THE DEVELOPMENT OF MANAGEMENT STRATEGIES AND RECOVERY SYSTEMS FOR HEAVY METAL WASTES

by

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REPORT TO THE WATER RESEARCH COMMISSION

by

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THE DEVELOPMENT OF
MANAGEMENT STRATEGIES AND RECOVERY SYSTEMS
FOR HEAVY METAL WASTES
DRAFT REPORT

SUMMARY

Discharge of heavy metals to sewer can have significant detrimental effects on the efficiency of the Municipal sewage treatment directly by their inherent toxicity, or indirectly by accumulating in the sewage sludges limiting sludge disposal opportunities, and by passing directly through the treatment system to be discharged to the receiving aquatic environment.

Many Municipalities do have Industrial Discharge Standards promulgated to limit discharges to sewer, but the operation of industries and limitations on the ability of Municipalities to practically monitor and control discharges continues to result in significant metal loads arriving at the sewage treatment plants in an unaccounted manner.

It has also been identified that stringent control through excessive penalties and restrictive practices may not be appropriate in encouraging the responsible handling of the wastes generated by industry. An integrated approach to heavy metal waste control through Waste Minimisation, Pretreatment and Waste Management Programmes is believed to offer a mutually acceptable and effective mechanism for managing and controlling metal wastes whilst optimising resource utilisation and relationship between industry and control authorities.

Waste Minimisation identifies opportunities to reduce the wastes generated, optimise reuse and recovery where practical. Where Waste Minimisation alone cannot reliably achieve a desired discharge metal load the **Pretreatment Programme** identifies opportunities for pretreating effluent on-site to meet required qualities. Associated with the approach would be the provision of a dedicated **Centralised Waste Treatment (CWT) facility** which would receive, treat and dispose of, or recover for reuse, the metal wastes in a well-regulated manner, and a **Waste Management Programme** to monitor and control the movement of contaminated wastes from their point of production to the final destination, and ensure that the industry programmes and the CWT operate responsibly and economically.

This report reviews local and international and practices in the management of heavy metal sewer discharges, handling of metals wastes, and utilises the Johannesburg Municipal area to assess and demonstrate the feasibility for a CWT and associated Waste Management Control programme opportunities.

ACKNOWLEDGEMENTS

The primary phases of the assessment of alternative metal waste handling opportunities and review of industrial practices of the Greater Johannesburg Municipal area has been undertaken under projects directly for the Johannesburg Municipality. The support and interest of the Municipality is appreciated, particularly Dr L Lötter, Mr A van Rooyen and the Municipal laboratory staff and facilities.

The Water Research Commission is acknowledged for their support in extending the Johannesburg Municipality project to produce a report indentifying opportunities and principles of Waste Minimisation, Pretreatment, Centralised Waste Treatment and Waste Management Programmes, which will be of interest to Municipalities, Authorities and Industries alike in the Republic of South Africa. The support and interest of the WRC is appreciated, particularly Dr OO Hart and Mr ZT Ngcakani.

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THE DEVELOPMENT OF MANAGEMENT STRATEGIES AND RECOVERY SYSTEMS FOR HEAVY METAL WASTES

1 INTRODUCTION

A preliminary investigation undertaken by SRK Consulting Engineers Inc. on behalf of Johannesburg Municipality into heavy metal containing effluent handling in the Municipal area indicated that few of the local Metal Finishing industries practise effective metal removal prior to discharge of effluent. The absence of effective metals containing effluent pretreatment results in significant loads of heavy metals entering the sewerage system and ultimately accumulating in the sewage sludges of the treatment works and passing through into the receiving river environment.

A further investigation for Johannesburg Municipality identified a number of opportunities for Metal Finishers to minimise the wastes discharged to sewer within the process operations and opportunities for effluent pretreatment of wastes that remain to achieve acceptable discharge quality control. However, the implementation of Waste Minimisation or Pretreatment Programmes within the industry is found to be expensive and unfavoured whilst discharge to sewer remains the easier and cheaper option.

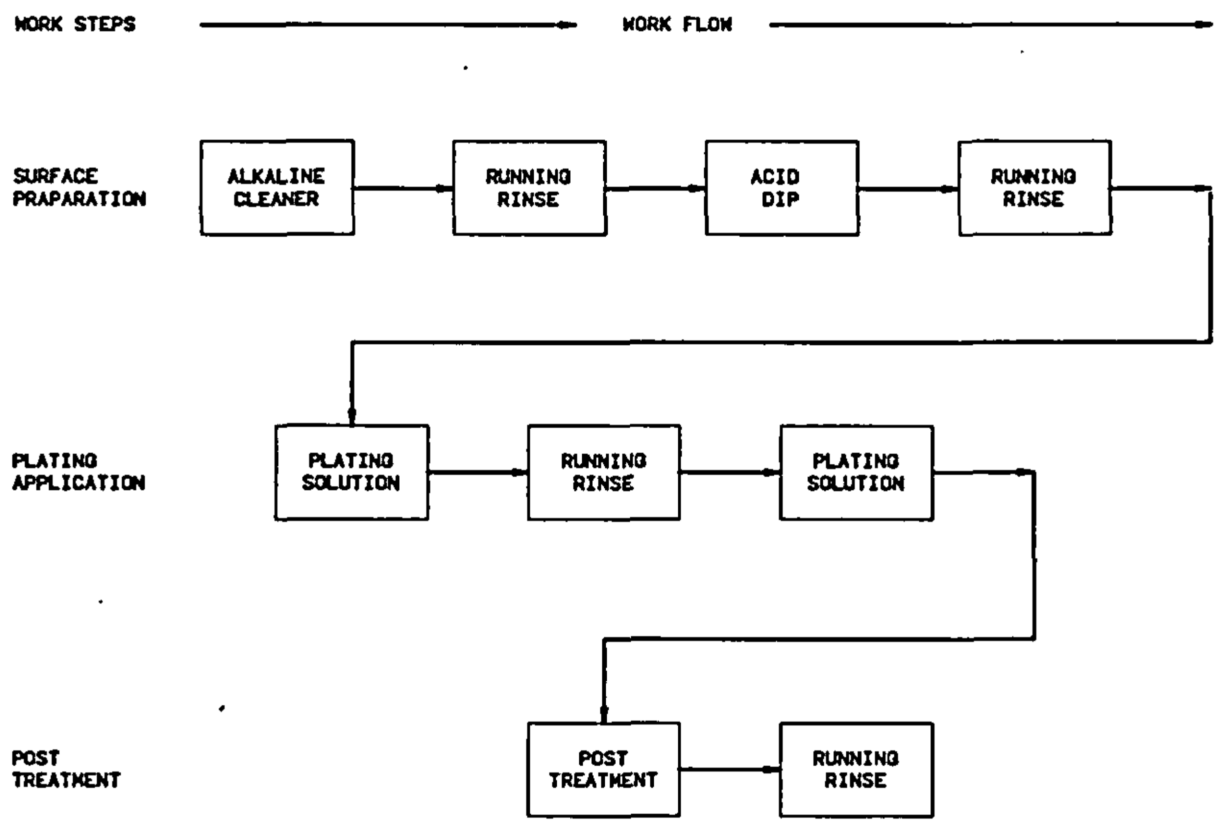
It has been recognised that few industries have the infrastructure to implement and operate waste minimisation and pretreatment facilities themselves. An alternative that is gaining acceptance internationally is to provide a waste management service whereby compatible facilities are installed in each Metal Finishing plant to rationalise operation and maintenance. Pretreatment facilities are under the management of the waste contractor who is also responsible for the collection of waste sludges and concentrates (spent baths etc) for further treatment, recovery and disposal.

The handling and disposal of waste concentrates generated by effective Waste Minimisation and Pretreatment represents the major expense of the operation, particularly where it becomes necessary to reduce the concentrate volumes as a sludge or liquid concentrate to reduce transportation costs for subsequent off-site processing and/or disposal. A CWT could be established to economically receive and process the sludges and concentrates and rationalise disposal or recovery of metals. The CWT approach would offer advantages in being operated by professional waste handlers. Secondly, CWT can increase the potential for recovery of chemicals, which not only reduces the firm's operating costs but also the burden of sludge handling and disposal. Thirdly, industries can share other facilities to further reduce their operational costs.

2 HEAVY METAL INDUSTRIAL EFFLUENT DISCHARGERS

2.1 Sources of Heavy Metal Loads from the Metal Finishing Industry

The primary contributors of heavy metals to Municipal sewerage systems are the industries associated with Metal Finishing. The major contaminants arising in the effluent are cyanides, heavy metals, associated salts, oils and greases, cleaning aids and solvents. These arise from the discharge of spent cleaners, acids and bright dips, process baths, rinses containing drag-out from previous process cycles and from metals leached from the work by the process chemicals. There are also ad-hoc accidental spills, leaks, and drips of process solutions to drain. Additional sources include the sludges from the bottoms of baths, backwash from plating tank filter systems, and the dust and vapours released from the baths and process lines. Figure 1 illustrates a generalised Metal Finishing operation, and Figures 2-5 a plant configuration of a Metal Finisher illustrating the variations in process requirement for different planting operations, and consequently waste loads being generated at any particular time.



JOB No.		FIG No.
192017	OVERVIEW OF THE ELECTROPLATING/ METAL FINISHING PROCESS	1

Central Wastewater Treatment Plant.

Industrial Wastewater Pretreatment Facility - Budgetary Estimate
- Construction Cost.

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Draft by Scientific Services, City of Johannesburg.

SRK Report 192017 - Alternative Handling of Metal Waste 1992

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- Plating and Surface Finishing 1991

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Description of Facilities

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Grasping the Metal by Peter Young, 1991

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Centralized Industrial Waste Pretreatment by Lynn H Palmer, David P Cunningham, Mark Goldman, 1992

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Effluent Discharge - City of Johannesburg, 1992.

America's Toxics Policy for the 1990s by Daniel Mazmanian and David Moell

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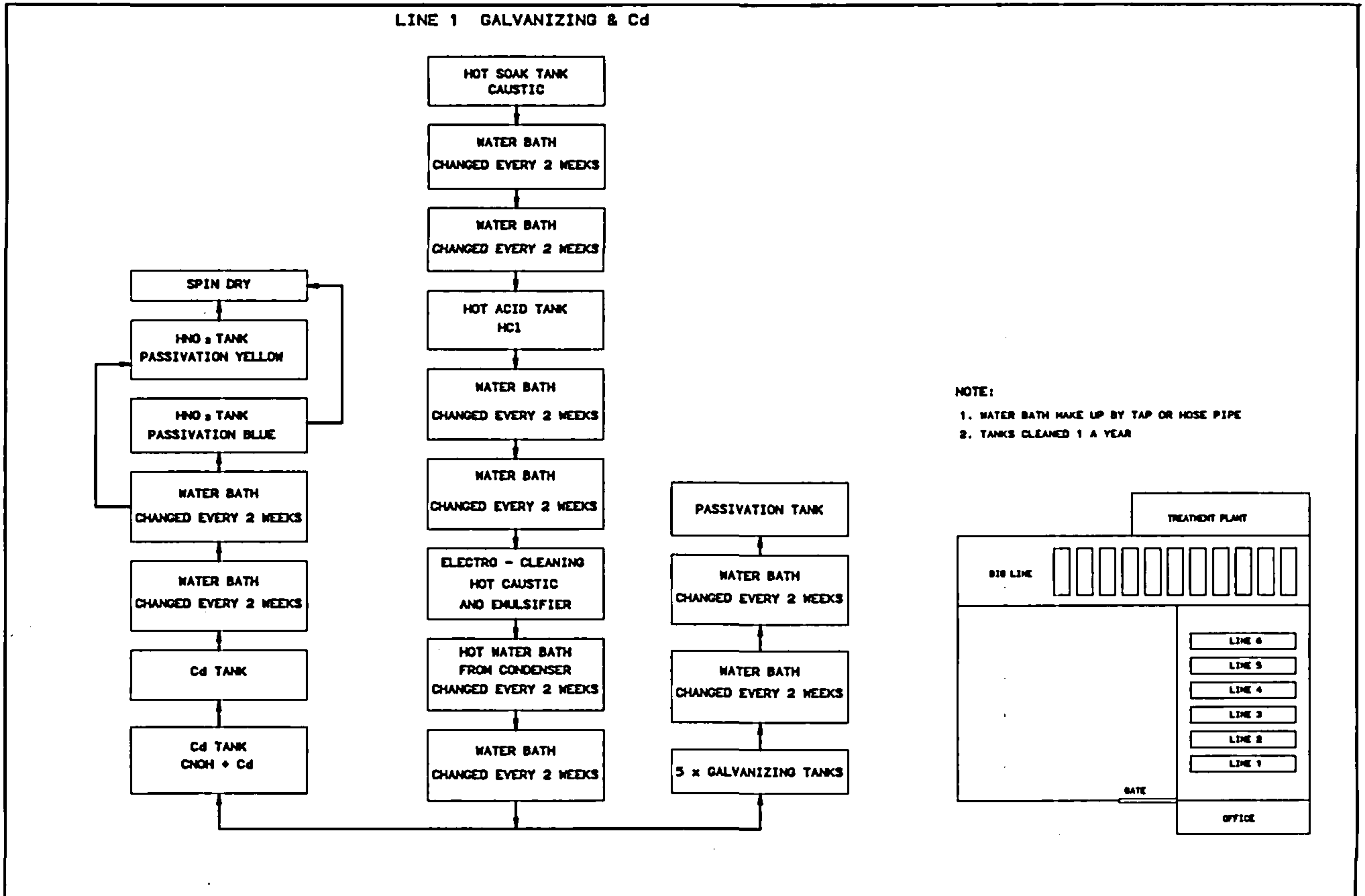
A Technical Guide - UNEP/IEO.

Typical Causes and Sources of Waste.

Components and Operations of the Treatment Plant.

Centralised Industrial Wastewater Treatment.

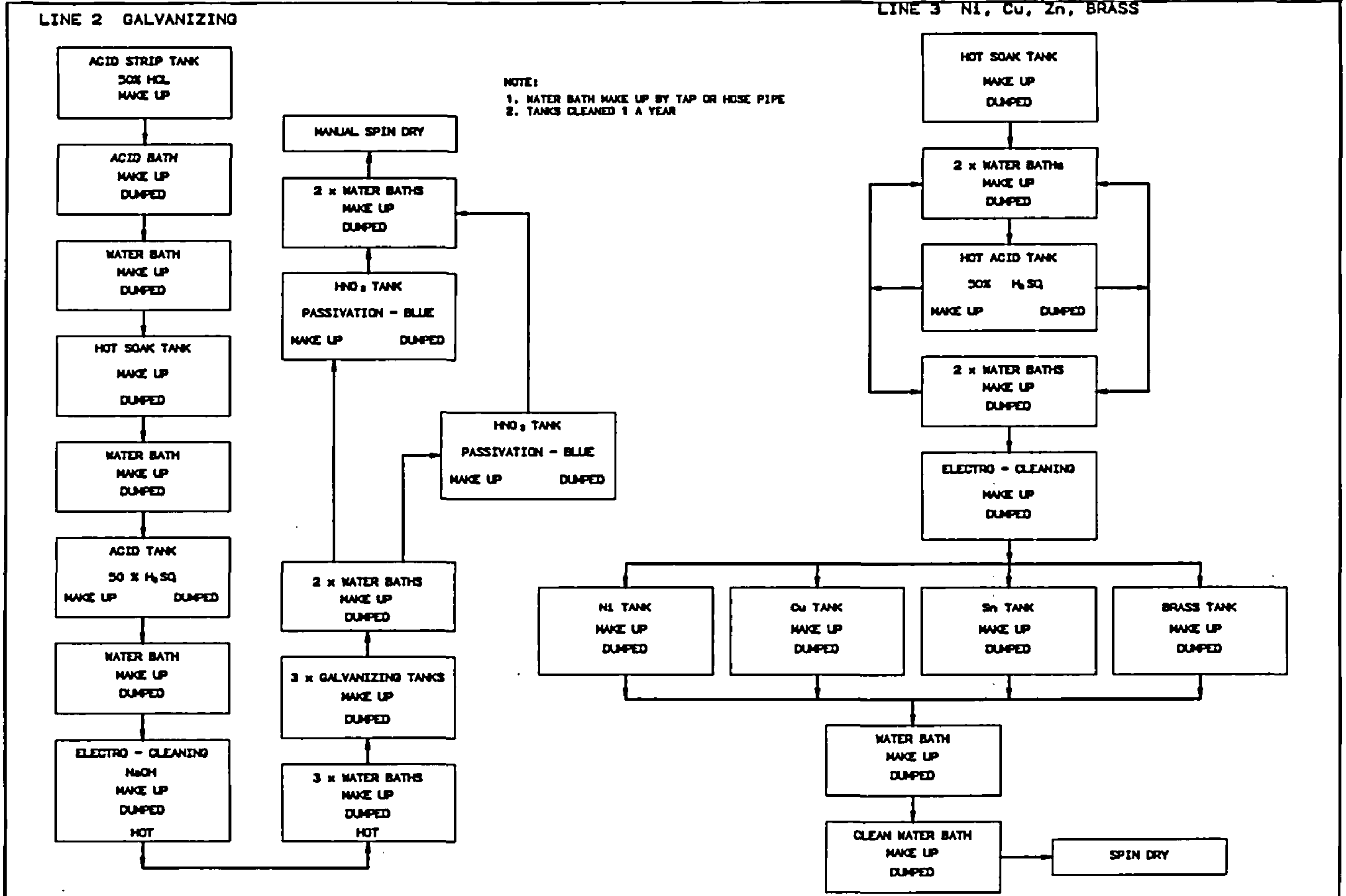
EPA Project Summary - Characterization and Treatment of
Wastes from Metal Finishing Operations, US EPA 1991



JOB No.

ELECTROPLATING SHOP - PROCESS DIAGRAM LINE 1

FIG No. 2

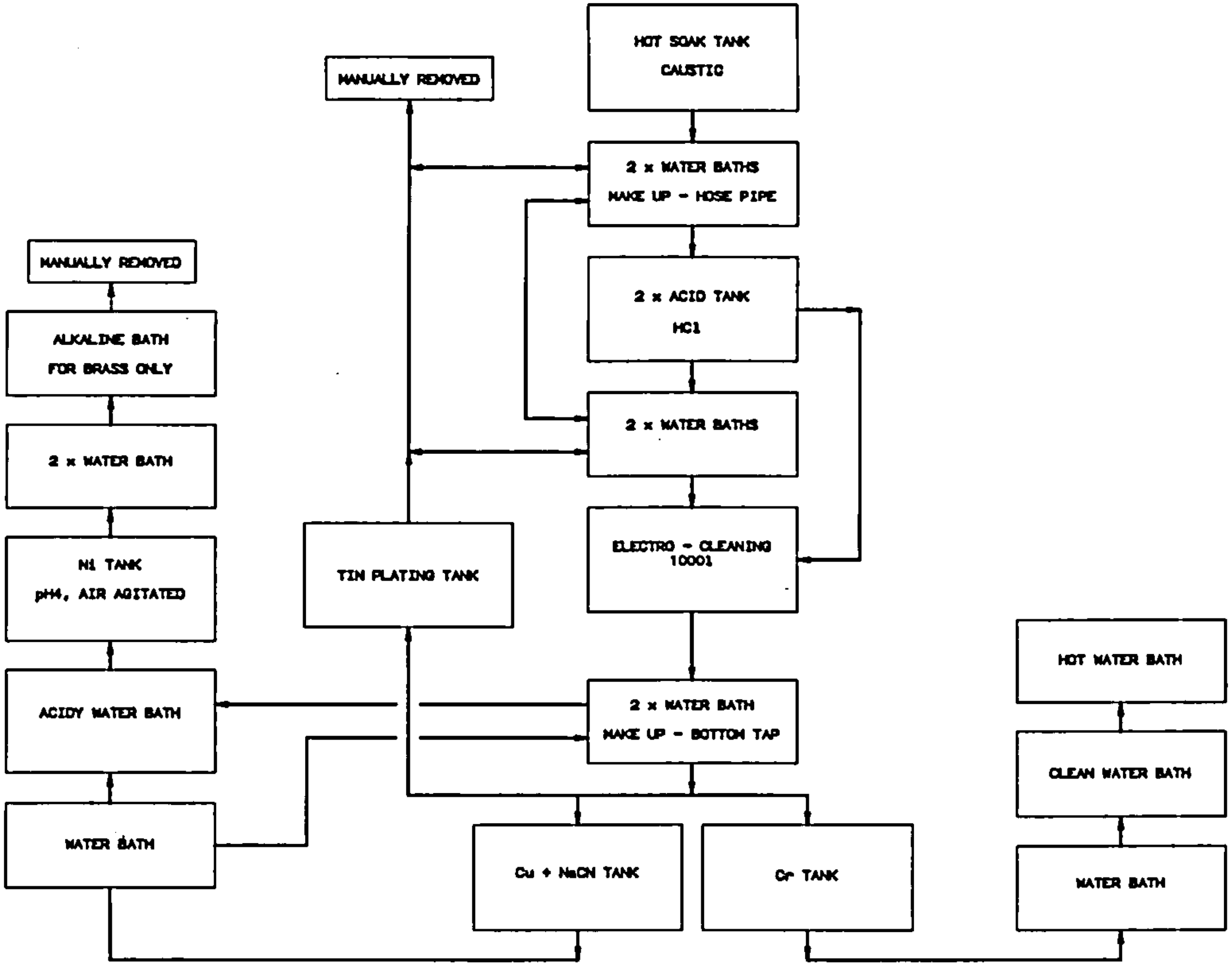


JOB No.

