A primary problem is found in the absence of use of a rack. The objects to be plated are bundled up by using copper wires and cannot be fixed inside the bath, preventing the plating bath from circulating, and keeping in a uniform composition by using air agitation.

2) As the pretreatment process is separated from the plating bath, the plating solution drips on the floor. Preventive measures are required, such as the installation of a drain board or the provision of a pump pit with a dam plate on the floor.

(4) Issues related to education and training

1) Technical staff needs to have practical skills. Knowledge must be accompanied by the ability to apply it to field work.

2) There is no formalized education for workers. Field work can be best learned through the OJT (on-the-job-training), which requires technical staff to have practical skills. They should be capable of teaching and training skills, and checking the progress.

Quality is incorporated into products by workers. Documented standards or knowledge possessed by engineers do not assure product quality. Quality comes from proper work practice of field workers who are adequately trained to carry out their own work according to correct procedures.

Chapter 4 Target Setting for Proposals and Recommendations

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Chapter 4 Target Setting for Proposals and Recommendations

4.1 Current State of the Electroplating Industry

This study aims to improve technology levels of the electroplating industry in the country and promote proliferation of waste water treatment technology. As mentioned in 3.1 "Current State and Issues of the Electroplating Industry," the electroplating industry in Sri Lanka is very small in size and has yet to develop into a full-fledged and independent industry.

The immaturity of the metalworking industry limits electroplating demand, and plating on machine elements requiring anti-corrosive quality and hardness is rarely demanded, preventing the industry from becoming an important support for industrial development as a whole. The market has low requirements for quality and electroplating technology levels, so that there is little motivation for improvement. However, if metalworking products are to be made in Sri Lanka as intended, the electroplating industry, as long as it has the current level of technology, will hinder attainment of this objective. In view of this development objective it is necessary for Sri Lanka to acquire electroplating technology suitable not for present products but the new ones to result from industrial development.

From the environmental point of view, the electroplating industry handles toxic substances, such as cyanide and chromium, and discharges acid and alkali waste water. At present, most electroplating shops in the country do not treat waste water properly. In particular, small shops rinse plated products in a scouring bath and discharge waste water without treatment. Since their discharge is small in volume as well as discontinuous, toxic substances contained in the waste water have not created serious damage. At the same time, however, in the absence of monitoring by a public organization, they do not face any pressure to invest in waste water treatment facilities. Nevertheless, it is a fact that industrial waste water currently discharged contains toxic substances with much higher concentration levels than permissible by effluent standards, and there is a high risk of pollution caused by substances that accumulate over time, such as chromium. Furthermore, the increase in electroplating work anticipated as concomitant with industrial growth will cause an increase in the amount of waste water which, for environmental protection reasons, cannot be discharged without treatment.

4.2 Target Setting for Proposals and Recommendations

As mentioned before, the lack of waste water treatment by the electroplating industry has presumably produced an environmental problem, for which few control measures have been taken. On the other hand, quality requirements of the market provide little incentive to upgrade electroplating technology but if no improvement is made, electroplating technology will not contribute to the improvement of industrial products, and will become a bottleneck for industrial development in future. The current state of the electroplating industry and its desirable direction in Sri Lanka is shown in Figure 4-1.

In recognition of the current and pressing issues, the electroplating industry should focus on two goals, quality improvement and reduction of environmental loads. To enable individual factories to work toward the goals, process improvement is essential at each unit, and IDB Electroplating Center must play a key role in providing technical assistance for individual manufacturers and the electroplating industry as a whole. For IDB to fulfill this role, it must first improve its own technical capability to the extent that will enable it to lead the industry. The study team discussed with the counterpart in Sri Lanka on target setting for the industry and IDB's role, and has agreed on proposals and recommendations to be made under the study, as follows:

Target setting for proposals and recommendations

To help the electroplating industry reduce environmental pollution loads and improve product quality through process improvement.

- Waste water treatment: To disseminate waste water treatment technology enabling compliance with environmental standards (including future standards) in the country.
- Electroplating technology: To improve electroplating technology so that it will not become a bottleneck for development of the metalworking industry.

Proposals and recommendations made by the study:

To realize the target levels for the study, recommendations are to be made in the following areas:

- Methods of technical guidance and dissemination to be performed by IDB Electroplating Center for waste water treatment and electroplating technologies
- Upgrading plan for waste water treatment and electroplating technologies of IDB Electroplating Center
- Policies and measures to be taken by the related authorities and organizations