ELECTROPLATING SHOP - PROCESS DIAGRAM

FIG No. 3

LINE 4 Ni, Cu, Sn, BRASS



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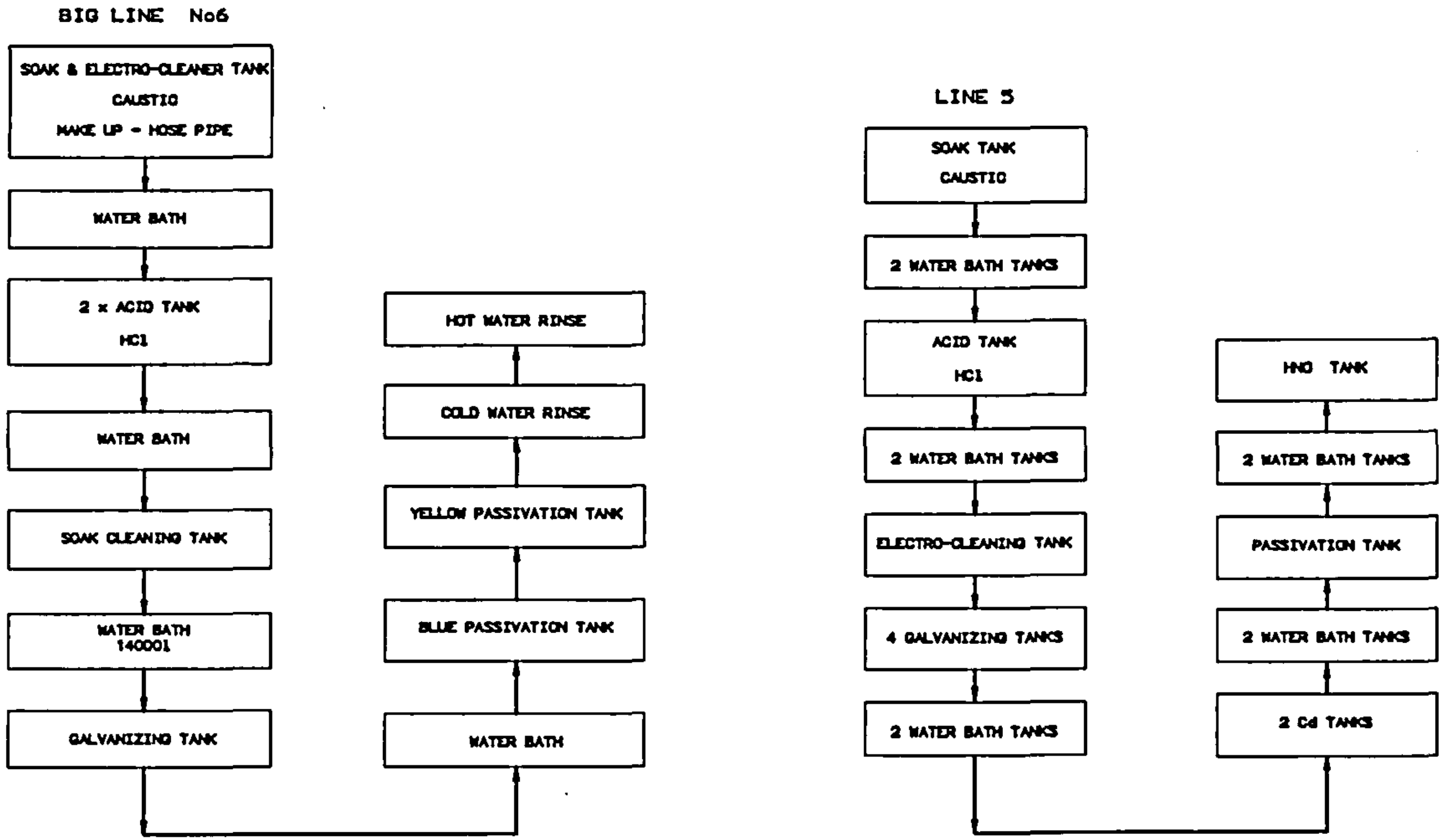
ELECTROPLATING SHOP - PROCESS DIAGRAM

FIG No.
4



NOTE:
1. WATER BATH MAKE UP BY TAP OR HOSE PIPE
2. TANKS CLEANED 1 A YEAR

JOB No.	ELECTROPLATING SHOP - PROCESS DIAGRAM	FIG No. 5

2.2 Metal Finishing Industry Effluent Characteristics

Dependent upon the degree of in-house waste management and operational control of the process lines, it is estimated that the effluent may contain in excess of 10% of the chemicals supplied to the line. The amount of pollutants contributed to the total pollution load by discarded process solutions varies considerably among plating shops. It is not uncommon to find cyanide and heavy metals in concentrations of several thousand milligrams per litre of spent solutions. This contamination caused by drag-in from previous process cycles and attack of the basic metals by the chemicals in the cleaning solutions. Accidental spills, leaks and drips of process solutions also can contribute significantly to effluent contamination. The plating room usually drains directly from the floor to the sewer system leaving the facility. Although it is not common for a tank to spring a leak that would allow the entire solution to leak away undetected, a slow leak amounting to a solution loss of 30 to 75 ℓ/d could go undetected for months. Also, it is not unusual to compensate for evaporation losses in a process tank by adding water to a process solution with an unattended hose that causes overflow of the solution to the floor drains.

Tables 1 to 5 illustrate the range of chemical and metal found in a variety of Metal Finishing Process Baths, and Table 6 Typical Lifetimes of Plating Solutions.

Table 1: General Range of Concentrations of Cyanide and Metals in Cyanide-Based Solutions

Plating Solutions	Total Cyanide as g/ℓ	Metal in g/ℓ
Copper	15 to 51	7 to 40
Zinc	4 to 64	8 to 50
Cadmium	20 to 67	15 to 25
Silver	12 to 60	13 to 45
Brass	16 to 48	Cu 6 to 25
		Zn 2 to 13
Bronze	40 to 40	Cu 30 to 35
		Sn 15 to 20
Tin-Zinc	12 to 18	Sn 25 to 30
		Zn 1 to 2

Table 2: General Range of Concentration of Chrome in Chromium-Plating Solutions

Type of solution	Chromic acid in g/ℓ	as Cr in g/ℓ
Bright chromium-plating	192 to 520	100 to 270
Hard chromium-plating	270 to 308	140 to 160

Table 3: General Range of Concentration of Free Acid and Metals in Acid-Plating Solutions

Plating solution	Free acid as H_2SO_4 in g/ℓ	Metal in g/ℓ
Copper	45 to 55	50 to 52
Zinc	-	70 to 80
Nickel	-	40 to 90
Tin	60 to 138	21 to 34
Zinc chloride	-	131 to 145

Table 4: General Range of Concentrations of Fluoborate and Metals in Fluoborate-Based Solutions

Type of Solution	Fluoborate as BF_4 in g/ℓ	Metal in g/ℓ
Tin	160 to 210	75 to 85
Lead	125 to 184	90 to 100
Tin-lead	125 to 150	Sn 7 to 60 Pb 25 to 88
Zinc	255 to 265	80 to 85

Table 5: Typical Anodizing Solutions

Constituent	Concentration
Sulphuric acid (H_2SO_4)	100 to 275 g/ℓ
or Oxalic acid ($H_2C_2O_4$)	30 to 100 g/ℓ
Chromic acid (as CrO_3)	80 to 100 g/ℓ
Chlorides (as Cl^-)	Max 20 mg/ℓ
Aluminium, dissolved (as Al)	Max 15 to 18 g/ℓ

Table 6: Typical Lifetimes of Concentrated Plating Solutions

Bath	Life	Problems
Alkaline cleaners	4 - 6 weeks	presence of cyanides
Chromic/Nitric Acid Passivation of Galvanising	2 - 3 weeks	presence of organics
Acid dip (Zinc die castings)	1 - 2 months	2 - 4 g/ℓ Zn
Zinc and Copper Cyanide	< 1 year up to 25 years	failure to remove carbonates will reduce bath life
Chromic acid Plating solutions	< 1 year up to 25 years	failure to remove reducing agents, foreign cations (Fe, Zn, etc.), chlorides and sulphates, will reduce bath life
Nickel	< 1 year up to 25 years	failure to remove reducing agents, foreign cations (Fe, Zn, etc.), chlorides and sulphates, will reduce bath life
Anodising solutions	depends on application	life determined by aluminium limit of 12 to 45 g/ℓ

The contribution by each pollution source to the pollutant concentration of the final effluent can vary substantially. For industries whose primary process is chrome plating (copper-nickel-chromium), drag-out usually will be the major cause of metal loss. At facilities that engage in large nickel plating operations, more nickel is lost from the operation of the chemical purification filters and through discharge of sludge from the tank bottoms after purification of the plating solution than through normal drag-out.

The main contribution to the effluent metal concentration in zinc or cadmium plating is the metal that is either stripped off the danglers or crack tips in the acid dip step of the cleaning cycle or removed from the work in dichromating. Although some plants may have a higher contribution of pollutants from other sources, in almost every case, the most significant pollution problem is drag-out and the resultant contaminated rinse water.

Table 7 illustrates typical evaporation of wastewater for Metal Plating facility. Figures 6 and 7 illustrate the variation in effluent discharge quality that can result for a Metal Finishing operation, illustrating the difficulties a control programme has in ensuring a responsible compliance by the industry.

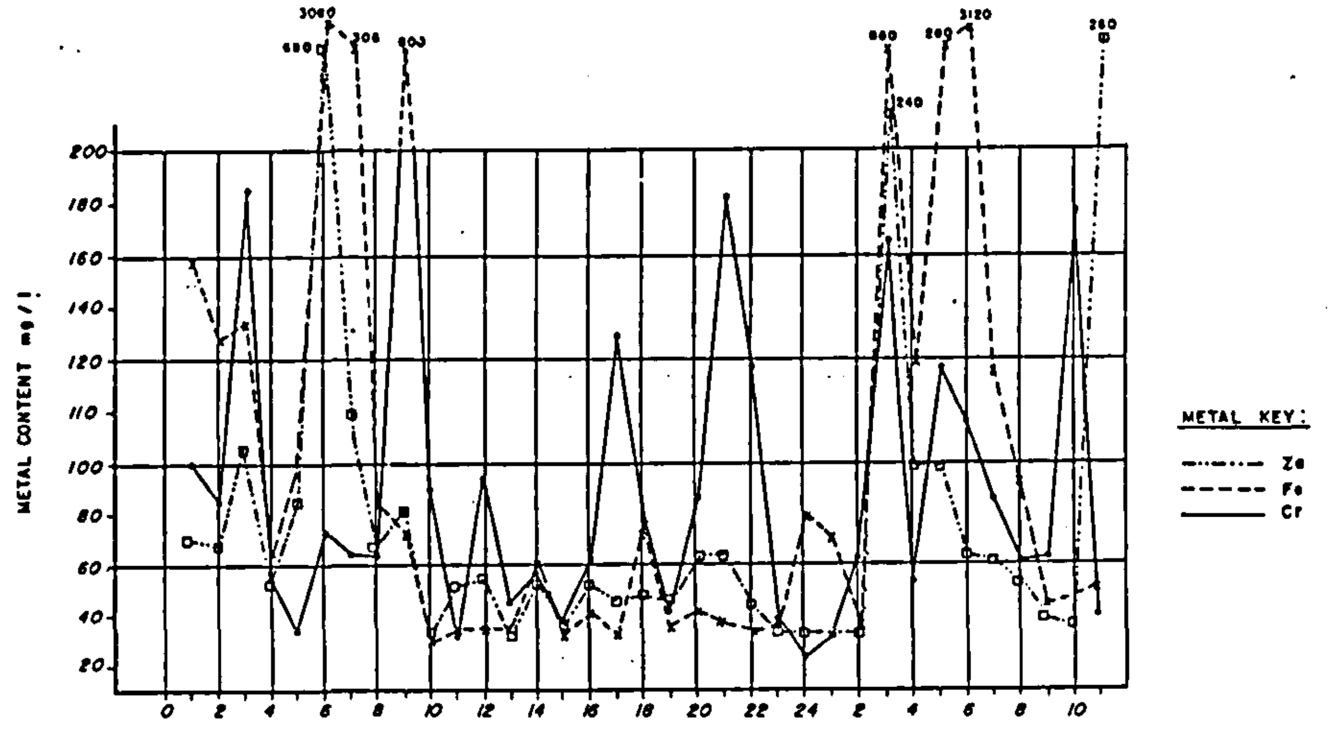
Table 7: Composition of Raw Waste Stream from Common Metal Plating

Constituent	Range (mg/ℓ)
Copper	0.032 - 272.5
Nickel	0.019 - 2 954
Chromium: Total	0.088 - 526
Hexavalent	0.005 - 335
Zinc	0.112 - 252
Cyanide: Total	0.005 - 150
Amenable to chlorination	0.003 - 130
Fluorides	0.022 - 142
Cadmium	0.007 - 21.6
Lead	0.663 - 25.4
Iron	0.41 - 1 482
Tin	0.060 - 103
Phosphorous	0.020 - 144
Total Suspended Solids	0.100 - 9 970

2.3 Metal Finishing Effluent Management

A review of a number of the Metal Finishing industries in the greater Johannesburg area has indicated that few industries actively practice effective effluent treatment on-site and that where there is rudimentary pretreatment it is often not particularly well organised, operated or maintained in relation to compliance with existing by-law quality standards, or disposal of waste sludges generated in the process. The systems are largely left to run themselves, with ad-hoc desludging to sewer, or via waste contractors on an irregular basis.

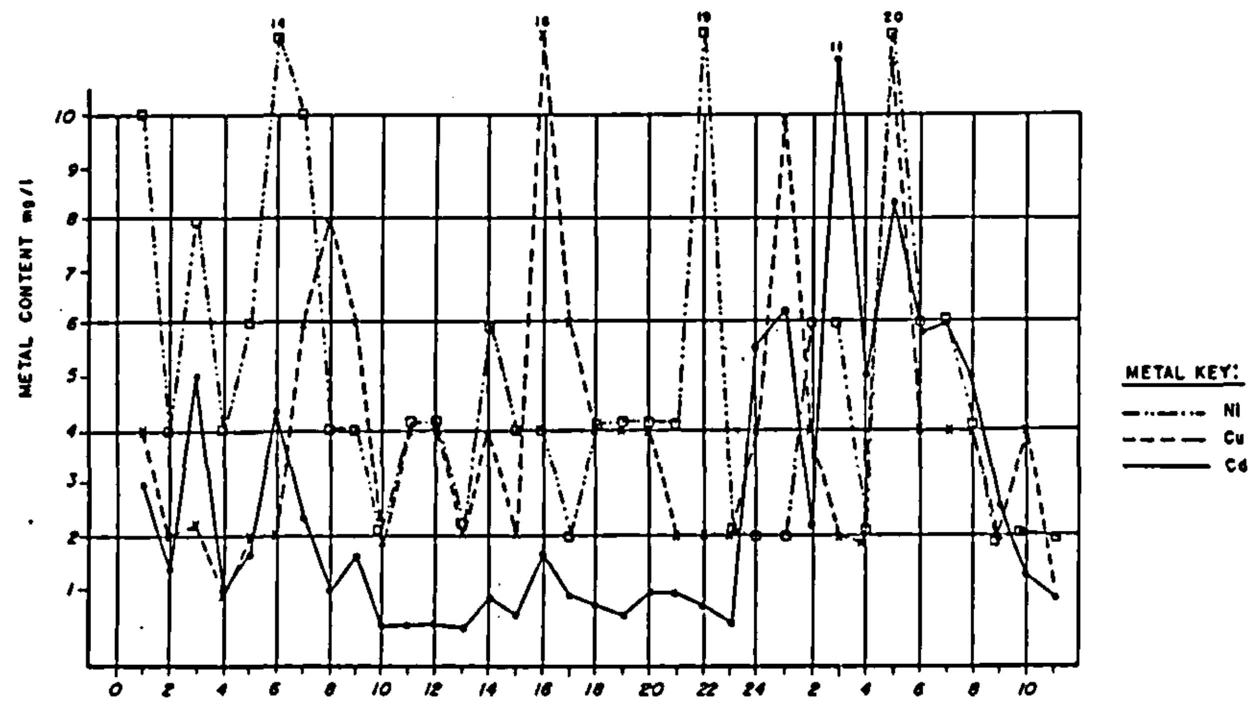
Although several plant operators cited waste haulers as the remover of its waste sludges it is apparent that the amount taken by waste hauliers represents a fraction of the metal wastes generated by the group, with the majority of metal load being discharged to sewer.



JOB Nº

METAL EFFLUENT SURVEY

FIG. Nº 6



JOB Nº

METAL EFFLUENT SURVEY

FIG. Nº 7

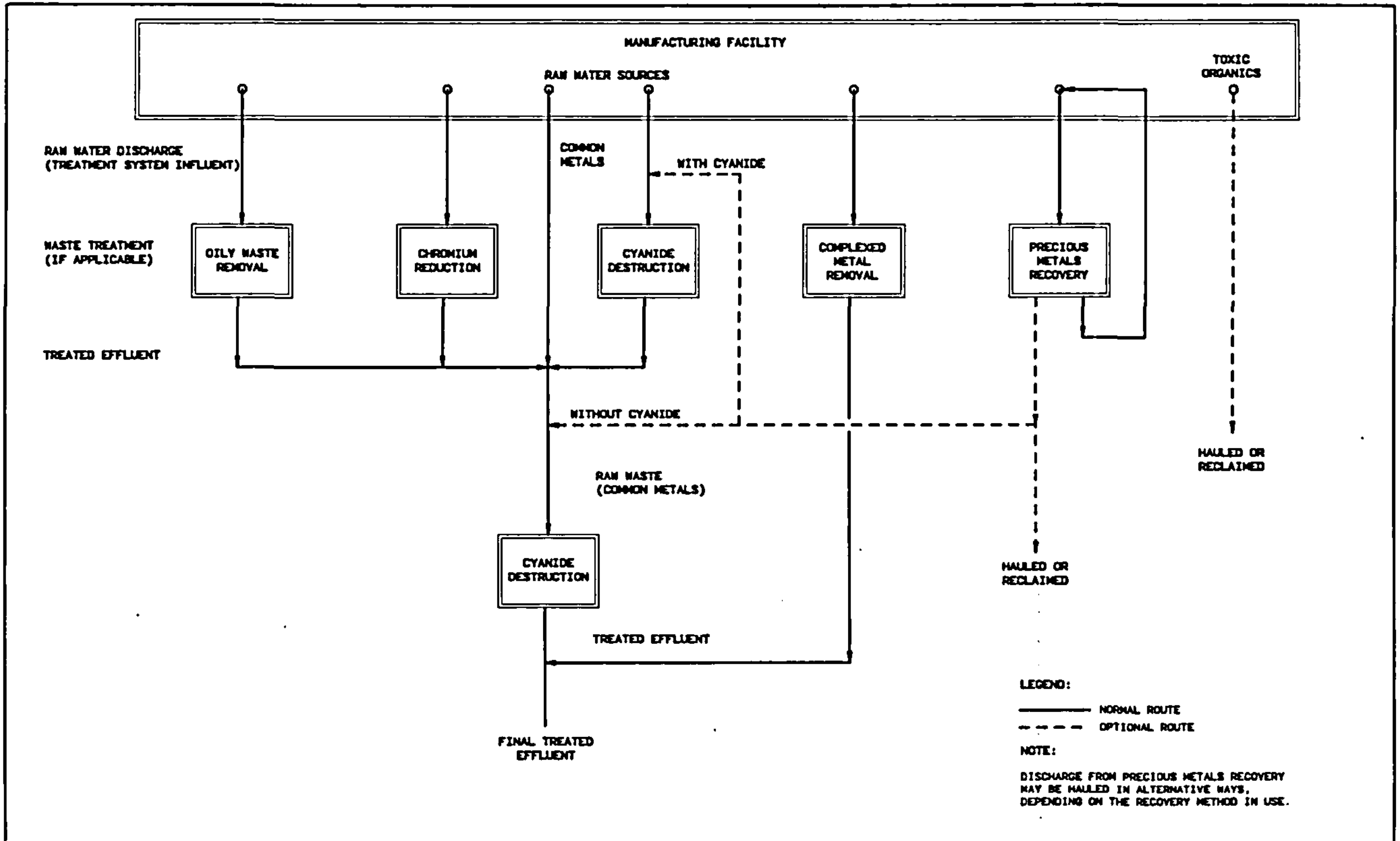
2.4 Waste Handling

The cost of handling and disposing of spent process baths and sludges containing heavy metals has increased significantly because of the increased regulatory requirements placed on the handling and disposal of hazardous wastes. As a result, metal finishers may find it economical to recover metals and metal salts from spent process baths and rinsewater and to reuse rinsewater.

However, for many it is not viable to recover metals from effluent due to the high metal purity required in the plating baths and the costs of achieving such qualities from generally mixed effluent streams. External processing for selected metals is viable where a larger metals base is available and economies of scale exist, though this may require subsidisation by the Municipalities or regional authorities in encouraging effective waste processing.

It is a very rare facility that can satisfactorily, and legally, meet their permitted effluent limits without some type of pretreatment prior to discharge. Most effluent pretreatment technologies are designed to remove a single pollutant; eg. cyanide, or a family of pollutants, such as heavy metals or greases and oils. Therefore, where there are several pollutants in an effluent treatment may combine several different technologies.

Figure 8 illustrates a conventional effluent treatment configuration for Mixed Metal Finishing effluent discharging to sewer.



JOB No.

WASTEWATER TREATMENT SCHEMATIC

FIG No. 8

3 WASTE MANAGEMENT OPTIONS IN CONTROLLING HEAVY METAL DISCHARGES

Waste Minimisation

Waste Minimisation is designed to improve the process operations and waste management to reduce the loads of metals discharged to sewer, and which would not necessarily involve the industry in extensive process changes or pretreatment.

Recovery and Recycle

Losses of metals and chemicals not only reduces the economics of raw material use it is a significant cost factor in the operation of a Metal Finishing plant. By controlled recovery and recycle of process liquors it is possible to reduce waste discharges, minimise raw material input and improve the control of discharges to sewer.

Wastewater Pretreatment

Where the WM alone cannot achieve the desired reduction and control of metal effluent loads Wastewater Pretreatment is designed to attain required consent limits on the quality of wastewaters discharged to a sewer or via alternative routes.

3.1 Waste Minimization

Opportunities for effective WM and consequently Pretreatment are largely dependent upon the size of the industry. However, the philosophy is applicable to all and significant savings can be achieved. The following section largely derived from US and European literature, as well as local understanding of the industry indicates Waste Minimisation opportunities that have been identified as applicable to Metal Finishers.

3.1.1 Storage and equalisation of wastes

Discharge Standards are usually based upon specific concentrations and discharge of tank contents as shock loads will inherently exceed the Standards and expose the industry to penalties.

3.1.2. Cleaning solution management

Cleaning baths must be replaced or replenished frequently. Solution life can be increased with in-line filtration and wastes should only be discharged to sewer neutralised and controlled.

3.1.3 Process management

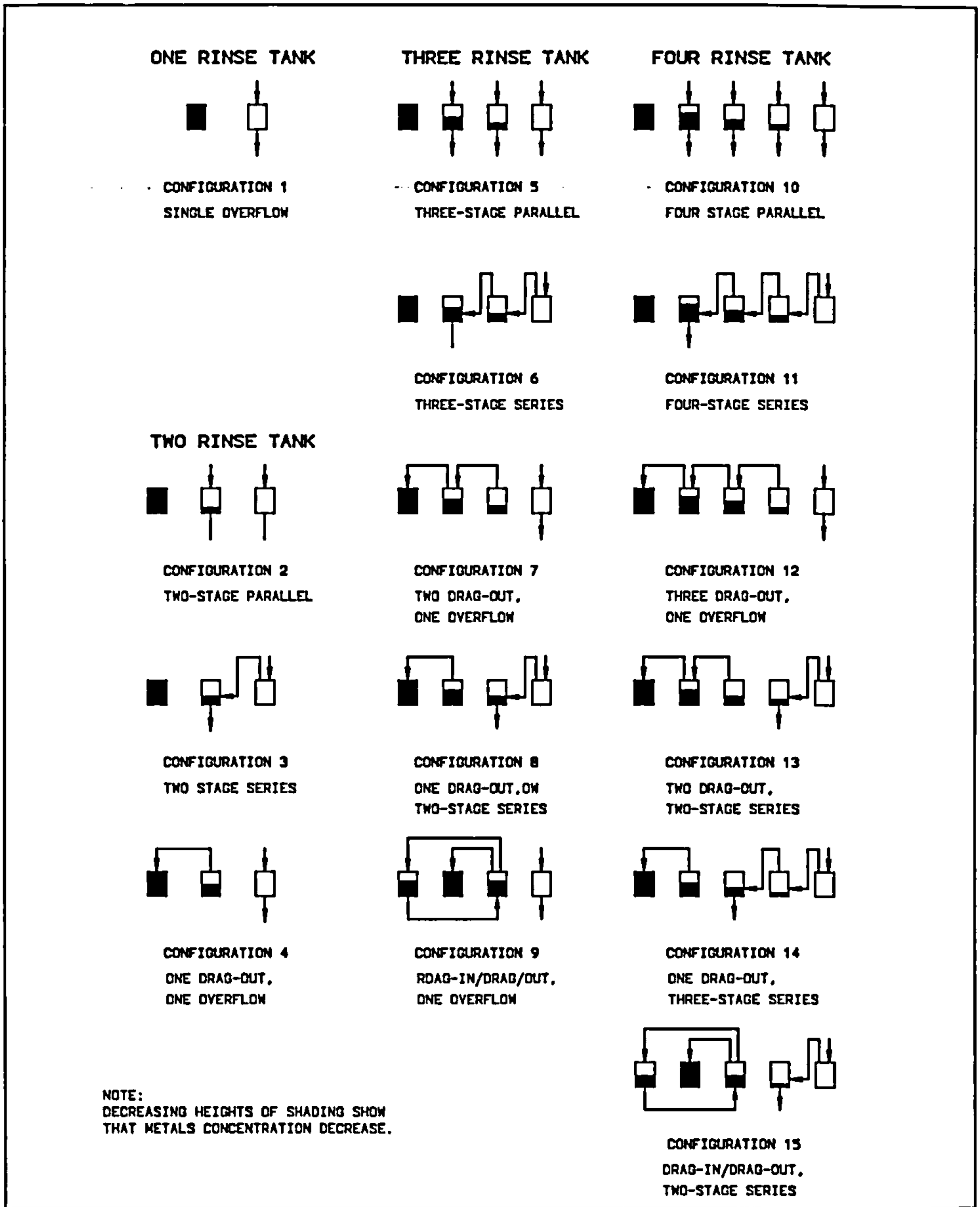
Improved management of the Metal Finishing processes to reduce discharge of contaminants.

3.1.4 Drag-out minimisation

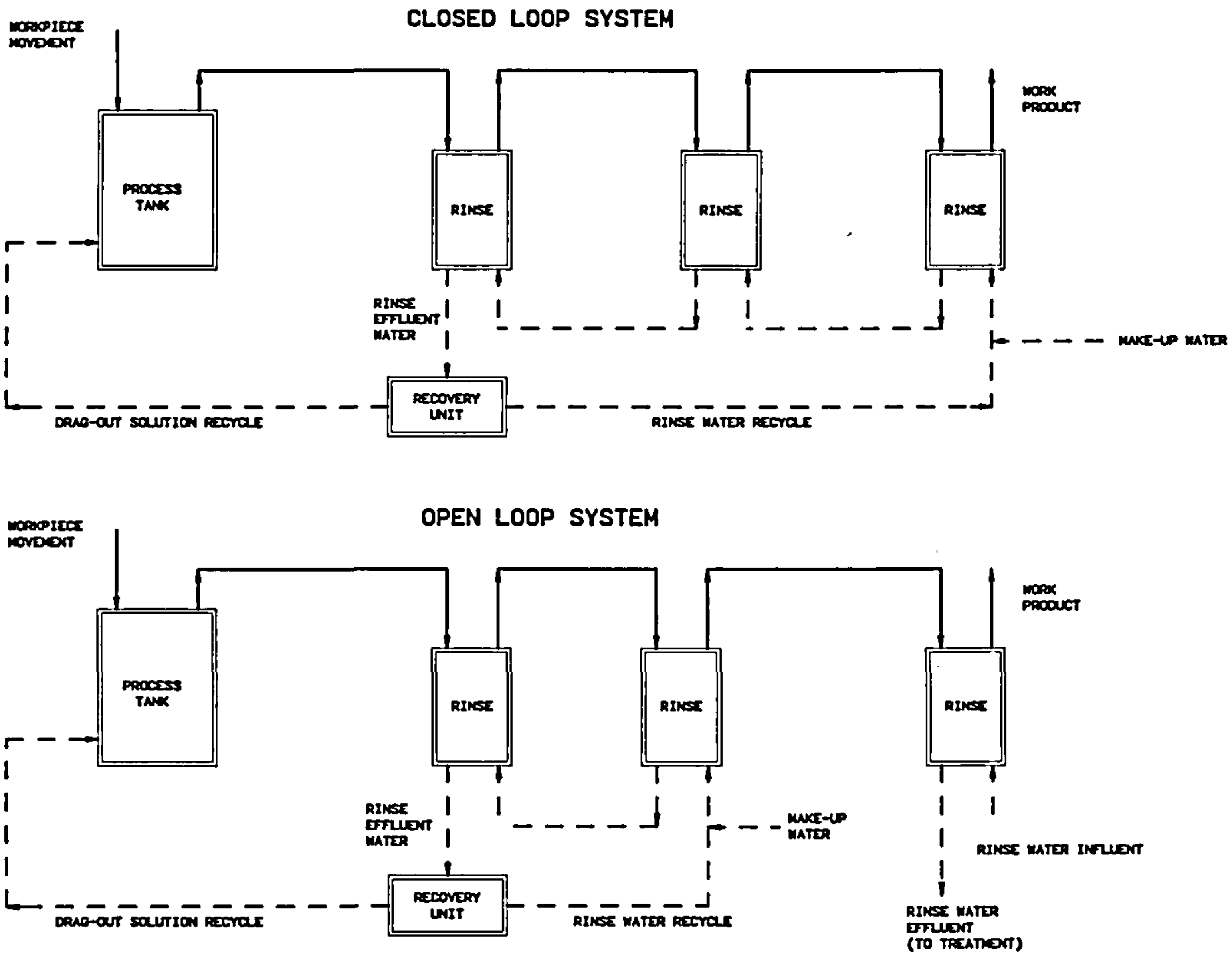
Minimizing drag-out from a plating or cleaning bath reduces the water needed to rinse off the workpiece, saving raw materials, treatment and disposal costs.

3.1.5 Rinsewater minimisation

Rinsewaters represents a large fraction of water used and metal load, optimising rinsing reduces the amount and/or toxicity of waste produced. Figure 9 illustrates options for rinsewater minimisation and recovery, and Figure 10 illustrates the chemical rinsewater recycling system.



	JOB No.	RINSING CONFIGURATION	FIG No. 9



JOB No.

CHEMICAL RINSE WATER RECYCLING SYSTEM

FIG No. 10

3.1.6 Bath management

Plating baths represent significant investment in chemicals and it is highly beneficial to minimise loss to drain whilst optimising the chemical active life.

Solution Maintenance can involve Preventative practices to avoid contamination or involve monitoring and adjusting of solution chemistry and Corrective practices physically remove contaminants from the bath solution.

3.1.7 Bath and/or process substitution

Rather than resort to treating plating bath chemicals it is possible in some cases to reduce the potential effluent metal load derived from the baths by replacing conventional bath chemistry or process configurations in some cases.

3.2 Recovery and Recycling

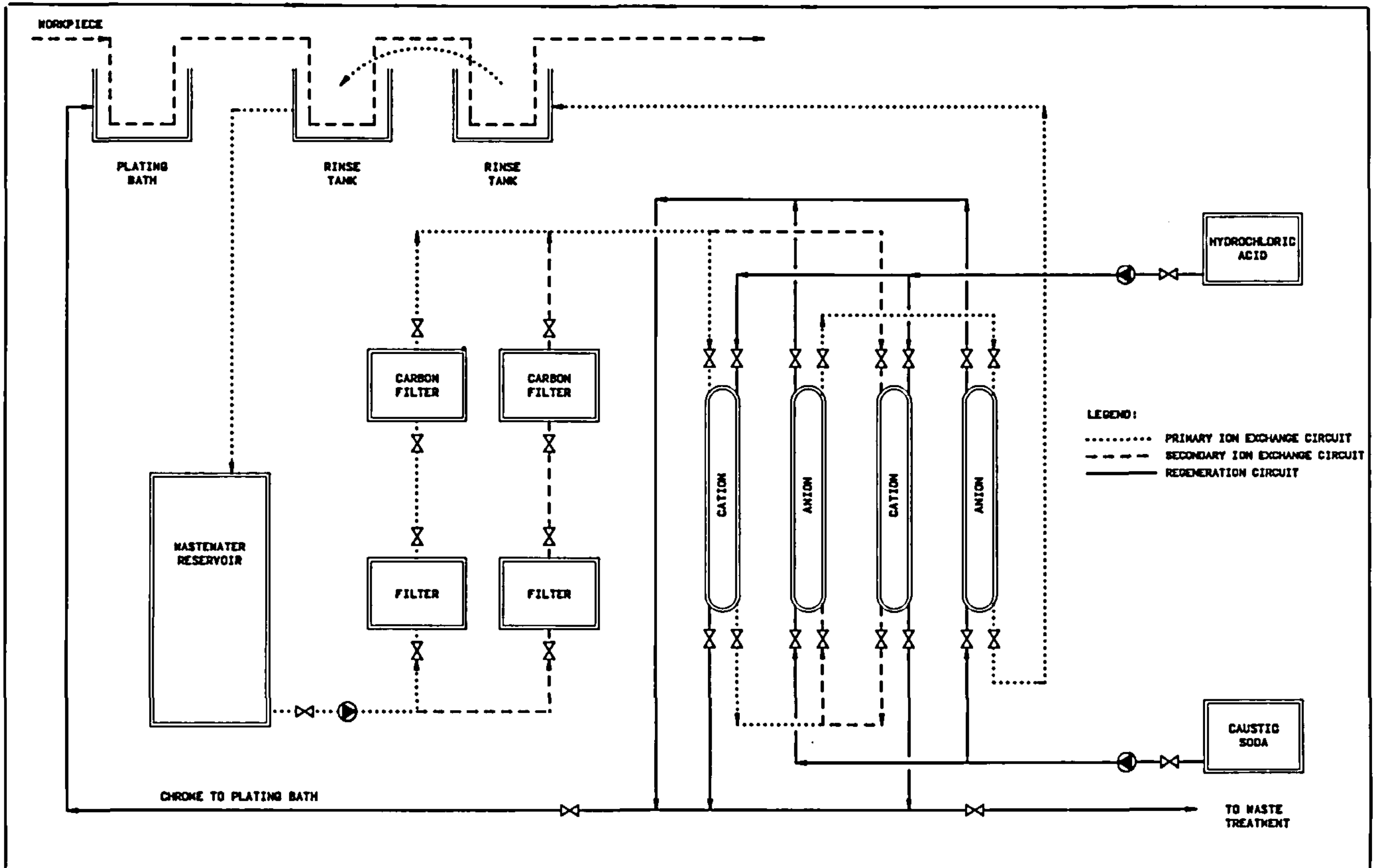
3.2.1 Recycling opportunities

Losses of metals and chemicals not only reduces the economics of raw material use it is a significant cost factor in the operation of a Metal Finishing plant. By controlled recovery and recycle of process liquors it is possible to reduce waste discharges, minimise raw material input and improve the balanced control of discharges to sewer. Options include:

- Rinse from acid cleaning reused as influent to a rinse tank following an alkaline cleaning bath. This technique can lead to precipitation problems.

- Drag-out on a workpieces from alkaline bath neutralized with acid rinses to reduces its viscosity and accelerate the rinsing process.

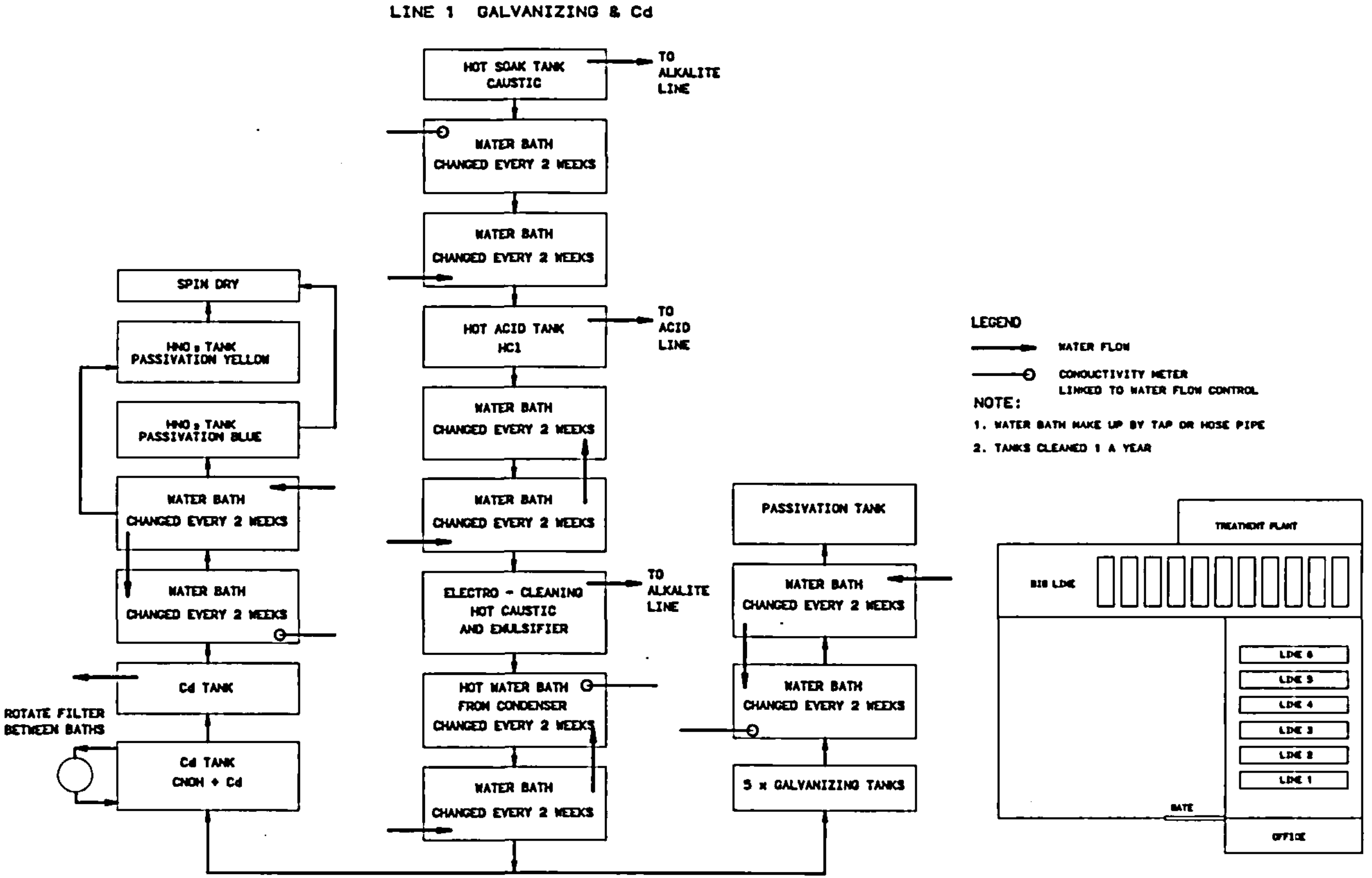
- Acid cleaning rinsewater used for rinsing after a mild acid etch process.



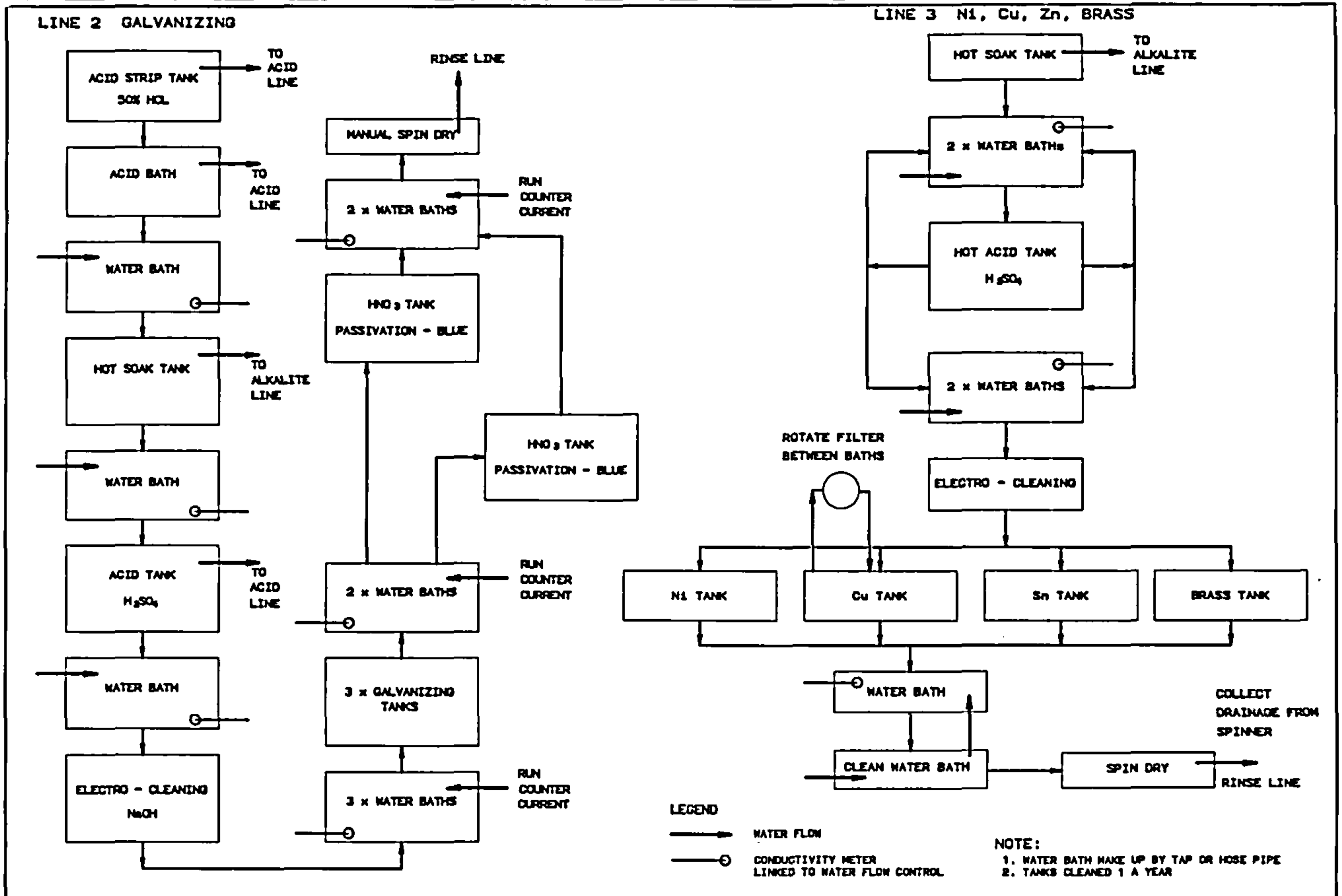
JOB No.

ION EXCHANGE SYSTEM FOR CHROMIC ACID RECOVERY

FIG No. 11



JOB No.	ELECTROPLATING SHOP - PROCESS DIAGRAM WITH WASTE MINIMISATION OPTION INCORPORATION	FIG No. 12



JOB No.

ELECTROPLATING SHOP - PROCESS DIAGRAM

FIG No. 13

3.2.2 Recycling technologies

3.2.2.1 *Filtration*

Filtration is the most commonly applied method of corrective bath maintenance. Various equipment are used for filtration including cartridge filters and precoat (diatomaceous earth) filters, sand, multimedia, carbon and microfilters.

3.2.2.2 *Ion exchange*

Ion exchange is used for a variety of purposes in the metal finishing shop, including treatment of raw water, recovery of plating chemicals from rinse water, purification of plating solutions, wastewater treatment, and waste water polishing. Dependent on the chemical nature of the process, the regenerant (eluate) solution can be returned directly to the plating tank for reuse, further processed and then returned, or the metals can be recovered by another technology such as electrowinning.

3.2.2.3 *Electrowinning*

Electrowinning is widely used in the plating industry for metals recovery. The basic unit of the electrowinning technology is the electrolyte cell, two electrodes (anode and cathode) are placed in a solution containing ions, when charge is introduced to the cell dissolved metals in the electrolyte are reduced and deposited on the cathode. The deposited metal is removed by mechanical (scraping) or chemical means and either reused as anode material or sent off-site for refining/reuse or disposal.

3.2.2.4 *Electrolysis (Dummying)*

Dummying is an electrolytic process in which metal contaminants in a bath are either plated out (low current density electrolysis) for general bath solutions or oxidised (high current density electrolysis) typically for oxidising trivalent chromium to hexavelant chromium in chronic acid baths and for gas-off of chloride to chlorine.

3.2.2.5 *Atmospheric evaporators*

Atmospheric evaporators are a widely used method of chemical recovery in the plating industry, or for concentrating liquid plating wastes prior to hauling off-site for treatment/disposal, thereby reducing transportation costs and in some cases treatment/disposal costs.