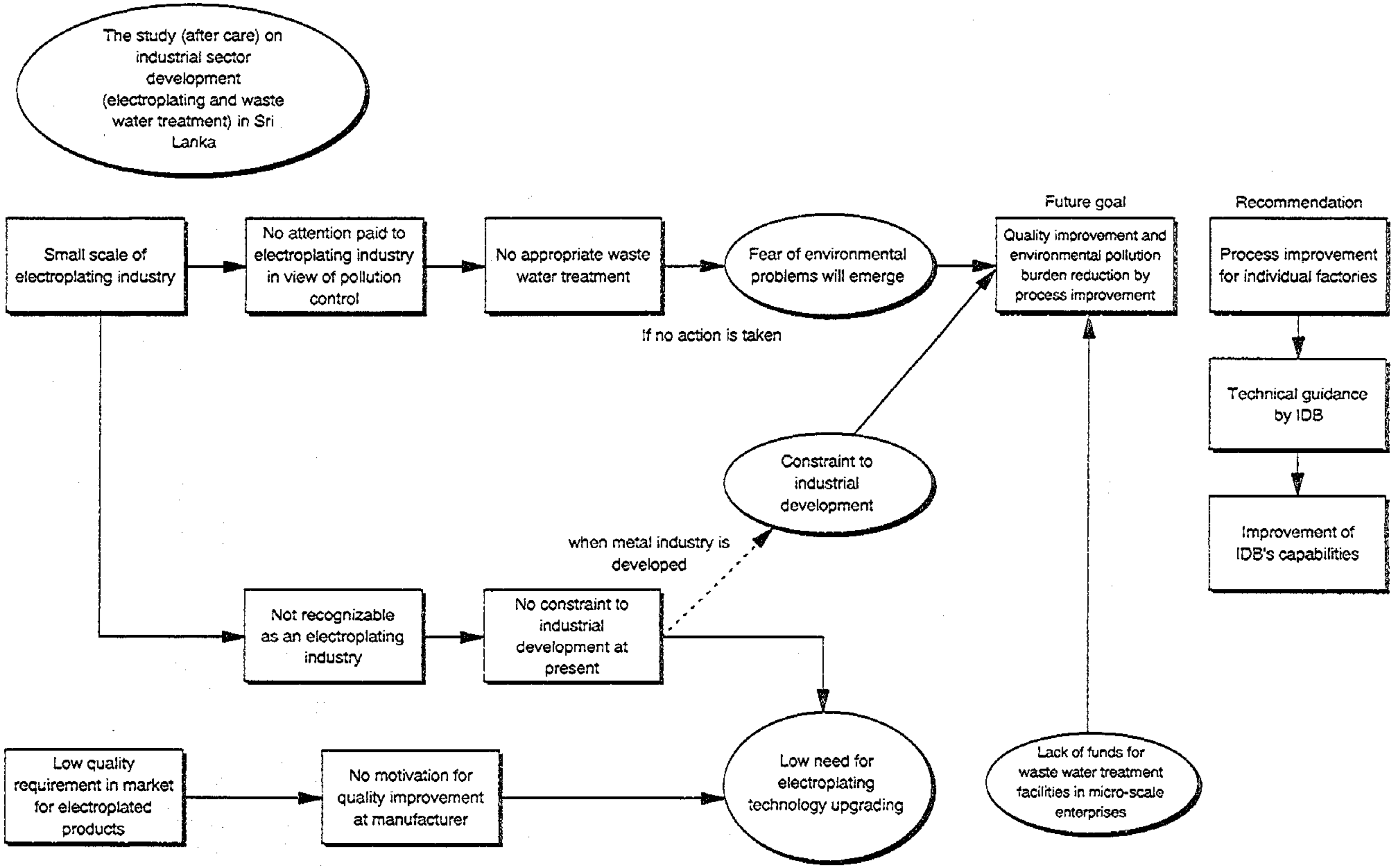

Figure 4-1 CAUSAL RELATIONS REPRESENTING THE CURRENT STATE OF THE ELECTROPLATING INDUSTRY AND ITS DESIRABLE DIRECTION

4.3 Promotion of the Metalworking Industry

To promote the electroplating industry, diversification of metalworking products which require electroplating as well as improvement of their quality and performance are essential driving factors, aside from efforts to overcome problems facing the industry itself. Unless the metalworking industry grows, the technologically improved electroplating industry will not enjoy benefits. Note that promotional measures for the metalworking industry are proposed in the report concerning the "Study on Industrial Sector Development" conducted by JICA in 1993. The result of the follow-up study on the report in connection with this study is discussed in Chapter 7.

Today, the metalworking industry has evolved into an industry that produces diverse machine products and is typical of the processing and assembly industries. Metalworking processes are roughly divided into assembly and parts manufacturing processes. The latter is further divided into parts assembly and shaping processes. In industrialized countries, most manufacturers do not conduct the entire production process internally, but subcontract some of them (from processing of raw materials to final assembly) to outside processors, with the extent and scope depending on the industrial development history and conditions in each country. In other words, the metalworking industry is an integrated system industry consisting of assembly industries and numerous parts suppliers (specialized in assembly and/or processing).

Metalworking embraces casting, forging, metal working, welding, heat treatment, and machining, followed by finishing operations including painting, coating, surface treatment, and plating. Parts assemblers and processors either take care of all the operations internally or outsource some of them to specialized processors. Note that general-purpose (commodity) parts/assemblies are products in themselves and are manufactured by many processors and assemblers. They are then sold in their own markets.