3.2.2.6 *Vacuum evaporation*

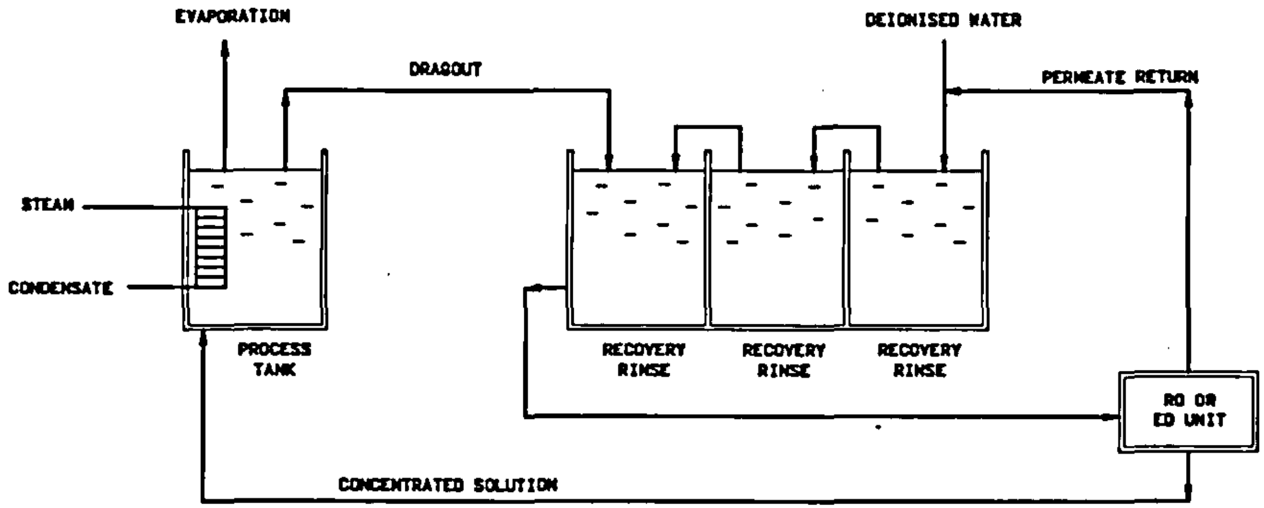
Vacuum evaporation is a distilling process that vaporises water at low temperatures when placed in a vacuum. There are several types of vacuum evaporators, generally consisting of a boiling chamber under vacuum, a liquid vapour separator and a condensing system. Vacuum evaporators tend to be relatively complex and therefore more expensive to construct and maintain than the simple atmospheric evaporators.

3.2.2.7 *Reverse osmosis (RO)*

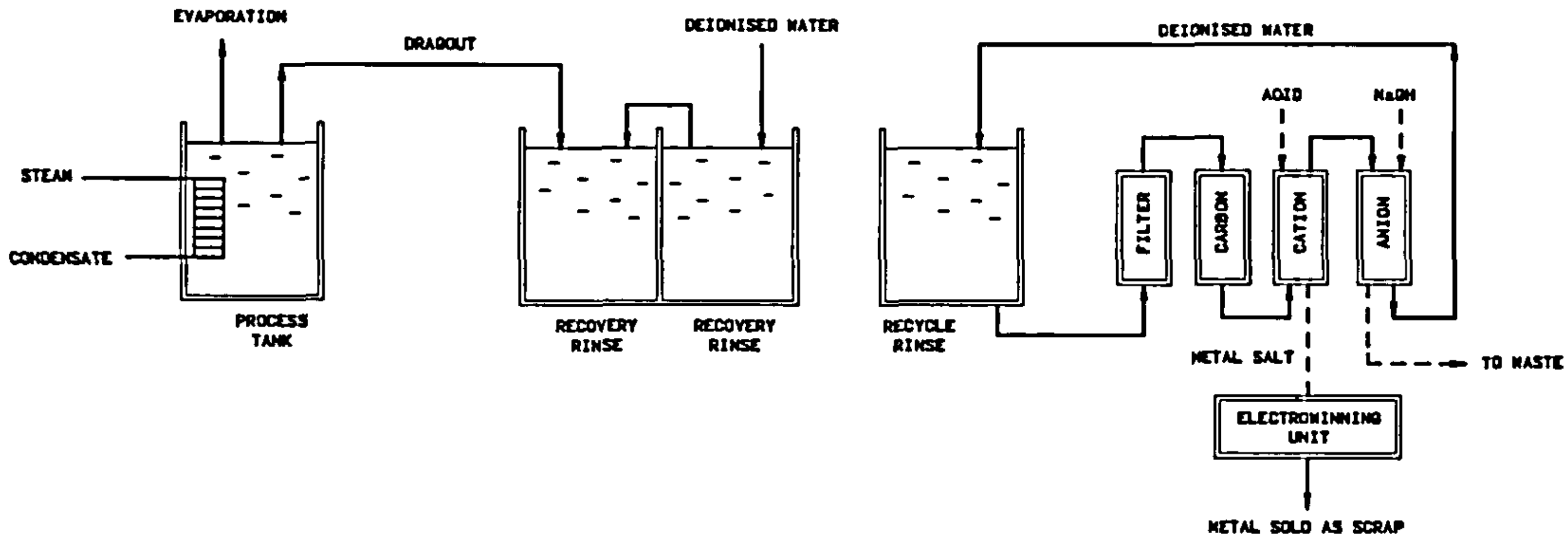
RO is extensively used for industrial effluent salt removal and recovery, and under ideal conditions will typically remove up to 98% of constituents from 70 to about 85% of the feed water. About 20% of the feed water is typically recovered as a brine containing the constituents rejected by the RO membrane at a concentration of about five times that in the feed water, which can be returned to the bath, or evaporated further for recovery or off-site transfer.

Figures 14 to 17 illustrate conceptual recycling options as applied. Figure 18 illustrates a generic concept for in-plant waste minimisation utilising ion-exchange recovery of rinsewater. Figure 19 illustrates a total plant waste minimisation and recovery system, the RMA concept of Dornier Technologies.

REVERSE OSMOSIS - ELECTRODIALYSIS EXAMPLE

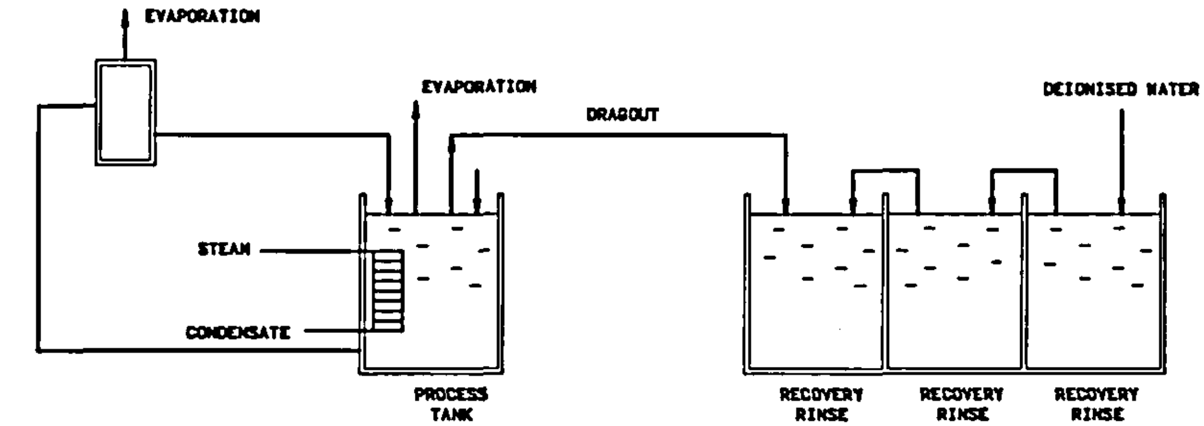


ION EXCHANGE - ELECTROWINNING EXAMPLE

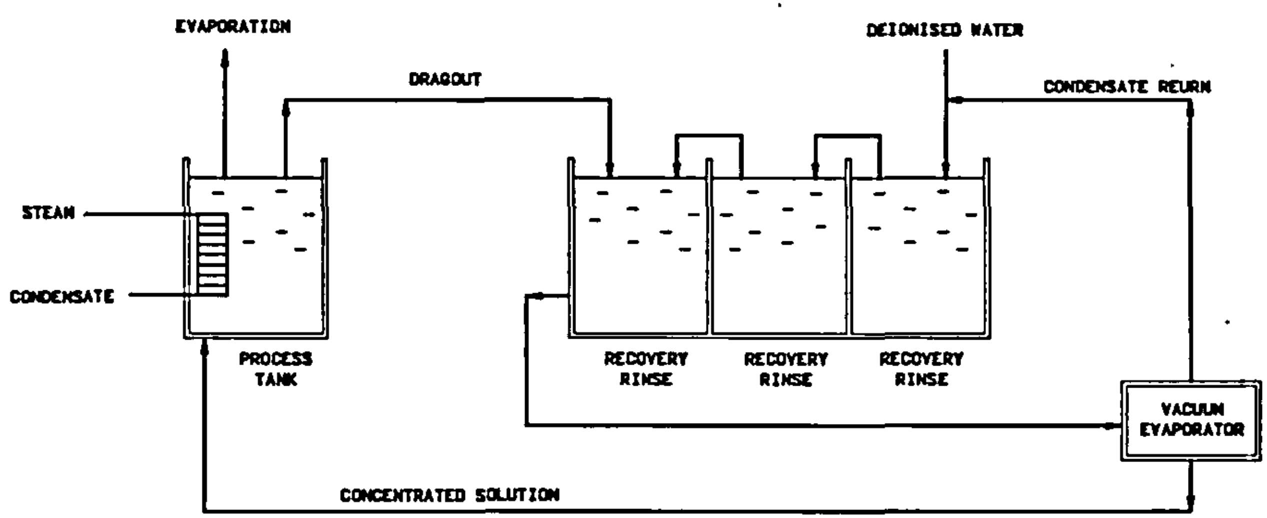


JOB No.	EXAMPLES OF RECOVERY - RECYCLE TECHNOLOGY	FIG No. 14&15

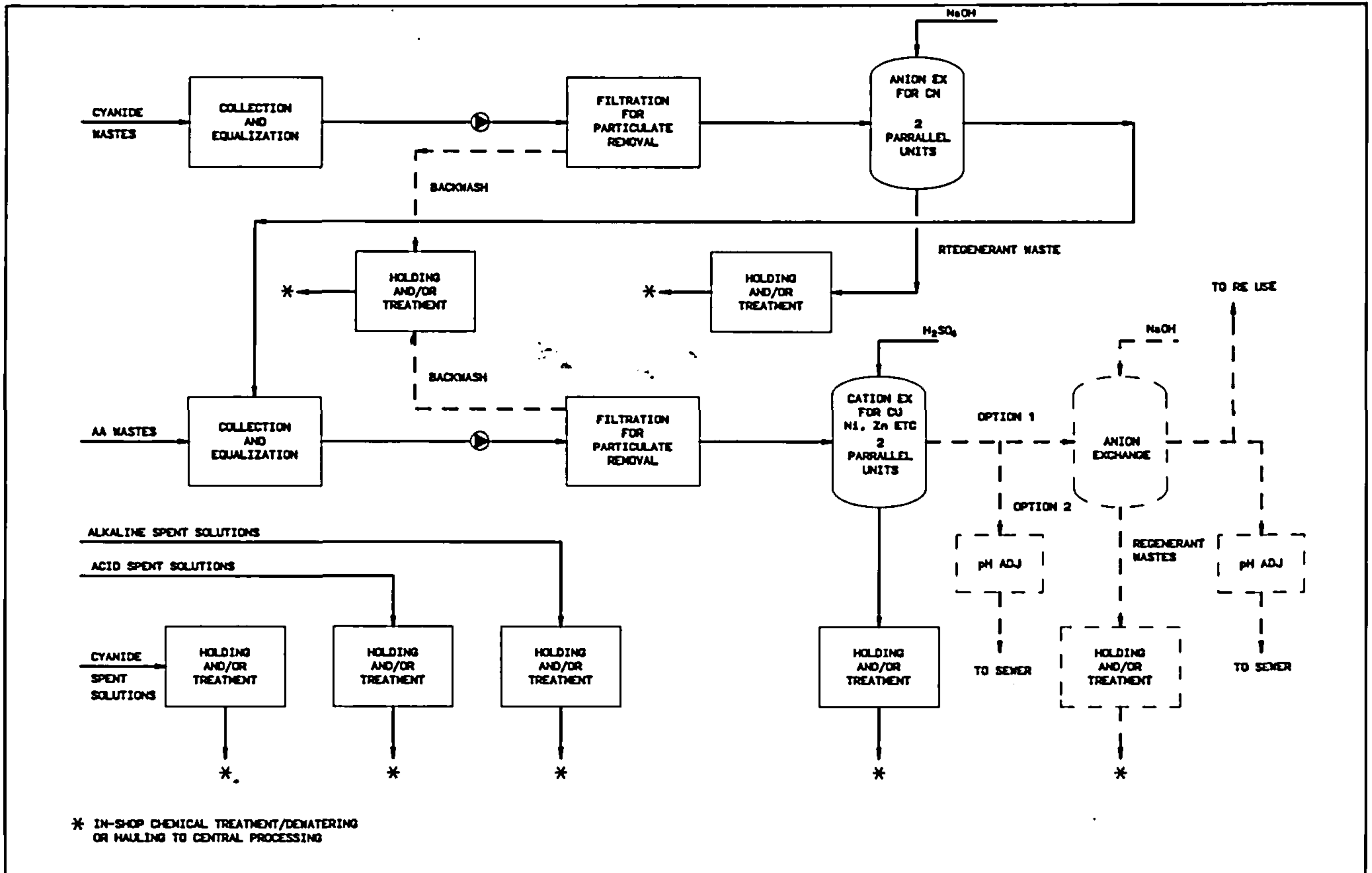
ATMOSPHERIC EVAPORATION EXAMPLE



VACUUM EVAPORATION EXAMPLE



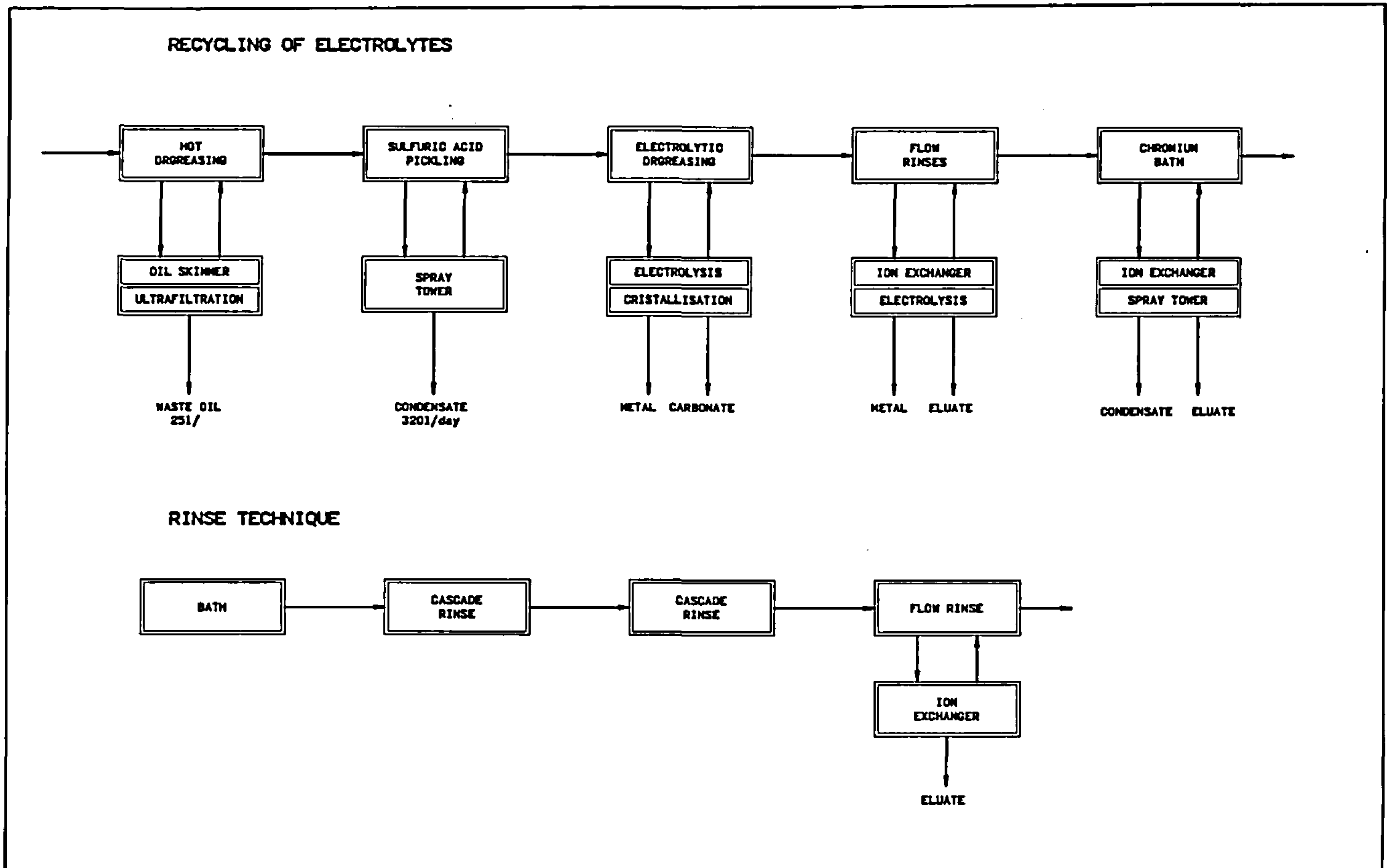
JOB No.	EXAMPLES OF RECOVERY - RECYCLE TECHNOLOGIES	FIG No. 16&17



JOB No.

IN-PLANT WASTE MINIMISATION UTILISING ION-EXCHANGE RECOVERY OR RINSE WATERS

FIG No. 18



JOB No.

FLOW SCHEMATIC OF RMA-TECHNOLOGY

FIG No. 19

3.3 Waste Minimisation and Recovery Installation Costs

Factors that will determine whether process modifications to apply waste minimisation measures or pretreatment are economically justifiable include the volume of waste that contains metals, the concentrations of those metals in the waste, and the potential to recirculate some of the metal salts and recovered waters as opposed to discharge charges and penalties. Many systems may not be economically feasible for small surface treatment and plating operations because the capital costs of installing the necessary equipment might outweigh the saving from recovering process chemicals, although without waste minimisation the pretreatment requirements will be significantly greater.

As a general assessment,it has been estimated that the installation of Waste Minimisation measures to include process reorganisation, additional rinse tanks and control equipment and toxic fume capture will be comparable to estimates for pretreatment.

These could be of the order of R 100 to 200 000 for the smaller applications where limited replacement is required to in excess of R 1 500 000 for facilities where significant upgrading of existing infrastructure and process control is required, and not including RO or IX recovery units.

3.4 Wastewater Pretreatment

3.4.1 Pretreatment options

Most Metal Finishers have a range of pollutants e.g cyanide, chrome, other metals or greases and oils. Therefore treatment to meet Municipal discharge specifications will usually combine several treatment technologies to satisfactorily treat their effluent consents. The following specific pretreatment technologies can be applied to a greater or lesser extent dependent upon the size of the facility, variability of process lines and practicality of on-site or off-site recovery:

* Cyanide Destruction
* Solvent Recovery and Removal
* Electrolytic Metal Recovery
* Ion Exchange
* pH Neutralization
* Grease and Oil Removal
* Metals Removal
* Solids Removal
* Reverse Osmosis
* Electrodialysis
* Equalization

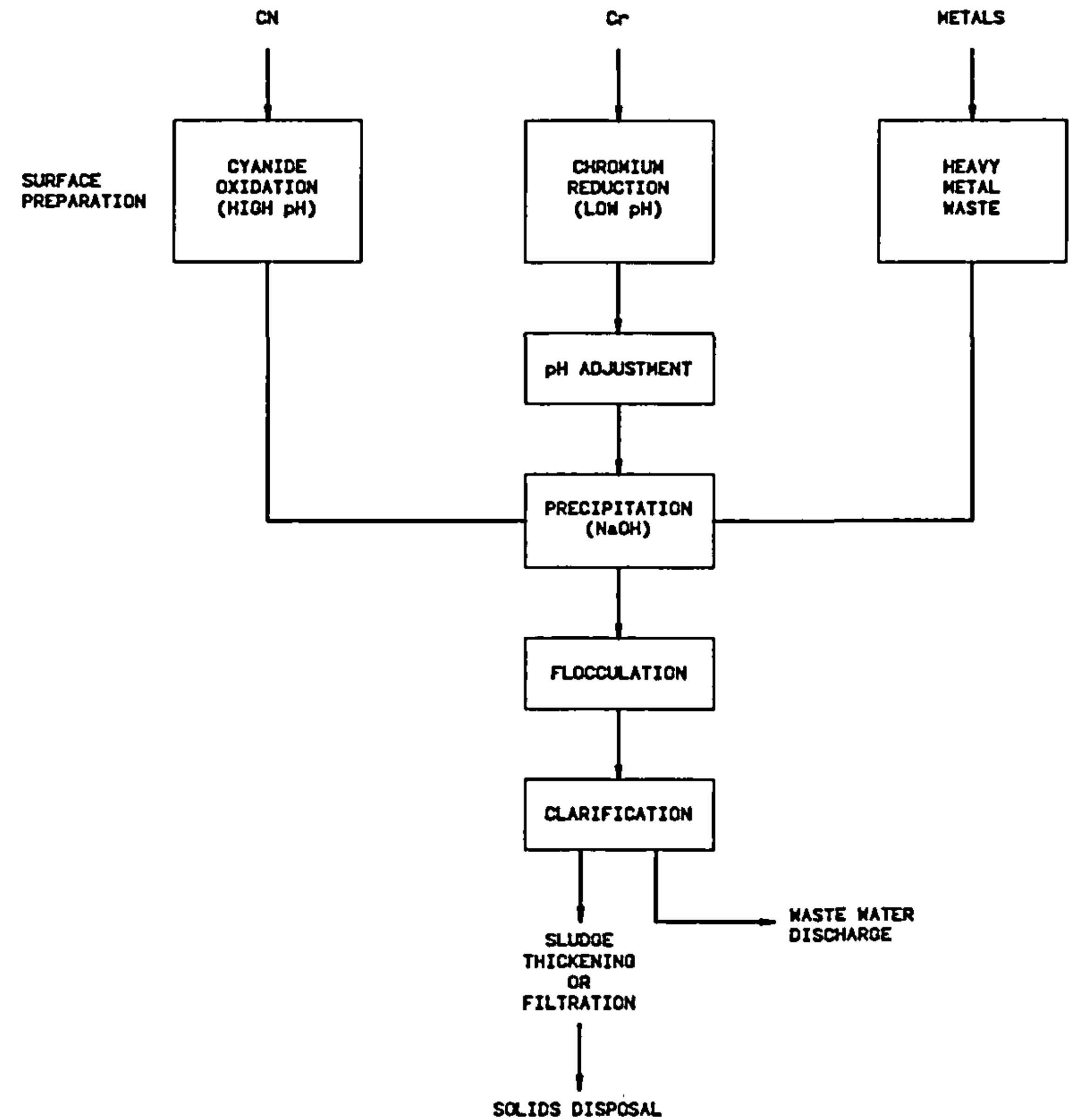
In many facilities it is not considered viable to recover metals from wastewaters or discharged sludges due to the extremely high purity required in the plating baths and the costs associated with such recovery as opposed to direct disposal and replacement. External processing does appear viable, though may require encouragements and possible subsidisation. Batch treating spent process baths rather than adding them to the wastewater treatment stream can also reduce waste generation. The spent baths can be chemically monitored and just the necessary amount added to treat it.

3.4.2 Best practical end-of-pipe treatment technology

The **Best Practical Technology (BPT)** for metal finishing effluent where off-site disposal is most practical, consists of:

1) segregation and destruction of oxidisable cyanide,
2) segregation and reduction of hexavalent chrome,
3) equalisation of the different streams and precipitation of the metals
4) settling of suspended solids
5) separation and disposal of the sludges
6) evaporation of excess water, if essential and cost-effective

Figure 20 illustrates the generic end-of -pipe treatment arrangement.



JOB No. 192017

CONVENTIONAL TREATMENT SCHEME

FIG No. 20

3.4.2.1 *Stream segregation*

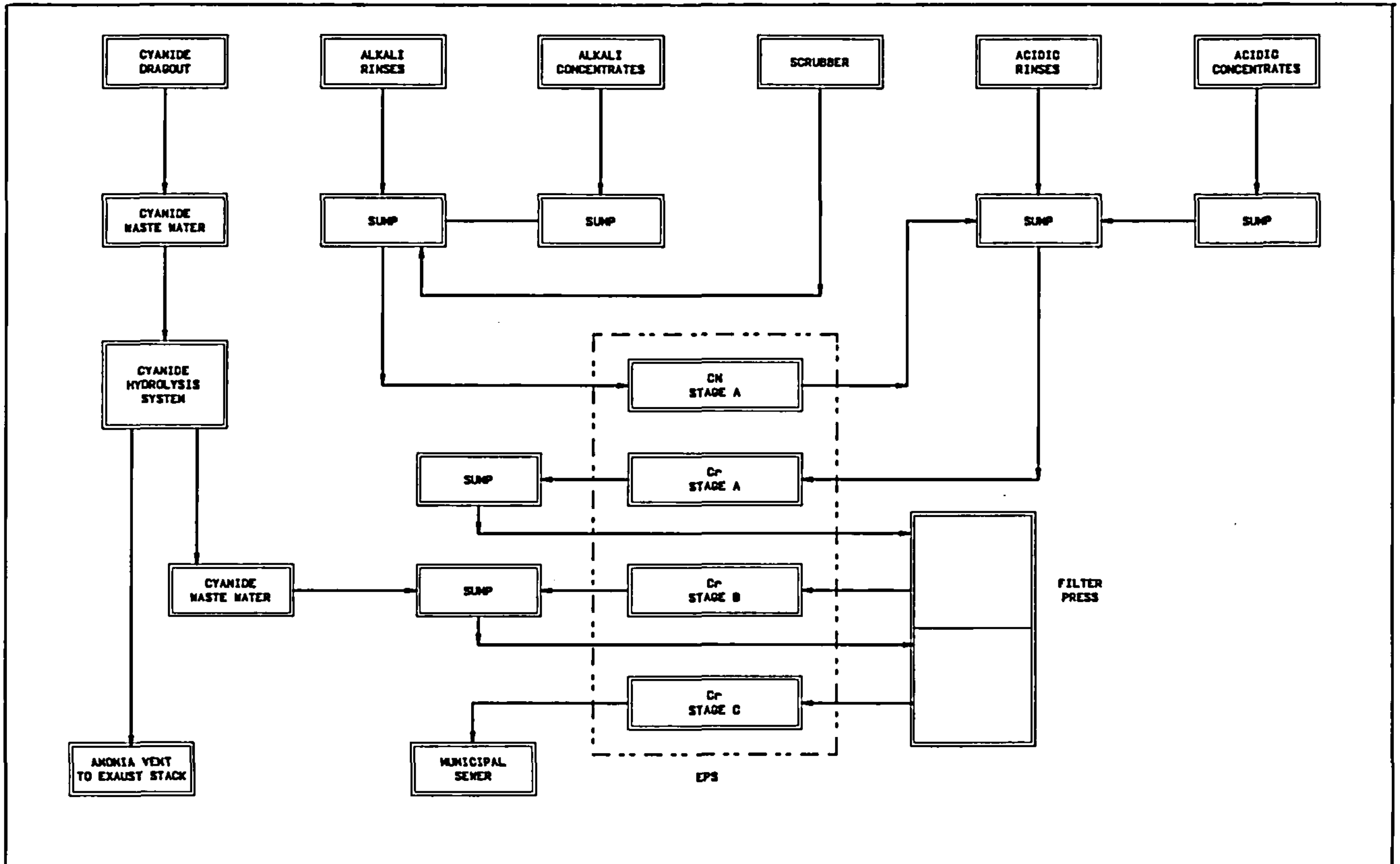
Many plants combine rinsewater streams in common drains, and the concentrations of the individual metals are diluted to less than 50 mg/l each and not condusive to selective recovery and reuse. Plating rinse stream may be segregated to allow individual waste streams to be reclaimed, reused, or pretreated. Stream segregation allows the plater to conduct his operations more economically; less rinse water is used; less chemicals to process the parts; and less waste of all types is produced, thereby eliminating a large expense.

3.4.2.2 *Cyanide destruction*

The most common method is alkaline chlorination by addition of sodium hydrochlorite or chlorine gas plus sodium hydroxide in static tanks placed after drag-out tank, and results in almost complete cyanide removal. A more recent development involves subjecting cyanide bath liquor to high temperatures under pressure in a sealed unit, capable of destroying high cyanide concentrates ie > 10 g/l CN to less than 1 mg/l. The discharged liquor is then subjected to metals precipitation and filtration to render an innocuous final effluent suitable for discharge to sewer. This approach has been adopted for South African Airways (SAA) by Chemserve Trio. Figure 21 illustrates how the waste streams are segregated and subsequently treated in a co-ordinated and effective manner, including cyanide destruction.

3.4.2.3 *Chrome Removal*

Chromium must be converted from the hexavelant to the trivalent state to facilitate subsequent precipitation and removal, by addition of sodium metabisulphite, or other sulphite compounds at a pH of 2,5 - 3. Chromium is precipitated at elevated pH (> 8.5). The sludge can be dissolved using sulphuric acid to obtain a reusable liquor or dewatered for transportation off-site by filter press or microfilter.



JOB No.	PROCESS FLOW SCHEMATIC OF METAL WASTE WATER TREATMENT AT SOUTH AFRICAN AIRWAYS PLATING SHOP (Courtesy Chemserve Trio PTY Limited)	FIG No. 21

3.4.2.4 *Removal of Heavy Metals*

Precipitation will only be an effective treatment if the cyanide and hexavelant chromium streams have first been treated separately. After treatment the streams are combined where the heavy metal content may be precipitated out, usually as a hydroxide or sulphide at appropriate pH dependent upon the metals present and in a clarifier which may incorporate inclined plates for improved efficiency.

3.4.2.5 *Sludge handling*

Metal concentrates and sludges generated by precipitation will generally be at a solids content of the order of 1 - 2% solids dry weight. This can be stored for removal to a central processing facility, or further dewatered through a filter press or Microfilter unit to produce a cake of ± 25 - 35% dry weight solids to reduce storage and transport costs. This represents an approximately 20 to 1 volume reduction from the original sludge volume discharged from the clarifier/thickener. Additional dewatering can be accomplished with sludge dehydration equipment that can produce a waste material with a solids content of approximately 90. This represents an approximately 4 to 1 waste volume reduction above that achieved by the filter press.

3.4.2.6 *Phosphate removal*

Many plating solutions contain high levels of phosphate which will attract charges in the some Municipal discharge tariff formulae. Permanganate can be utilized as an effective oxidant for oxidation of reduced phosphorus prior to lime precipitation of phosphate.

3.4.2.7 *FOG removal*

Fats, Oils and Grease components should be limited prior to sewer discharge this is usually accomplished through an appropriately designed grease trap of either segregated or combined effluent streams and skimming of the FOG scum float for collection, storage and ultimate off-site disposal.

3.4.2.8 *Effluent polishing by microfiltration*

Microfiltration as an end-of-pipe technology is similar to a conventional hydroxide precipitation system with the exception that the clarifier/thickener is replaced by the microfiltration unit. Also, since microfiltration systems do not depend on the ability of the precipitated metals to settle, a polymer addition/flocculation step is not present, and would tend to foul the membrane.

Microfiltration is able to achieve TSS, and residual metal levels of towards 1 mg/ℓ, significantly better than conventional clarification and settlement. To enhance metal precipitation and removal reagents such as calcium chloride, sodium sulphide and ferrous sulphate are used, as well as more conventional hydroxide precipitation. The process chemistry will vary depending on the type and concentration of the constitutes in the feed stream and the target effluent levels.

3.4.2.9 *Zero effluent*

Zero effluent may be achieved by the incorporation of one or more of the tecnologies discussed in res pect of recycling and recovery options ie Reverse Osmosis, Ion-Exchange, Electrodialysis, Electrowinning and Evaporation (Atmospheric or Vacuum).

Evaporation may also be used as an end-of-pipe treatment where the objective is to reduce or eliminate the discharge of wastewater and not to recover chemicals.

3.4.2.10 *Bath Rejects Handling*

Precipitates accumulating in the plating and chemical baths should be considered a hazardous waste and be handled accordingly. This would usually involve neutralisation, dewatering and disposal as a solid waste. If the pretreated metal or toxin (CN) load is too excessive for acceptance to sewer, the plater should arrange for the waste to be collected for off-site treatment and disposal.

3.4.3 Best practical end-of-pipe recovery technology

The Best Practical Technology (BPT) for metal finishing effluent where on-site or off-site recovery is possible usually involves Ion Exchange (I-X) as an important end-of-pipe treatment technology.

Three common approaches using Ion Exchange are employed:

1) removal of metals from large volumes of miscellaneous wastewaters and concentrate them into a smaller volume for subsequent treatment by conventional means. This reduces the capacity requirement of the conventional system and therefore may result in capital savings.

2) as a polishing technology to remove residual pollutants following conventional treatment. This is not suitable for recycling water which requires both anion and cation columns (deionisation). Because the wastewater treatment process adds such an abundance of sulphates and chlorides to the wastewater it is usually economically impractical to recycle it using ion exchange. If water recycle is the objective it is better to segregate wastewaters and recover the water.

3) as the primary end-of-pipe treatment for segregated metal and cyanide bearing rinse waters and the resin columns are sent to a CWT facility for regeneration. Because the wastewaters are segregated before I-X, the regenerants contain metals that can be recovered by relatively easy means (eg electrowinning). Resins may be regenerated on-site, and the regenerant sent to an off-site metals recovery firm.

As with conventional treatment I-X end-of-pipe treatment also requires the segregation of cyanide and its destruction, filtration and carbon treatment. The pH adjustment step is needed to ensure that the pH is within the operating range of the resin. Cyanide destruction will reduce the number of steps of the ion exchange process when CN complexes are present.

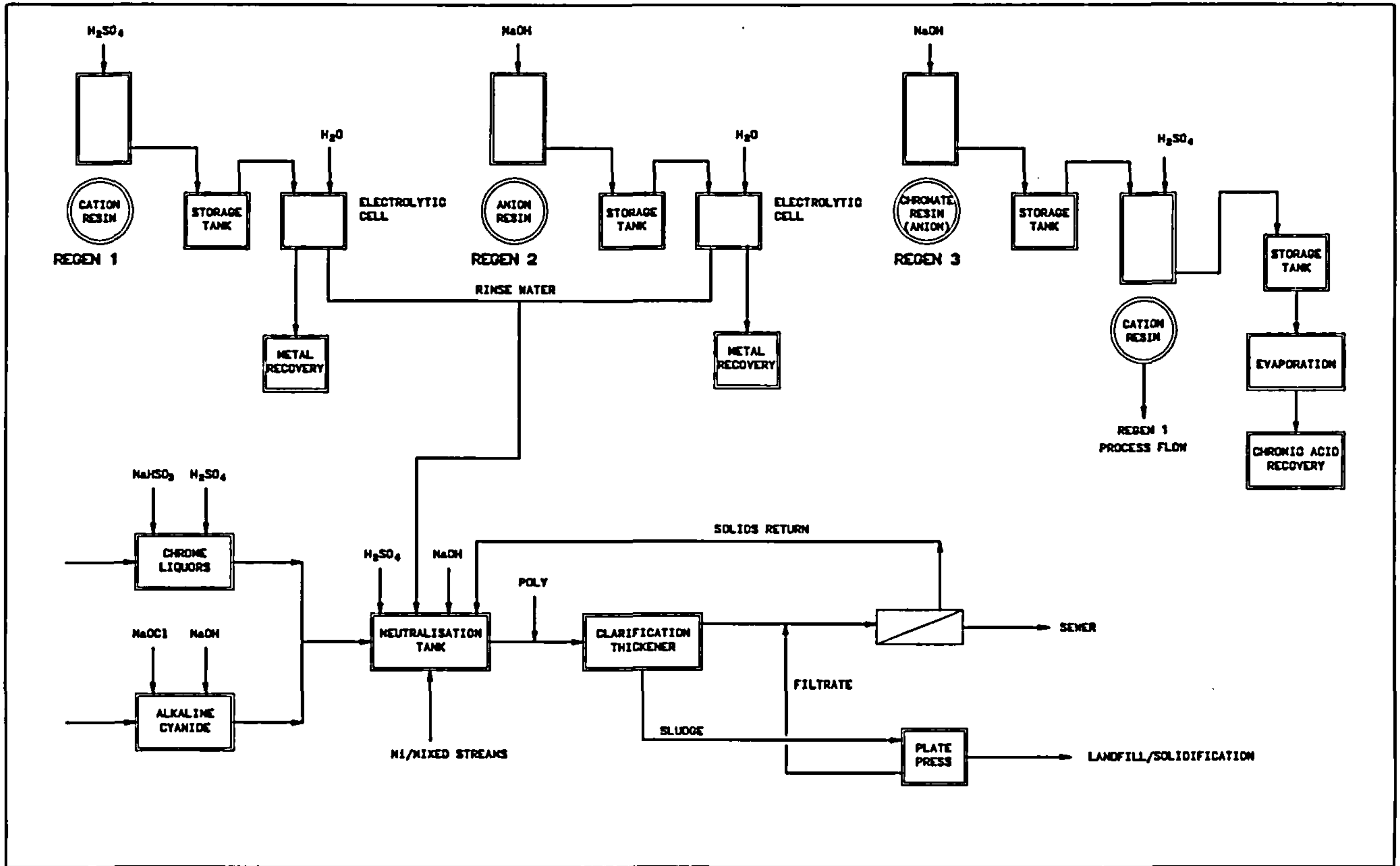
Filtration and carbon treatment, which are the most common pretreatment technologies, are needed to remove suspended solids and organics that may foul the resin beds. If water recycle is desired, the ion exchange system must consist of both anion and cation columns. Cation only systems can be used if water recycle is not desired and there are no chromates or cyanide present (removed by anion resins). Concentrated wastes generated in the plating shops (eg batch dumps) should be discharged to a batch treatment system, rather than the main I-X stream. I-X is not a good technology for concentrated streams as the regenerant may be less concentrated than the original waste.

An end-of-pipe treatment/water recycle system may be applicable to chromium, cyanide and acid/alkaline rinse waters. The unit would usually employ duplex cation and anion beds employed in a parallel/standby mode of operation, and usually includes a batch treatment system for regenerants as well as an atmospheric evaporator or electrowinning unit for further processing of the regenerants. Figure 22 illustrates the pretreatment of independent streams with I-X.

3.4.4 Pretreatment plant installation costs

Costs for Metal Finishing effluent treatment equipment are estimated to be of the order of R450 000, R850 000 and R1 250 000 for flows of 10 m^3, 50 m^3 and 100 m^3/day respectively, largely as a result of dewatering requirements, or RO or IX units. Such costs are considered prohibitive for most Finishers at present. To rationalise pretreatment requirements it is estimated that in-house Waste Minimisation measures such as enhanced rinsing can drastically reduce waste generation rates (>50%) and are particularly suitable to medium and large scale plants. This can be taken further to include Reverse Osmosis or Ion Exchange to produce a 'clean' effluent for recycle or recovery, but may be considered un-economical at this stage. For smaller operations, simple pH adjustment without metal precipitation appears adequate. In each case spent acid, alkali cleaning and plating baths still require transportation to a central handling facility. In a particular industrial area where Metal Finishing shops are located in close proximity it may be feasible to combine the effluent in a single treatment plant via local reticulation, or transport of wastes to the local treatment plant.

These approaches would be economically and technically advantageous but management and control of such combined facilities would require careful consideration.



JOB No.

INDUSTRIAL WASTEWATER PRETREATMENT FACILITY

FIG No. 22

3.4.5 Requirements for metals recovery from E-O-P treatment

In assessing whether a concentrate or sludge generated by pretreatment is suitable for metals recovery there are several important considerations:

- Metal recycling benefits from the provision of mono-metal solutions or sludges rather than mixed metals solutions and sludges to aid selective recovery. Production of a non-metal solution or sludge requires segregation of plating operations which is not always easy or cost-effective.

- Hydroxide sludges are generally preferred to sulphide sludges because the latter can make reclamation more difficult. Sodium hydroxide is usually preferred to lime as the alkali reagent because it adds the least amount of inert material to the waste. Sludges generated with cationic polymers used for flocculation are usually preferred to alum and ferric compounds, also due to a lower inert material content.

- The presence of some constituents (eg. cyanide, arsenic, solvents) may preclude acceptance of the waste or significantly increase processing costs. The waste should be free of miscellaneous debris such as rubber gloves, cartridge fillers, mop heads, etc, which add to the complexity of the treatment and handling process.

- Preferred moisture content is dependent on the material storage, handling and processing facilities and equipment.

- High volume waste streams are preferred due to economies of scale and reduced change-over time for individual processing requirements.

- Waste recycling firms prefer waste streams that are chemically consistent from shipment to shipment.

4 WASTE MANAGEMENT

4.1 Waste Management Programme Requirements

To control the handling and disposal of hazardous wastes it is necessary to have a Waste Management Plan which is effective and accepted by the industries it regulates. Both the "duty of care" and the "cradle to grave" principles may be implemented. "Duty of care" provides for the generator of waste to be held legally responsible for personal injury or damage to the environment caused by the waste. The "cradle to grave" principle, requires a "manifest" accompany a hazardous waste until it is responsibly and legally disposed of. A suitable approach, following the US EPA lead is to establish a **'Permitting, Tracking, and Control approach'.**

- **An identification and permitting system** where each industrial user is issued a permit to identify its production process and wastes for disposal to sewer and/or collection, treatment and disposal. Where waste is to be handled off-site the industrial user must ensure the waste is contained and labelled properly for transportation to the site of treatment, recovery and/or safe disposal, and accompanied by a certified manifest detailing the waste being transported.

  Individual hazardous waste unit processes, such as plating baths, may complete a specific manifest identifying the bath materials and allows for the hazardous tanks drains to be sealed and only opened upon notification to, and witnessed by an authorised officer.

- **A tracking system** enables the waste to be monitored by the Municipality in whose area the waste is generated, through whose area it is being transported, and in whose area it is to be disposed of (if different). It also allows the regional and national authorities to assure the safe operation of all facilities involved in the transportation, treatment, storage and disposal of hazardous waste.

The Manifest records the details of each load collected from an industrial user, tracking the frequency of removals and identifying sites that have not had removals in some time. These may then be inspected to investigate where expected wastes are being disposed to, if not via the certified waste haulier, and to head off possible problems in the sewerage system if disposal to sewer is continuing.

- **A system of restrictions and controls** on discharges to sewer and/or for off-site treatment and disposal in the form of Discharge Standards and Conditions. Where a Pretreatment service may be operated on behalf of the industries the Municipality should monitor the operation of the Service, the associated operational costs and environmental liabilities. Where a Centralised Waste Treatment plant receives hazardous waste concentrates the Municipality should monitor the operation of the CWT which becomes a potentially serious polluter should operations malfunction and all local wastes are now accumulated at a single location. The Municipality may also monitor the discharge of effluent from the CWT, the stabilisation and placement of hazardous waste, on or into the land, and the recovery of materials from wastes.

  A most important requirement of a waste management plan is an effective enforcement programme to ensure compliance, and to effectively address and, where necessary, penalise non-compliance.

4.2 Discharge Standards

4.2.1 Basis for discharge standards

Discharge Standards for industrial sewer discharges are intended to prevent the introduction into a Sewage Treatment Works (STW) of pollutants that will interfere with its operation, and/or accumulate into waste sewage sludges at unacceptably high levels, or pass through the treatment works to exceed river discharge Standards, and threaten aquatic life.

In line with International experience it is considered beneficial to promulgate **National Categorical Discharge Standards** for Heavy Metal Dischargers which are a basis for minimum requirements and sets a Uniform Pretreatment Standard for the Industry irrespective of location. Above this, each Province is able to further tighten the **Provincial Standards** to meet their own particular requirements and quality control needs. Municipalities may also have the authority to impose **Local Discharge Limits** in terms of Drainage by-laws and are responsible for the permitting, monitoring and compliance tracking of the Standards.

A Municipality may revise Local Discharge Limits to prevent redundant treatment capacity at the STW as industries comply with Pretreatment Standards over a given time scale, **Removal Credits.** These credits are assigned as long as the concentration of the pollutant in the STW sludge or final effluent discharged to river do not exceed their prescribed limits.

The objective in setting **Specific Discharge Standards** is to reduce the contaminants in metal finishing discharges to environmentally acceptable levels while remaining technically feasible and affordable for the industry in relation to alternative metal control options, in line with the accepted international norms, with local considerations. Table 8 illustrates the US EPA Specific Standards for Metal Finishing Industries on the basis of daily maximums and monthly averages and Standards considered achievable by the use of Best Practical and Available Technologies as defined by the EPA.

Most Municipalities prescribe limits on wastewater contaminants. Table 9 illustrates an example derived from the Johannesburg Municipal By-laws for parameters appropriate to the Metal Finishing industry:

Table 8: US EPA Best Practical Technology Guidelines

Pollutants	Pretreatment and Effluent Guidelines (mg/ℓ)	
	Daily Maximum	30-Day Average
Cadmium	1,29 (0,064) *	0,27 (0,018) *
Chromium - total	2,87	0,80
Copper	3,72	1,09
Nickel	3,51	1,26
Lead	0,67	0,23
Silver	0,44	0,13
Zinc	2,64	0,80
Cyanide - total	1,30	0,28
Total toxic organics	0,58	0,58
Oil and grease **	42,0	17,0
Total suspended solids **	61,0	22,9

* - Cadmium limit for new sources.
** - Applies only to direct dischargers. pH limit for direct dischargers is 6,0 - 9,0.