The electroplating process is one of finishing steps for metal products. It is designed to give gloss to the surface of sheet metal products, machined products or castings/forging, increase their hardness, and/or add anti-corrosiveness and wear-resistance. The electroplating process is performed either by parts suppliers which finish their products internally (in-production plating) or by specialized platers. In a narrow sense, the latter comprises the electroplating industry. However, so far as electroplating technology (including waste water treatment technology) is concerned, there is no difference between them. Regardless of the type of operation, the electroplating process is a subordinate process which makes an electroplating shop and its customer factory locate relative close to each other. The electroplating industry is usually operated in such way to handle specific types of parts for several regular customers, and consists of relatively small enterprises. It is the objective of increasing pressure from the environment-conscious public, and electroplating factories which are unable to comply with waste water standards nor receive assistance from customers will be forced to withdraw from the business.

Considering the nature and potential of the electroplating industry, the fostering of the industry in Sri Lanka should logically be started from the fostering of metalworking and machinery industries (or attracting them from other countries) for which domestic demand is expected to increase. Step-by-step localization of their parts industries will create the need for electroplating of industrial products. In the meantime, IDB is expected to improve electroplating technology and make the industry ready for meeting diverse and higher requirements of various parts industries that will emerge. Such efforts constitute an essential element of industrial development as a whole in the country.

In this context, the study makes the following propositions for promotion of the metalworking industry, which would have direct impact on the future of the electroplating industry.

(1) A basic approach is to help make the industry to be adaptive to domestic demand

Sri Lanka, although having low-cost and relatively highly-educated labor force that offers a potential advantage for industrial development, does not have base metal industries such as iron and steel, nor does the country have abundant energy resources except for hydropower. Industrial infrastructure including transportation systems has still to be developed. Obviously, the country is not endowed with favorable conditions to foster the metalworking industry. At present, metalworking is performed by a number of industries including processors of construction materials and household products, manufacturers of office furniture, kitchen goods, bolts and nuts, residential ornaments, and power transmission equipment (utilities poles, switches, and transformers), all of which mainly serve the domestic market. Few of them are related to the electroplating industry and require high-level industrial electroplating.

As the economy grows and the standards of living of the general population rises in future, demand for consumer products, such as household appliances, will rise and diversify. At present, much or most of these goods are imported. The government's industrial policy, however, can encourage domestic production of such goods by encouraging new investment by local and/or foreign capital. New domestic industry will emerge, starting from assembly of imported parts, and will gradually develop so as to purchase locally produced parts from newly-emerging specialized parts suppliers. To achieve this goal, manufacturers and their employees must learn diverse production technologies as well as production control techniques, in addition to receiving support from the government, that would encourage their growth. In other words, the industry supported by domestic demand can be fostered and can become capable of succeeding in competition with imported products, with occasional government assistance as required and through its own efforts.

The fostering of the metalworking industry in the country will take some time, and a traditional approach to start from products serving domestic demand seems to be justifiable.

(2) It is not feasible to attract parts industries alone

The nation's metalworking industry is not highly structured and is far from forming a integrated production system industry consisting of assembly and parts making processes. As mentioned in (1), domestic demand can help the assembly industry to emerge, but without the assembly industry, it is difficult to establish and maintain the parts industry. Generally, the assembly industry and the parts industry are closely related. Under the relationship, parts suppliers must meet various requirements of assembly manufacturers in terms of quality and delivery, not to mention price. In Japan, the strong yen has prompted assembly manufacturers to move their production bases to overseas, followed by suppliers who first serve their customers, then export products to other destination and customers, in Japan and other countries. There are a small number of cases where suppliers have initiated the move, in quest of a low-cost labor force. Thus, many suppliers have decided on foreign investment if conditions are met to ensure quality and delivery schedule. Generally speaking, parts suppliers take a conservative view about overseas operation and are not likely to invest alone, or without direct cooperation by their key customers.

For these reasons, it is difficult for Sri Lanka to attract parts suppliers who will export all of their products, unless the company has long-stranding trade with the country and decides on investment by knowing its merit. A possible solution is to develop an environment to allow free movement of people, goods, and capital within short distances.

Furthermore, contract electroplating for foreign manufacturers is more difficult than the attraction of parts suppliers. Products to be plated have been processed to final shape and need to be protected during transportation by careful packaging. Then, plated products need to be more carefully handled and transported, with attention paid to environmental conditions during transportation. With exception of simple products, packaging and transportation costs become higher than other costs, at times close to the plating cost itself, and this makes it an unattractive option for foreign manufacturers to subcontract electroplating to Sri Lankan companies. Moreover, shipment and delivery cost and time requirements will add an extra disadvantage for specialized electroplating, to further reduce its viability as commercial business.