Table 9: General Discharge Standards For Johannesburg Municipality (abridged)

Parameter	Limit
Temperature (°C)	44° C
Electrical Conductivity (mS/m)	500 mS/m at 25° C
pH	Not Less than 5
Substances not in solution	2 000 mg/ℓ
Cyanogen compounds (as HCN)	20 mg/ℓ
Sulphides, hydrosulphides and polysulphides (as S)	50 mg/ℓ
Sulphate in solution (as SO_4)	1 800 mg/ℓ
Anionic surface active agents	500 mg/ℓ
Copper (as Cu)	10 mg/ℓ
Nickel (as Ni)	10 mg/ℓ
Zinc (as Zn)	10 mg/ℓ
Cadmium (as Cd)	2.5 mg/ℓ
Chromium (as Cr)	20 mg/ℓ
Lead (as Pb)	2.5 mg/ℓ
Nickel (as Ni)	10 mg/ℓ
Arsenic (as As)	2.5 mg/ℓ
Cobalt (as Co)	20 mg/ℓ

5 WASTE MANAGEMENT CONTROLS

5.1 Industrial Sewer User Permits (IUP's)

Municipalities are empowered to regulate or prohibit discharges into their sewerage systems. Permits typically identify the industrial users responsibilities and obligations, restricts what can be discharged, requiring reports on discharges and provides for inspections, and specifies that if compliance is not assured the Municipality can refuse to accept the discharge. Permitting may also be designed to raise funds to pay for the operation of the necessary waste management service to ensure that the Standards are met and the sewerage system, treatment plant, and external environment is protected. As industrial and Municipal practices and requirements change a permit is typically effective for a limited time period, and revocable any time for just cause.

Additional specific information that may be requested of Heavy Metal industries include information on the following:

- Inventory of raw feedstock
- Usage of raw materials, stable unit production or variable production and processing practices
- Records of exhausted and/or waste materials removal by waste hauliers or inhouse processing and disposal
- Results of inspections, including documentation of spills, compliance history, general practices

Permits or Consents are a unique document and will also contain the limits and conditions based on the nature and quantity of the specific industry and its discharge and reflecting the ability of the sewerage system to accept and handle it. The Permit may contain appropriate limits for:

- Sampling Frequency and Method which would be used to monitor compliance and to subsequently assess effluent charges according to a published effluent tariff formula, and opportunities for rebates.

- Discharge Standard: The quality of specified pollutants that can be discharged to sewer at any particular time, and daily and monthly maximums and averages for acceptance.

Daily concentration limits are set at a higher figure than the long-term limit but low enough to avoid shock loads to the works. These may be based upon average concentration for the relevant metal of an extended period of effluent and production data; i.e. 1 to 2 years, or derived from a specific monitoring period representative of production conditions. A Discharge Standard may be revised on a regular basis in relation to the status of the Municipal sewerage and sewage treatment plant capacity to assimilate pollutants.

- **Load:** Individual consents can be tied to load rather than concentrations to ensure that the total load received by the sewage treatment plant is within acceptable conditions which may be masked if an industry discharges a high load waste not reflected in concentration terms. Load limits may be imposed on all dischargers, on those responsible for the greater volumes of effluent who would be expected to have the higher loads, or those discharging a load equivalent to a certain percentage of the total load of specific metals of concern or total metals that the sewage works can accommodate. Load limits can be set as for concentration limits; i.e. daily maximums and monthly averages,etc.

- **Flow:** limits are set on the rate of discharge and the daily discharge volume to ensure that the sewerage system and the sewage treatment works are not overloaded by shock discharges. It will be necessary to specify the percentage of water intake to be regarded as effluent if this is not to be individually monitored.

- **Toxicity and treatability:** Tests can be required and limits set to protect the sewage treatment works and to improve the efficiency of the available treatment plant.

- **Harmful substances:** each industry will be advised as to Prohibited substances, both General and Specific which can adversely affect the sewerage system, the sewage treatment works and the environment.

5.2 Monitoring and Reporting Requirements

Industrial users should fulfil a reporting requirements specified by the Municipality. These requirements may include the submission of baseline monitoring reports (BMR's), compliance schedules, general compliance reports (GCR's), notices of slug loading, and record-keeping requirements. These reporting requirements is briefly summarized below. All reports submitted by industrial users must be signed by an authorized representative. An industrial user shall maintain records of all information resulting from any monitoring activities for a minimum of three years. These records shall be available for inspection and copying by the Municipality.

5.2.1 Baseline Monitoring Reports (BMR's)

The purpose of the BMR is to provide information to the Municipality to document the industrial users current compliance status with a Discharge Standard, in terms of discharge qualities and quantities. Table 11 illustrates a conceptual BMR format.

5.2.2 General Compliance Reports (GCR's)

Unless required more frequently by the Municipality, industrial users subject to the Discharge Standards may submit a biannual "General Compliance report", which indicates the concentrations of the regulated pollutants in its discharge to the sewer the average and maximum daily flow rates of the facility, the methods used to sample and analyze the data, and a certification that these methods conformed to accepted methods.

If an IU is not in compliance, a compliance schedule may be submitted that describes the actions, and associated timing, the user will make to achieve compliance with the Standard. If compliance is phased, a report may be submitted at the completion of each phase describing progress. Table 12 illustrates a conceptual GMR format.

5.2.3 Concentrated chemical bath manifest or certification

To monitor the disposal of concentrated plating and chemical baths, and where such bath materials are to be taken for off-site treatment and/or recovery, the drains of such baths may be individually sealed and only opened upon notification to, and witnessed by an authorised officer. The specific manifest identifies the bath materials, date and mass of chemicals at filling, and subsequently the date and mass of chemical make-up as appropriate and ultimately the date and means of disposal and associated quantity and quantity, certified by the witnessing authorised officer. Table 13 illustrates an example of how such a manifest may be structured.

5.2.4 Notice of slug loading or spills

Industrial users may be required to notify the Municipality immediately of any slug loading of any pollutant, including oxygen demanding pollutants released to the sewer system at a flow rate and/or pollutant concentration which will cause interference with the sewage treatment works.

5.2.5 Toxic organic certification

Sampling and analysis for toxic organic may only be required for those organic "which would reasonably be expected to be present" in the effluent, this may include cyanide. For routine compliance monitoring, the industrial user may certify that toxic organics are not used at the facility or to present a plan demonstrating appropriate controls to prevent excessive organic compounds from entering the waste stream.

Table 11: Conceptual BMR Format

BASELINE MONITORING DATA

I. General Information

Facility Name: ______

Facility Address: ______

Managing Directors Name/Designated Responsible Person: ______

Work phone no: ______ After Hours phone no: ______

Emergency response contact: ______ Title ______

Secondary contact: ______ Title ______

Work phone no: ______ After hours phone no: ______

Type of Business/Manufacturer: ______

Operating Schedule: ______

II. Baseline Monitoring Data

Baseline Monitoring Period: from: ______ to ______

Production Capacity, as Percentage of Maximum, During Monitoring Period: ______ %

Operational Production Hours During Monitoring Period: ______

Mass/Area of Material Plated During Monitoring Period: ______ kg/m^2

Mass of Material Used During Monitoring Period:

Chemical Material	Mass/Volume Utilised During Monitoring Period

Daily Water Consumption: Average ______ m^3/d, maximum ______ m^3/d, and minimum ______ m^3/d

Daily Effluent Volume: Average ______ m^3/d, maximum ______ m^3/d, and minimum ______ m^3/d

Daily Water Consumed: ______ m^3/d

Daily Effluent Discharged: ______ m^3/d

Waste Sludges/

Concentrate Volumes: Average ______ m^3/d, maximum ______ m^3/d, and minimum ______ m^3/d

Total Waste Sludge Concentrate Discharged: ______ m^3/d

Waste Sludge/Concentrate Collector's Name: ______

Work phone no: ______ After Hours phone no: ______

Contact: ______ Title: ______

Effluent Discharge Quality:

	Monitored Effluent Quality (mg/ℓ)		Pretreatment Standards (mg/ℓ)	
Pollutants	**Daily Maximum**	**Monitoring Period Average**	**Daily Maximum**	**30-Day Average**
pH			6,0 - 9,0	6,0 - 9,0
Cadmium			1,29	0,27
Chromium - total			2,87	0,80
Copper			3,72	1,09
Nickel			3,51	1,26
Lead			0,67	0,23
Silver			0,44	0,13
Zinc			2,64	0,80
Cyanide - total			1,30	0,28
Total toxic organics			0,58	0,58
Oil and grease			42,0	17,0
Total suspended solids			61,0	22,9

III Sampling Protocol

Method of Sampling Effluent: ____________________

____

____

____

Analytical Laboratory: ____________________

Work phone no: ____________________ After Hours phone no: ____________________

Contact: ____________________ Title ____________________

IV Notes and Comments on Baseline Monitoring

____

____

____

____

V Certifications

I certify that the information provided in this document is to the best of my knowledge true and that the accidental spill prevention measures described in the document will be implemented as described.

Name: ____________________ **Date:** ____________________

Title : ____________________
(as authorised representative of the industry)

Table 12: Conceptual GMR Format

GENERAL COMPLIANCE MONITORING DATA

I. General Information

Facility Name: ____________________

Facility Address: ____________________

Managing Directors Name/Designated Responsible Person: ____________________

Work phone no: ____________________ After Hours phone no: ____________________

Emergency response contact: ____________________ Title ____________________

Secondary contact: ____________________ Title ____________________

Work phone no: ____________________ After hours phone no: ____________________

Type of Business/Manufacturer: ____________________

Operating Schedule: ____________________

II. Compliance Monitoring Data

Monitoring Period: from: ____________________ to ____________________

Production Capacity, as percentage of maximum, During Monitoring Period: ____________________%

Operational Production Hours During Monitoring Period: ____________________

Mass/Area of Material Plated During Monitoring Period: ____________________kg/m^2

Mass of Material Used During Monitoring Period:

Chemical Material	Mass/Volume Utilised During Monitoring Period

Daily Water Consumption: Average ____m^3/d, maximum ____m^3/d, and minimum ____m^3/d

Daily Effluent Volume: Average ____m^3/d, maximum ____m^3/d, and minimum ____m^3/d

Daily Water Consumed: ____m^3/d

Daily Effluent Discharged: ____m^3/d

Waste Sludges/
Concentrate Volumes: Average ____m^3/d, maximum ____m^3/d, and minimum ____m^3/d

Total Waste Sludge Concentrate Discharged: ____m^3/d

Waste Sludge/Concentrate Collector's Name: ____________________

Work phone no: ____________________ After Hours phone no: ____________________

Contact: ____________________ Title: ____________________

Effluent Discharge Quality:

	Jan/ Jul		Feb/ Aug		Mar/ Sep		Apr/ Oct		May/ Nov		Jun/ Dec		Pretreatment Standards (mg/ℓ)	
Pollutants	DM	MM	DM	MM	DM	MM	DM	MM	DM	MM	DM	MM	Daily Max	30-Day Average
pH													6,0 - 9,0	6,0 - 9,0
Cadmium													1,29	0,27
Chromium - total													2,87	0,80
Copper													3,72	1,09
Nickel													3,51	1,26
Lead													0,67	0,23
Silver													0,44	0,13
Zinc													2,64	0,80
Cyanide - total													1,30	0,28
Total toxic organics													0,58	0,58
Oil and grease													42,0	17,0
Total suspended solids													61,0	22,9

DM = Daily Maximum *MM = 30 Day Average*

III Sampling Protocol

Method of Sampling Effluent: ____________________

____

____

____

Analytical Laboratory: ____________________

Work phone no: ____________ After Hours phone no: ____________

Contact: ____________ Title ____________

IV Notes and Comments on Compliance Monitoring

____

____

____

____

V Certifications

I certify that the information provided in this document is to the best of my knowledge true and that the accidental spill prevention measures described in the document will be implemented as described.

Name: ____________________ **Date:** ____________

Title : ____________________
(as authorised representative of the industry)

Table 13: Example of Bath Manifest

BATH MANIFEST												
Facility Name: ______												
Facility Address: ______												
Managing Directors Name/Designated Responsible Person: ______												
Report for Operating Period: ______												
BATH IDENTIFICATION No.	1	2	3	4	5	6	7	8	9	10	11	12
Bath Volume (Liquid)												
CHEMICAL COMPOSITION Chemical 1 mg/ℓ												
Chemical 2 mg/ℓ												
Chemical 3 mg/ℓ												
Other mg/ℓ												
DATE OF CHEMICAL MAKE-UP												
REPLENISHMENT DATE												
REPLENISHMENT CHEMICAL and MASS												
BATH DISCHARGE DATE												
DISCHARGE VOLUME												
DISCHARGE QUALITY												
pH												
E.C. mS/m												
CN												
T. Metals												
Other parameters												
DISCHARGE ROUTE												

Discharge Route: S = Sewer; C = Container; T = Tanker; P = Pretreatment; O = Other

5.2.6 Short-term storage facility permits

Where wastes are to be accumulated on-site for subsequent removal to a centralised processing and/or disposal facility it is necessary to ensure the safe storage of the wastes. The British Columbia specifications for special waste handling may be utilised as an example:

Where liquid waste is stored in containers or tanks the site owner shall -

- provide space to allow for manual, visual inspection for leaks,

- provide and maintain an impervious containment system sufficient to hold the larger of
  - i. 110 % of the largest container or tank, or
  - ii. 25 % of the total volume of special waste in storage,

- provide controlled forced air ventilation to any indoor facility so that 0.3 $m^3/min/m^2$ of a facility is exhausted at all times.

- provide overflow protection for tanks by means of
  - i. fixed piping to an empty adjacent tank with a capacity equal to or greater than 20% of the protected tank,
  - ii. a high level alarm set at 90 % of the full liquid level of the tank, or
  - iii. an automatic feed system set at 95% of the fall liquid level of the tank container,

- use dripless hose connections when transferring liquid special waste by means of detachable hoses or pipes,

- ensure that all materials on pipes, pumps, containers and any other equipment which comes into contact with the special waste is compatible with the special waste, and

- ensure that all special waste transfer lines, hoses and pipes are equipped with automatic shutoff or close on failure valves which close off the special waste in the event of a sudden accidental escape.

5.2.7 Pretreatment performance standards

- The owner of a treatment facility shall ensure that:
  - a. any discharge of liquid effluent to the environment or to any system of waste disposal operated by a municipality or public authority which results from the operation of the treatment facility meets the effluent criteria prescribed, and

  - b. any emissions to the atmosphere resulting from
    - i. a treatment facility process, or
    - ii. the ventilation system of a treatment facility,

    meet approved emission specifications.

- The owner of a treatment facility shall not allow solid residue to be discharged from the treatment facility unless the residue is
  - i. recycled or
  - ii. managed

  at a special waste management facility in accordance with approved procedures that the residue no longer poses a hazard to human health or to the environment and that the residue is suitable for disposal to an authorised landfill.

5.2.8 Pretreatment Facility Control

Where pretreatment is to be practised on-site it is necessary to ensure the effective operation and control of the facilities. The British Columbia specifications for special waste treatment facilities may be utilised as an example:

- The owner of a treatment facility shall provide an automatic means of stopping the process equipment, and the waste feed system in the event of an accidental release or in circumstances which might lead to an accidental release of special waste.

- Before beginning operation of a treatment facility the owner shall conduct an approved demonstration trial to demonstrate the effectiveness of any process intended to treat the type of special waste to be received at the facility.

- the demonstration trial referred to in subsection 2 must provide
  a. an adequate test of the treatment process to be used,

  b. a qualitative and quantitative description of the physical, chemical and biological properties of
     i. the special waste to be treated,
     ii. any liquid or solid residues remaining after treatment, and
     iii. any emissions to the atmosphere resulting from the treatment process

  c. a description of operating conditions in the treatment process including but not limited to
     i. temperatures,
     ii. pressures, and
     iii. residence times, and

  d. a description of any conditions which may cause a detrimental effect on human health or the environment.

- The owner of a treatment facility shall submit a report with all the information described in subsection 3 to a manager or the director before beginning operation of the treatment facility.

5.2.9 Transportation of hazardous wastes

Where industries are required to comply with Pretreatment Standards and/or a Pretreatment Service is provided, it is necessary for the Municipality to be able to monitor and control the movement of waste not discharged to sewer and to ensure that the transporters of the wastes are appropriately experienced, certified and responsible to the Municipality in whose areas they are operating. The provision of a manifest to accompany the waste from source to ultimate disposal assists in monitoring waste movement and quantifying wastes generated from individual industrial users and operation of a Pretreatment Programme. As with Industrial User permitting, permitting of Waste Haulage Contractors should contain all pertinent ownership and operational information on the haulier and information on the operation and maintenance procedures and programmes, means of ensuring compatibility of waste transported from more than one source, spill and leak containment procedures, emergency action plans and reporting formats, insurance information, and health and safety training programmes for employees.

On a monthly basis a complete report for all trucks operated by the company should be submitted to the Municipality in whose area the wastes are generated as well as to Municipalities through whose area it is being transported, and in whose area it is to be disposed of (if different), and may be submitted to regional and national authorities to form a data base for the safe operation of all facilities involved in the generation, transportation an disposal of hazardous wastes. The report should list the generator, type, volume of waste removed, and the date, time, and exact location of treatment, recovery and/or disposal.

The "cradle to grave" principle also requires a "manifest" accompany a hazardous waste until it is responsibly and legally disposed of. The Manifest identifies the industrial user, the waste material, is generation point, quality, quantity and toxicity. Table 14 illustrates a format for reporting the waste streams generated in a plant, Table 15 illustrates an Input Materials Summary, Table 15 illustrates a Liquid Waste Hauler Ticket as an example of such a manifest, and Table 16 illustrates a RSA example of a Hazardous Waste Manifest, courtesy of Wastetech Pty Ltd.

Each load brought to a treatment and/or disposal plant must be accompanied by a completed waste manifest or load ticket and handed to the operator of the treatment and/or disposal site upon arrival, and prior to discharge.

This establishes a consciousness of responsibility and liability concerning each load, not only with the transporter, but also with the customer. The manifest is evidence of process that could mitigate any question concerning the treatment plant, transporter, and customer environmental liability. Upon receipt of a waste, the treatment plant operator must:

1 Sign and date the manifest
2 Note any significant discrepancies in the manifest
3 Immediately give the transporter a copy of the signed manifest
4 Send a copy of the manifest to the generator within 30 days after the delivery
5 Retain a copy of the manifest at the facility for at least 3 years after the date of receipt

Table 14: Example of Report for Waste Streams Generated in Plant

WASTE STREAMS GENERATED IN THE PLANT

Facility Name: ____________________

Facility Address: ____________________

Managing Directors Name/
Designated Responsible Person: ____________________

Report for Operating Period: ____________________

PROCESS	WASTE STREAM	
Machining Operations	Coolant/cutting Fluid	☐
	Other: ____________	☐
Metal Parts Cleaning and Stripping	Solvents	☐
	Alkaline Wastes	☐
	Acid Wastes	☐
	Abrasives	☐
	Waste Water	☐
	Air Emissions	☐
	Other: ____________	☐
Surface Treatment and Plating	Spent Bath Solutions	☐
	Filter waste	☐
	Rinse Water	☐
	Spills and Leaks	☐
	Solid Waste	☐
	Air Emissions	☐
	Other: ____________	☐
Paint Application	Leftover Paint in Containers	☐
	Overspray	☐
	Drippings	☐
	Air Emissions	☐
	Other: ____________	☐
Other Processes	Leftover Raw Materials	☐
	Other Process Wastes	☐
	Types of Wastes: ____________	
	____________	

Table 15: Input Materials Summary

INPUT MATERIALS SUMMARY

Facility Name: ______________________________

Facility Address: ______________________________

Managing Directors Name/Designated Responsible Person: ______________________________

Report for Operating Period: ______________________________

	CHEMICAL IDENTIFICATION									
Source/Supplier										
Usage Control[1]										
Delivery Mode[2]										
Shipping Container Size or Type[3]										
Storage Method[4]										
Transfer Mode[5]										
Empty Container Disposal[6]										

1 = Stockroom attendants access limited to designated personnel, sign-out sheet, readily accessible to all personnel

2 = Suppliers vehicles, own collection, agents delivery etc

3 = 25ℓ drum, 200ℓ drum, tank, crate, bag etc

4 = Outdoor, warehouse, underground, above ground, bunded area

5 = Manual, pump, forklift, pneumatic, conveyor

6 = Municipal refuse, waste contractor, return to supplier, clean recycle

Table 16: Example of Liquid Waste Hauler Ticket Manifest

LIQUID WASTE HAULER LOAD TICKET

Company name: ______________________________

Permit Number: ______________ Truck licence number: ______________

Card number: ______________ Litres pumped: ______________

Date pumped: ______________ Time pumped: ______________

Date dumped: ______________ Time dumped: ______________

Customer name: ______________________________

If Customer is a business, type of business: ______________________________

Customer phone number: ______________________________

Address: ______________________________

____

Vessel pumped was: Cyanide Bath __________ Acid Bath __________ Alkali Bath __________

Other (describe): ______________________________

Customer Certification

As an authorised representative of the above named customer, I certify under penalty of law that the above information is true and correct to the best of my knowledge, and further acknowledge and certify that the material being pumped does contain hazardous wastes as generated from heavy metal industrial practices.

Signature : ______________ Date : ______________

Print Name/Title: ______________________________

Liquid Waste Haulier Certification

I certify under penalty of law that the above information is true and correct to the best of my knowledge, and further certify that the truck listed above contains the hazardous materials listed above in Customer Certification.

Signature : ______________ Date : ______________

Print Name/Title: ______________________________

Table 17: RSA Example of a Hazardous Waste Manifest

				WASTE MANIFEST DOC	
				No.	
Generators name, mailing, physical address				ID No.	
				DATE	
				TEL No.	
				FAX No.	
Transporters name, mailing, physical address				ID No.	
				VEHICLE No.	
				ROUND No.	
				DEPOT CODE	
Treatment, disposal facility, name, mailing, physical address				FACILITIES ID No.	
				DATE	
				TEL No.	
				FAX No.	
Waste name, Hazard class ID number				CONTAINERS	
NAME				No.	
RSA No		PLACE		TYPE	
NAZCHEM No.		SWOP		Volume	
ID No		REMOVE		Total Volume	
ADDITIONAL HANDLING INSTRUCTIONS FOR ABOVE					
SAFETY				HAZARD WARNING	
PROTECTIVE CLOTHING					
GENERATORS CERTIFICATION			I hereby declare that the contents are properly described, packaged, marked and labelled prior to transportation according to all relevant legislation.		
PRINTED NAME:				SIGNATURE:	
TRANSPORTERS ACKNOWLEDGEMENT OF RECEIPT OF MATERIALS					
PRINTED NAME:				SIGNATURE:	
FACILITIES/OR OPERATORS ACKNOWLEDGEMENT OF RECEIPT OF MATERIALS					
PRINTED NAME:				SIGNATURE:	
DISCREPANCY INDICATION SPACE					

If a discrepancy is found either prior to or after waste analysis, the waste site operator must attempt to reconcile the discrepancy with the generator or hauler. If the discrepancy is not resolved within 15 days after the date of delivery, the waste site operator must send a letter to the Municipality or Regional Authorities that includes a description of the discrepancy, the attempts to reconcile it, and a copy of the manifest.

5.2.10 Prescribed waste amounts for manifesting

It is necessary to specify the masses or volumes of individual wastes that would require a manifest. The British Columbia requirements may be utilised as a guideline: Prescribed amounts of special waste which require a manifest to be used for transportation may be:

a. solids in quantities of 5 kg or more,

b. liquids except for waste oil in quantities of 5 l or more,

c. gases of any quantity with a total liquid capacity of 5 l or more,

d. waste oil in quantities of 100 l or more, or

e. liquids or solids that contain more than 100 mg/l of total metals.

The requirement would not apply if the special wastes are transported solely within the bounds of property owned, leased or controlled by the person who generates or stores the special waste.

The prescribed form of the manifest and manner of completing and filing need to be set out in the Municipal Waste Management Regulations.

5.2.11 Loads from multiple consignors

1. Where a carrier collects special waste of the same type from more than one generator to establish a bulk load, the carrier may use one manifest for each bulk load to be transported.

2. Where the carrier maintains one manifest, he shall complete a carrier's register for bulk loads in or a form containing equivalent information.

3. Prior to transferring a bulk load to a consignee, the carrier shall, if he elects to maintain one manifest,

   a. complete the manifest, entering the word "multiple" for the company name and the shipping site address,

   b. attach a legible copy of the completed carrier's register, or the equivalent form, to copy 1 of the manifest,

   c. send the 2 forms referred to in paragraph b to the appropriate authority, and

   d. retain for a period of at least 2 years a copy of the carrier's register, or equivalent form, with copy 4 of the manifest.

6 PRETREATMENT PROGRAMMES

6.1 Implementation of Pretreatment Standards

To rationally implement Pretreatment Standards it is generally considered most practical to phase Standards in according to the size of the industry or load it discharges, and upon the history of the industry; i.e. limits set for existing facilities may be more lenient than for new users who will find it easier to plan for Pretreatment from inception of a facility rather than to retrofit Pretreatment to existing facilities. New Metal Finishing industries may also be encouraged, to become established in specific area identified for Heavy Industries where a Centralised Pretreatment (CWT) plant could be erected and operated by a private company or the Municipality if so desired.

6.2 Compliance Phasing

Where compliance by industry requires pretreatment and/or modification in its manufacturing operation a preset implementation period should be set by which time full compliance must be attained. Once the compliance date is reached, and compliance not attained enforcement actions should be taken forcefully. The compliance dates for existing facilities may be phased in relation to the size of the facility over a 5 year period

i.e: Year 1 - Dischargers > 100 000 l/day
Year 2 - Dischargers > 50 000 < 100 000 l/day
Year 3 - Dischargers > 20 000 < 50 000 l/day
Year 4 - Dischargers < 20 000 l/day

6.3 Financial Incentives

The National Government and/or Regional or local Authority may provide incentives to encourage wastewater reuse and recycling which include opportunities tor temporary relief from some Pretreatment Standards, as well as tax incentives and financing alternatives to ease the compliance.

6.4 Privatisation of Pretreatment

Where industries do not have the infrastructure to effectively implement pretreatment a commercial waste handling service may be provided. This may involve the installation of compatible treatment technologies at each site, to meet the specific discharge consents. These may be offered either at the industries cost or on a lease basis. The operation and maintenance of such facilities would be under the management of the waste handler, who would also be responsible for the collection of waste sludges and concentrates, spent baths and reject chemicals and liquors, and the further treatment and recovery or disposal.

6.5 Enforcement

A most important requirement of a pretreatment programme is an effective enforcement programme to ensure industrial user compliance, and to effectively address and, where necessary, penalise non-compliance.

To achieve the necessary speed and consistency in responding to violation sit is necessary to develop an Enforcement Response Plan which outlines the procedures to be followed by the Municipality to identify, document, and respond to pretreatment violations, selecting initial and follow-up enforcement actions, identifying staff responsibilities for these actions, and specifies appropriate time frames in which to take them.

A Municipality may choose to specify different responses but all formal enforcement responses must be expressly authorised by local laws. The following criteria are recommended for consideration by the US EPA when determining a proper response:

- Magnitude and duration of the violation
- Effect of the violation on the receiving water and on the industrial user
- Compliance history of the industrial user and good faith of the industrial user.

Table 18 illustrates an Enforcement Response Plan example

Table 18: Example of Enforcement Response Plan

ENFORCEMENT RESPONSE PLAN

A most important requirement of a pretreatment programme is an effective enforcement programme to ensure industrial user compliance, and to effectively address and, where necessary, penalise non-compliance.

An Enforcement Response Plan outlines the procedures to be followed by Control Authority staff to identify, document, and respond to pretreatment violations. Once adopted, the plan provides guidance in selecting initial and follow-up enforcement actions, indicates staff responsibilities for these actions, and specifies appropriate time frames in which to take them.

The following criteria are recommended for consideration by the US EPA when determining a proper response:

- Magnitude of the violation
- Duration of the violation
- Effect of the violation on the receiving water
- Effect of the violation on the industrial user
- Compliance history of the industrial user
- Good faith of the industrial user.

The Tables below present a model enforcement response guide which identifies types of violations, indicates initial and follow-up responses, and designates personnel and time frames for these responses. A Municipality may choose to specify different responses but all formal enforcement responses must be expressly authorised by local laws.

- **Description of Terms**

Terms and abbreviations used in the model guide are defined below.

A	-	Administrative Order
Civil	-	Civil litigation against the industrial user seeking equitable relief, litigation monetary penalties and actual damages.
Criminal	-	Pursuing punitive measures against an individual and/or organisation Prosecution through a court of law.
Fine	-	Monetary penalty assessed by Municipality officials.
I	-	Inspector
IU	-	Industrial User
Meeting	-	Informal compliance meeting with the IU to resolve recurring noncompliance.
NOV	-	Notice of Violation
PC	-	Pretreatment Coordinator
M	-	Municipality
SV	-	Significant Violation
Show Cause	-	Formal meeting requiring the IU to appear and demonstrate why the Municipality should not take a proposed enforcement action against it. The meeting may also serve as a forum to discuss corrective actions and compliance schedules.

MODEL ENFORCEMENT RESPONSE GUIDE

NONCOMPLIANCE	NATURE OF THE VIOLATION	ENFORCEMENT RESPONSES	PERSONNEL
UNAUTHORISED DISCHARGES (no permit)			
1. Unpermitted discharge	IU unaware of requirement; no harm to STW/environment	Phone call; NOV with application form	PC
	IU unaware of requirement; harm to STW	- A with fine - Civil action	PC S
	Failure to apply continues after notice by the STW	- Civil action - Criminal investigation - Terminate service	S S S
2. Nonpermited discharge (failure to renew)	IU has not submitted application within 10 days of due date	Phone call; NOV	PC
DISCHARGE LIMIT VIOLATION			
1. Exceedance of local or Federal Standard (permit limit)	Isolated, not significant	Phone call; NOV	I, PC
	Isolated, significant (no harm)	A to develop spill prevention plan and fine	PC
	Isolated, harm to STW or environment	- Show cause order - Civil action	PC, S S
	Recurring, no harm to STW/environment	A with fine	PC
	Recurring; significant (harm)	- A with fine - Show cause order - Civil action - Terminate service	PC PC, S S S
MONITORING AND REPORTING VIOLATIONS			
1. Reporting violation	Report is improperly signed or certified	Phone call or NOV	PC
	Report is improperly signed or certified after notice by STW	- A - Show cause order	PC PC, S
	Isolated, not significant (eg. 5 days late)	Phone call; NOV	I, PC
	Significant (eg. report 30 days or more late)	A to submit with fine per additional day	PC
	Reports are always late or no reports at all	- A with fine - Show cause order - Civil action	PC PC, S S
	Failure to report spill or changed discharge (no harm)	NOV	PC
	Failure to report spill or changed discharge (results in harm)	- A with fine - Civil action	PC S
	Repeated failure to report spills	- Show cause order - Terminate service	PC, S S
	Falsification	- Criminal investigation - Terminate service	S S

NONCOMPLIANCE	NATURE OF THE VIOLATION	ENFORCEMENT RESPONSES	PERSONNEL
MONITORING AND REPORTING VIOLATIONS (continued)			
2. Failure to monitor correctly	Failure to monitor all pollutants as required by permit	NOV or A	PC
	Recurring failure to monitor	- A with fine - Civil action	PC S
3. Improper sampling	Evidence of intent	- Criminal investigation - Terminate service	S S
4. Failure to install monitoring equipment	Delay of less than 30 days	NOV	PC
	Delay of 30 days or more	A to install with fine for each additional day	PC
	Recurring, violation of A	- Civil action - Criminal investigation - Terminate service	PC S S
5. Compliance Schedules (in permit)	Missed milestone by less than 30 days, or will not affect final milestone	NOV or A with fine	PC
	Missed milestone by more than 30 days, or will affect final milestone (good cause for delay)	A with fine	PC
	Missed milestone by more than 30 days, or will affect final milestone (no good cause for delay)	- Show cause order - Civil action - Terminate service	PC, S S S
	Recurring violation or violation of schedule in A	- Civil action - Criminal investigation - Terminate service	S S S

NONCOMPLIANCE	NATURE OF THE VIOLATION	ENFORCEMENT RESPONSES	PERSONNEL
OTHER PERMIT VIOLATIONS			
1. Wastestreams are diluted in lieu of treatment	Initial violation	A with fine	PC
	Recurring	- Show cause order - Terminate service	PC, S S
2. Failure to mitigate noncompliance or halt production	Does not result in harm	NOV	PC
	Does result in harm	- A with fine - Civil action	PC S
3. Failure to properly operate and maintain pretreatment facility	See no. 2 above		
VIOLATIONS DETECTED DURING SITE VISITS			
1. Entry denial	Entry denied or consent withdrawn Copies of records denied	Obtain warrant and return to IU	I
2. Illegal discharge	No harm to STW or environment	A with fine	PC
	Discharges causes harm or evidence of intent/negligence	- Civil action - Criminal investigation	S S
	Recurring violation of A	Terminate service	S
3. Improper sampling	Unintentional sampling at incorrect location	NOV	I, PC
	Unintentionally using incorrect sample collection techniques	NOV	I, PC
	Unintentionally using incorrect sample collection techniques	NOV	I, PC
4.Inadequate record keeping	Inspector finds files incomplete to missing (no evidence of intent)	NOV	I, PC
	Recurring	A with fine	PC
5. Failure to report additional monitoring	Inspection finds additional files	NOV	I, PC
	Recurring	A with fine	PC

TIMEFRAMES FOR RESPONSES

A. All violations will be identified and documented within five days of receiving compliance information.

B. Initial enforcement responses [involving contact with the industrial user and requesting information on corrective or preventative action(s)] will occur within 15 days of violation detection.

C. Follow up actions for continuing or reoccurring violations will be taken within 60 days of the initial enforcement response. For all continuing violations, the response will include a compliance schedule.

D. Violations which threaten health, property or environmental quality are considered emergencies and will receive immediate responses such as halting the discharge or terminating service.

E. All violations meeting the criteria for significant noncompliance will be addressed with an enforceable order within 30 days of the identification of significant noncompliance.

7 CENTRALISED INDUSTRIAL WASTE TREATMENT

7.1 Opportunities for Centralised Industrial Waste Treatment

To safely handle and dispose of the waste concentrates generated by on-site pretreatment it is envisaged that the industries undertaking pretreatment will send their wastes to a **Centralised Waste Treatment (CWT)** plant. The concept of organised CWT would appear to offer several advantages in Environmental Management:

i. in being operated by professional waste handlers who should be trained to treat and manage the waste more effectively than the generators.

ii. a CWT increases the potential for materials recovery which reduces operating costs and burden of sludge handling and disposal.

iii. industries share facilities reducing operational costs.

7.2 Possible Management and Ownership Options

1. Complete ownership, financing, and management responsibility by an outside firm.

2. Complete ownership and management responsibility by an outside firm with financing assistance (i.e. loan guarantees, loans, or non-recourse financial investments) by state/local government and/or an industry user group.

3. Ownership, financing, and management responsibility by an outside firm of a CTF built on government-owned or industry-owned land.

4. Ownership and management responsibility by an outside firm of a CTF built on government-owned or industry-owned land; state/local government and/or industry financing assistance.

5. State/local government and/or industry user group ownership and financing of a CWT Facility which is managed under contract by an outside firm.

6. Complete state/local government and/or industry user group ownership, financing, and management responsibility.

7.3 International Experience With CWT of Heavy Metal Wastes

7.3.1 Germany

Cushnie (1985) in reviewing the German experience with CWTs identifies a number of characteristics:

- CWT serve a major town or city in a 10 - 20 mile radius and between 50 - 250 industrial Waste dischargers.

- CWT does not provide all treatment. Industries typically pretreat by segregation and concentration through to physical-chemical treatment. The amount of pretreatment being directly related to transportation and CWT handling costs.

- Wastes are transported, rather than sewered to the CWT. To avoid siting conflicts, transport costs are uniform.

- Collection stations are used for temporary storage and pretreatment of special wastes usually located away from the main industrial centres to minimise transport costs to the CWT.

- Secure sites for land disposal of sludges are provided at the CWT, with facilities to handle leachates and contaminated stormwaters.

7.3.2 Chuo Park Island Project

In Japan industries producing problematical wastes, such as electroplaters, are encouraged to locate or re-locate to group sites. The Chuo Park Island Project in Tokyo Bay has been created to relocate 10 electroplaters previously scattered around Tokyo city to a single location for exclusive use and control by the industry.

The scheme has included the introduction of in-line recycling and recovery processes to reduce the volumes of effluent and sludges conventionally discharged by an order of 10, and the creation of a CWT directly linked to each factory site to further process the concentrates and sludges generated by all the users. The cost of operating the collective treatment facility are distributed among the firms based on the amount and quality of the discharges. However, all users share fixed expenses such as interest and depreciation costs whether or not they use the facility. Each share is predetermined in proportion to two elements, land area and workshop area. In addition to user fees, the treatment facility generates income from recovery and detoxification services and sales of recovered substances.

7.3.3 Washington County

Washington County has a number of industrial parks covering almost 800 ha and serviced by a CWT. Being situated in an industrial park the CWT has the advantage that many of the industries are connected via direct pipelines or to pumping stations whilst the more distant industries rely on road transportation. Also located on the site are support facilities, including administrative offices, laboratories and maintenance shops. Because management and skilled personnel are available 24 hours a day, waste transportation activities can be observed, samples taken, analysis obtained and decisions made quickly.

The Industrial Wastewater Pretreatment Facility (IWPF) at the Conococheague WasteWater Treatment Plant (WWTP) of Washington County USA is designed to treat high BOD and metals bearing industrial wastewaters. The principle treatment processes provided are oil removal, hydroxide precipitation and biological oxidation using sequencing batch reactors (SBRs). A second physical chemical treatment precipitation process train treats wastewaters which will produce a hazardous sludge which is then stored in a segregated hazardous sludge area for appropriate stabilisation and disposal. Sludges generated in the processes are dewatered in plate and frame filter presses or transferred to the sewage treatment plant and dewatered by belt filtration in association with the general waste sludges.

The CWT facility discharges pretreated wastewater to the domestic wastewater treatment system. The advantage of locating the industrial facility near, and under, the same operating management as the domestic facility allows good communication between operations and minimises upsets.

7.3.4 New York City

New York City has several hundred relatively small plating plants. To economise on increasing energy costs and pollution control a plating city was established for the relocation of the existing platers, the provision of gas-fired electricity generation plant and CWT. As the plating city was created within a small space requirement segregation of waste streams and independent piping to the CWT was possible. The wastes were separated into independent chromium, cyanide and acid/alkali sewers. The CWF consists of three basic treatment processes. Hexavalent chromium is reduced to the trivalent state, cyanide is destroyed ny alkaline oxidation and these combine with the acid/alkali stream for metal precipitation as hydroxides. The treated effluent is then discharged to the city sewer.

7.3.5 West Thurrock Industrial Wastewater Treatment Facility

The West Thurrock CWT Facility in the UK acts both as treatment plant and transfer station for waste products mainly from metal bearing wastes. In principle the wastes transported to the facility are flocculated and settled to precipitate the metals as a sludge which is dewatered on a Rotary Vacuum Filter. The filter cake produced is then solidified using cementitious reagents to produce a mortar-like material suitable for land reclamation. The filtrate from the dewatering stages is passed through a cross-flow microfiltration unit to further remove heavy metals present in the liquor prior to discharge to sewer.

7.3.6 Minneapolis, Minnesota US Filter Recovery Services

US FILTER Inc. operate a commercial hazardous waste facility in Minneapolis, Minnisota to receive canisters of spent, anion and cation resins used to treat wastewaters generated from various industries, including metal finishing and printed circuit fabricating industries. The canisters are transported back to the US FILTER facility where the spent resins are regenerated, and then returned to the industries for reuse. Various metals including copper, zinc, and nickel are recovered from wastestreams received at the CWT using the electrowinning process. Some metal hydroxides and salts are also recovered from these wastestreams. Chemical oxidation is used primarily to oxidize both free and complex cyanide wastes. Chemical reduction is used primarily to reduce hexavalent chrome wastes to trivalent chrome, which facilitates subsequent precipitation and removal of the chrome.

Wastes which cannot be recovered are treated to discharge limitations through the pretreatment system, which consists of chemical precipitation processes. The sludge processing system receives effluent from the precipitation processes and removes the suspended solids by thickening and pressure filtration. The liquid filtrate from this process undergoes additional treatment and final pH adjustment as needed to comply with discharge requirements, and is then discharged to the Metropolitan sewer system. The filtered solids are collected and sent (1) to on-site recovery processes, (2) to an on-site sludge drying process, or (3) off-site to an approved disposal or recovery facility.

7.3.7 Thailand

In 1984 the Thai Govememnt established a programme to improve the handling of 1.2 million tons of hazardous waste produced annually in Thailand which subsequently resulted in the opening of the first of four CWT's in Bangkok in 1988. The centres accept hazardous liquid wastes, sludges and solid waste from all industries in a specified geographical area. The centres being located near waste generators to minimise the costs of collection and transportation of wastes, and treat the wastes before final disposal. Secure landfills located near the centres receive the stabilised waste sludges and concentrates.

The Thai Government owns the four centres with private contractors leasing the facilities and managing the operations for which it recovers service charges from the users. Initially the Government provided seed money for the centres, with the intent of reducing the financial and legal risks involved for the private firms and thus encouraging business to participate in the centres. The government play a supervisory role, ensuring that environmental performance standards are being maintained, and retain the right to define or approve treatment specifications and service fees as well as any expansion of the centre and services.

8 JOHANNESBURG CWT ASSESSMENT

8.1 Johannesburg Heavy Metal Loads

Based upon the metal analysis of the Municipal sludges and estimated sludge production rates for each works (at a basis of 215 tons/day total) approximately 680 kg/d of Group A metals (Co, Cr, Cu, Ni and Zn) are assimilated into the Municipal sludges and 50 kg/d of group B (Cd and Pb).

Taking the sludge metal uptake to be an average of 60% of the total metals arriving at the sewage works, it may be estimated that there is approximately 1 130 kg of Group A and 85 kg of Group B metals being discharged into the Johannesburg sewerage system daily. The load of Group A metals discharged by the industries in the Johannesburg area for which qualitative and quantitative data is available, accounts for approximately 310 kg/d (Co concentrations have not been determined in the industrial effluent), and 12 kg/d for Group B metals.

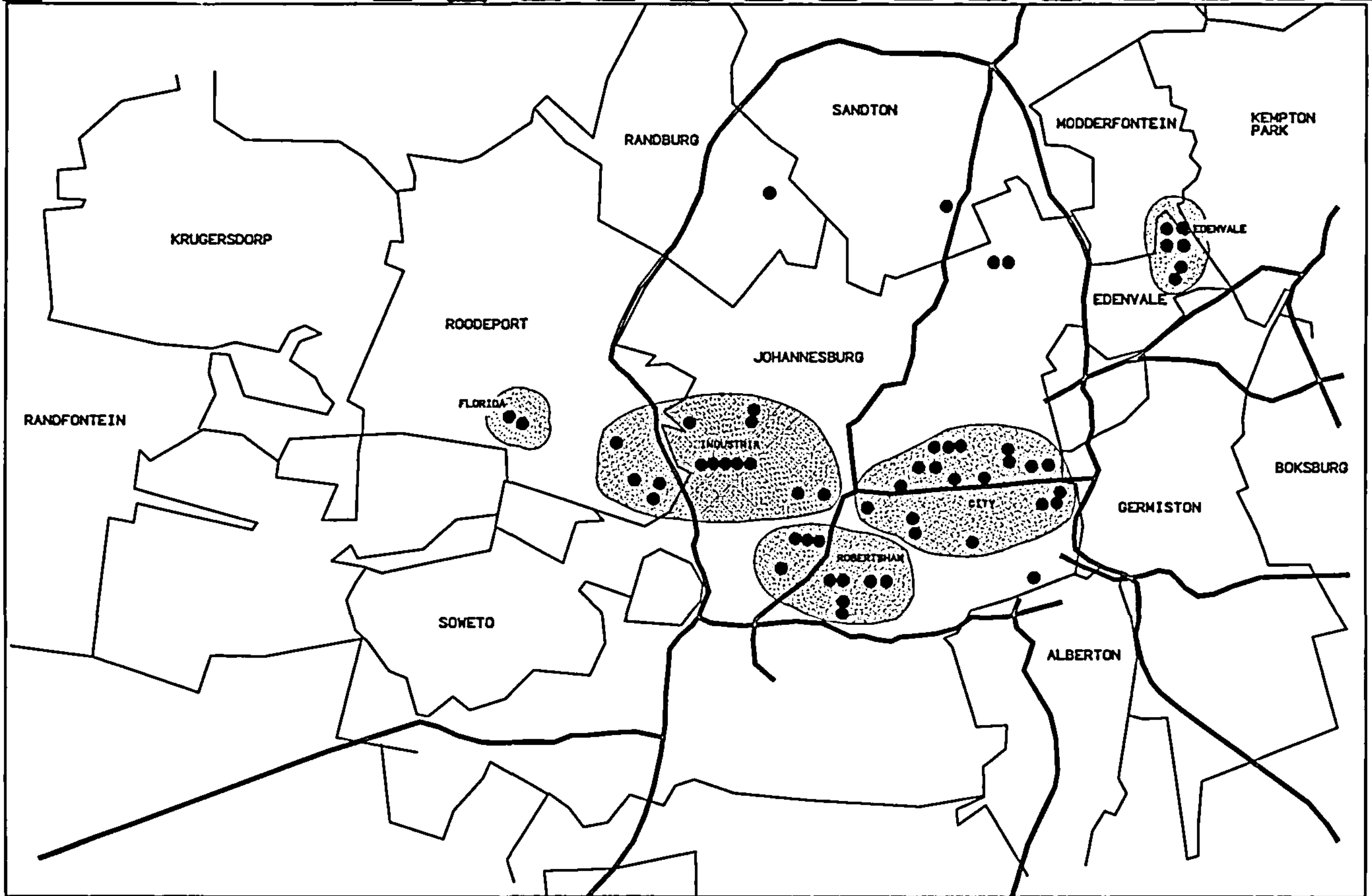
It would therefore appear that there is either a significant contribution of heavy metals into the sewerage system from alternative sources, or that the industry monitoring programme is not adequately recording the volumes and qualities of effluent being discharged into the system.

8.2 Johannesburg Industrial Metal Dischargers

For the CWT feasibility assessment the number of industries consistently producing heavy metal containing wastewaters is taken to be 57 of which 18 account for 75% of the metals load discharged, and a further 14 take the metal loads to approximately 90%, suggesting 44% of the industries contribute minimally (10%) to the total metals load and allowing a degree of rationality in terms of pretreatment requirements.

In terms of operating a Pretreatment Service it has been assumed that industries will be managed on an area basis. Figure 23 represents a layout of the Johannesburg area pinpointing the position of each industry, segregated by 7 area groupings. The relatively small areas into which industries are grouped is only intended as an example as to how locally the industries may be serviced to minimise the distances to a central storage or treatment depot where the liquid concentrates could be further processed and particularly dewatered on-bulk, prior to transfer to the CWT for further treatment and ultimate disposal. The metal loads for each of the grouped areas has also been calculated both in terms of individual metals and total metal loads, Tables 19 and 20.

It may be appropriate to establish a local group waste handling facility at one of the industry sites, such as that of the largest waste producer for example to optimise the utilisation of his installed pretreatment facilities to the benefit of the group. Alternatively, it may be necessary to establish a local group facility on an independent, but readily accessible and monitorable site, such as municipal land. The precise nature and extent of the industry groupings, and the location and operation of localised waste depots, will need to be developed in association with the industries and waste contractors if the system is to be privatised.



JOB No.		FIG No.
205580	JHB	23

Table 19: Percentage (%) of Metal Load by Area

Area	Cu	Cd	Cr	Ni	Pb	Zn
A	43,8	4,7	42,0	15,9	33,5	10,2
B	32,7	1,4	41,9	30,8	4,1	5,2
C	13,1	18,9	34,2	15,6	51,8	24,5
D	3,7	74,9	6,9	5,8	3,0	57,8
E	1,1	0,1	0,2	3,7	1,0	0,1
F	1,6	0,1	0,7	3,8	1,4	0,3

Table 20: Total Heavy Metal Load % by Area

Area	Heavy Metal % by Area
A	19,4
B	19,3
C	24,8
D	35,3
E	0,6
F	0,9

8.3 Conceptual Centralised Waste Treatment (CWT) for Johannesburg

Three primary options have been identified in respect to the practicalities of implementing a successful scheme. The options identified are:

Option 1: Industry does not discharge any contaminated process waters to the municipal sewer system. All concentrated wastes are transported to a CWT for treatment.

Option 2: Some pretreatment is undertaken on-site, ie cyanide, sulphide and acid-alkaline wastes. The dilute waste sludge and raw chromium-containing waste stream is transported to the CWT.

Option 3: Pretreatment of all contaminated streams in-house and waste concentrates and sludges are transported to the CWT.

In Europe, Japan and the USA a number of industrial parks have been created with a CWT to which the liquid effluent are discharged directly via the sewers and requiring minimal pretreatment on site. Aligned with this approach is the transportation of small effluent volumes by tanker to an acceptably close CWT to off-set pretreatment costs. In the present Johannesburg situation, it does not appear feasible to retrofit the industrial sewer connections to a new CWT facility and consequently remove them from the main sewerage system. However, this would appear to be a sensible option for future planning of properly coordinated and located industrial development.

8.4 CWT Design and Operation

The design and operation of the CWT will inherently be dependent upon the mechanisms by which Pretreatment is undertaken.

8.4.1 Metals precipitation as a mixed sludge

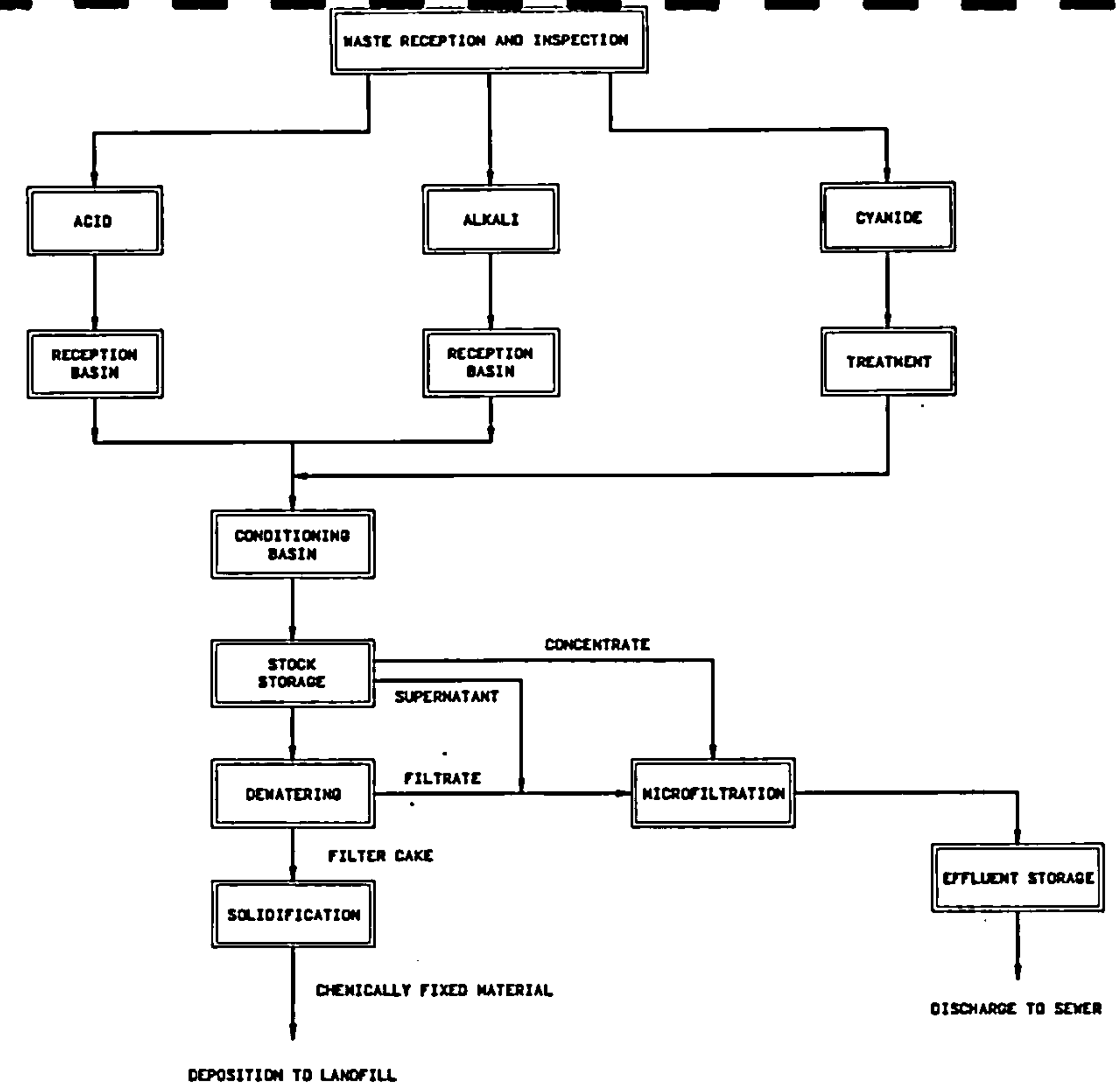
Based upon the Best Available Technology for Metal Finishing Wastes of metals precipitation as a combined sludge, the CWT must be able to receive and stabilise the mixed sludges and concentrated solutions that are generated independent of the metals sludges. In this facility there is little opportunity to recover chemicals and metals from the waste streams, but the facility is relatively easy to operate and control.

Figure 24 illustrates the Thurrock concept of waste precipitation, stabilisation and solidification.

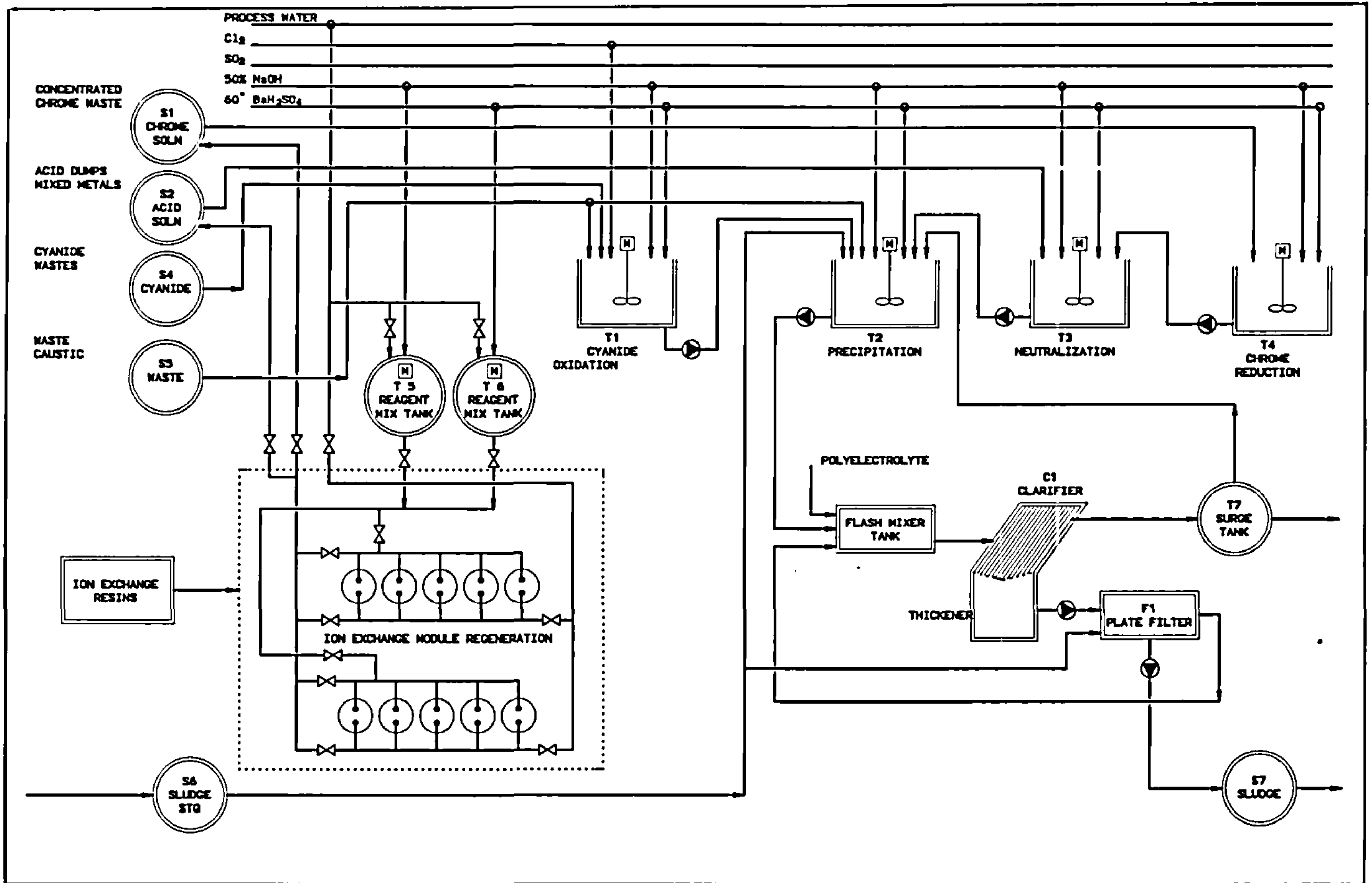
8.4.2 Metals immobilisation by ion-exchange

Based upon the option where individual plating streams are isolated and processed by ion-exchange (I-X), the CWT is a more sophisticated facility with independent processing of I-X columns for return to the individual industrial user, stabilisation of cyanide wastes and treatment of concentrated solutions not handled by I-X units. This option allows for the recovery and resale or return of the metals and chemicals to the Metal Finisher, or alternative user, and thereby a return on the investment of the Pretreatment and CWT programmes.

Figure 25 illustrates the Cleveland USA CWT system incorporating regeneration of I-X units.



JOB No.	SUMMARY OF PROCESS REGIME FOR WEST THUROCK CENTRAL WASTE HANDLING FACILITY (Courtesy Cory Environmental PTY LTD)	Fig no 24



	JOB No.	PROCESS DESIGN FOR CWT FACILITY	FIG No. 25

8.5 Process Activities for Recovery, Regeneration and Destruction of Metal Wastes

A CWT facility for the treatment of Metal Finishing concentrates, sludges and dilute effluent would consist of a number of sub-activities which would include:

i. Regeneration plant for the I-X cartridges received from individual metal Finishers and returned directly to the same user, with or without sale of recovered metals to the user.

ii. Stabilisation, neutralisation and treatment of exhausted plating baths.

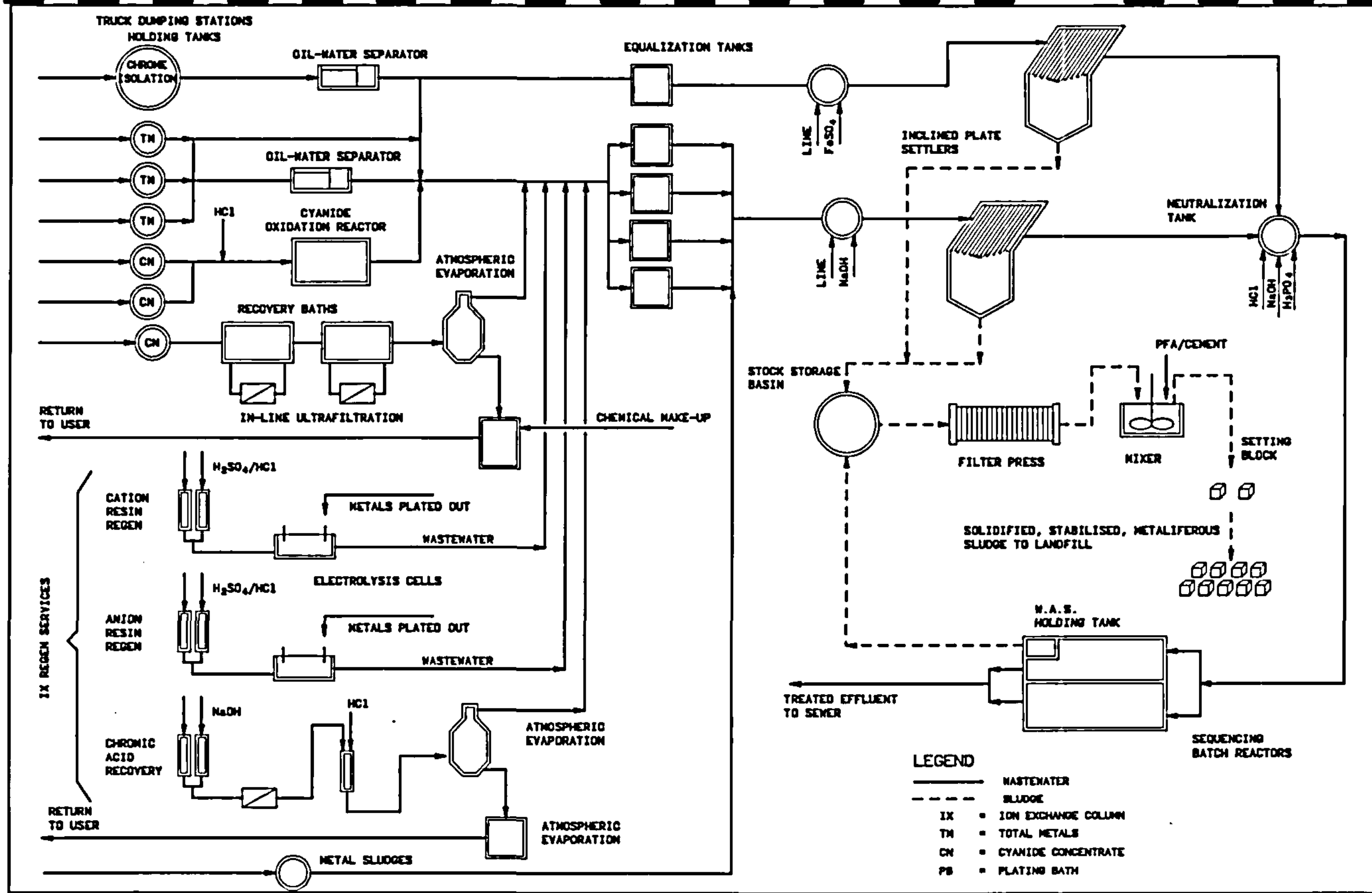
iii. Treatment of effluent generated by recycling and recovery operations and destruction of spent liquors.

iv. Stabilisation, dewatering and disposal of waste sludges.

To these may be added the recovery of plating bath contents and return to same or alternative user, where the baths are able to be independently processed.

Combining aspects of the facilities provided at Minnesota, USA; West Thurrock, UK and Constance, Germany, it is possible to conceptualise a CWT facility for Johannesburg to incorporate process activities for recovery, regeneration and destruction of metal wastes, and treatment of final wastewaters for discharge to sewer or to a receiving water course.

Figure 26 illustrates the format of the conceptual CWT facility.



JOB No.	INDUSTRIAL WASTEWATER PRETREATMENT FACILITY	FIG No. 26

8.5.1 Bulk liquor treatment

Spent baths and mixed liquors received from a user which cannot be recovered would be discharged to dedicated equalisation basins, acid, alkali, oil contaminated and cleaning solutions etc to optimise subsequent neutralisation and stabilisation. Wastewater may be transferred from any truck holding tank to either equalization tank or first through the oil/water separator and then to the equalization tanks.

Material from acid and alkaline basins may be pumped to independent pH adjustment tanks for metals removal, can bypass metals removal and be pumped to the neutralization tank, or can be combined in a Conditioning Basin to produce a stock material suitable for the final treatment stages with pH control and addition of reagents to minimise the presence of soluble metals.

Precipitated solids (containing the majority of metals) are removed in the inclined plate settlers. Clarified flow will enter the neutralization tank, where hydrochloric acid (HCl) is used to adjust the pH to approximately neutral. Phosphoric acid (H_2PO_4) is also metered into the neutralization tank as required to correct the phosphorus (P) deficiency resulting from the lime precipitation process. The capability to meter NaOH into the neutralization tank is provided to allow adjustment of pH in either direction.

8.5.2 Bath recovery

Where relatively good quality plating baths are received for direct recovery the bath will be discharged to a dedicated recovery basin. After detailed analysis of the bath contents the liquor will be filtered to remove particulates, residual particulates and oils would be captured via microfiltration. The liquor would then pass to atmospheric evaporation to be concentrated up to a manageable concentration and made-up with the correct mix of materials as required, prior to return to the user.

8.5.3 Chrome Reduction

Liquors containing hexavelant chromium are discharged to the dedicated holding tank where the liquor pH is reduced to 2.5-3 by addition of hydrochloric acid prior to dosing with sodium metabisulphite. The liquor pH is then adjusted to pH 8.5 with caustic soda to encourage precipitation of trivalent chromium sludge. The segregated chromium sludge can be dissolved using sulphuric acid to obtain a reusable liquor or can be transferred to the bulk liquor holding tanks for co-treatment, dewatering, stabilisation and disposal.

8.5.4 Cyanide solution destruction

Liquors containing elevated cyanide levels are similarly discharged to a dedicated cyanide holding basin where cyanide destruction is undertaken by addition of sodium hypochlorite and calcium hydroxide. When no further reduction in cyanide concentration is observed or the level is below 500 mg/l, the contents are pumped to the alkaline reception basin to join the bulk liquors.

8.5.5 Organics reduction

Neutralized wastewater which still contains levels of organic contaminants is then be fed to the Sequential Batch Reactors (SBRs) operating on short-term cycles per day per reactor where aerobic activated sludge oxidises the majority of the residual organic fractions. Decant from the SBRs may be transferred to the Municipal sewer for final treatment in association with normal mixed domestic sewage.

8.5.6 Sludge dewatering

Lime sludge from the inclined plate settlers is transferred to the lime sludge holding tanks where the sludge is expected to concentrates to approximately 6% solids. Biological sludge is wasted from the SBRs to the Waste Activated Sludge (W.A.S) holding tank.

For dewatering, the two sludge types are simultaneously transfer biological and lime sludge to the sludge conditioning tank to be blended. The conditioned sludge is then be fed to the plate and frame filter press by the filter press feed pumps. Dewatered sludge (approximately 40% solids) falls from the filter press to a dumpster for appropriate land-fill disposal.

8.5.7 Metals solidification

Where simple precipitation of metals as a wet sludge is unacceptable for long-term land-fill material facilities are provided for the solidification of the sludges. Pre-weighed quantities of filter cake, cement or Pulverised Fuel Ash (PFA) are mixed forming a slurry which is conveyed to a clay lined cell where it sets to a Chemically Fixed Solid (CFS) within 24 hrs.

8.5.8 Recovery and regeneration service

Where segregated rinsewater treatment is undertaken by I-X, the saturated I-X cartridges of the user may be regenerated as a service operation in the CWT. The heavy metals contained in the eluates is recovered for the user, or alternative thereby reducing quantity and metal toxicity of waste sludges generated in the treatment plant. Pre-requisite is the monometallic saturation of the cartridges by strictly separate treatment of the respective metal type.

8.5.9 I-X column regeneration

The regeneration plants will regenerate the anion and cation exchanger cartridges loaded by the user. Cation resins being regenerated with H_2SO_4 or HCl, and anion resins with NaOH. Depending on the metal, the eluates containing cyanide are discharged into the provided storage tank of the electrolysis plant. The concentrates containing chromate are discharged into a separate storage tank of the chromic acid recovery plant. The rinse waters are discharged to the wastewater treatment facility.

8.5.10 I-X metals recovery

The electrolysis plants serve for the depletion of the heavy metals and the cyanide oxidation of the alkaline eluates. Nickel solutions which cannot be plated out in the electrolysis cells will be pre-treated by precipitation and resolution. After depletion of eluates from the metals, the eluates are pumped into the wastewater treatment facility. At the stainless steel cathodes the metals are separated in metallic form which can be pulled off. The stainless steel cathodes are then reused. Where the eluate contained cyanide the cyanide is additionally oxidized at the anode into non-toxic cyanate.

8.5.11 Chromic acid recycling

The recovery of chromates from eluates of the anion exchanger cartridges is effected via an ion exchanger plant as well as a spray-tower evaporation plant. The chromate contained in an alkaline solution is converted into chromic acid. The eluates containing chromate are pumped into a storage tank of the I-X exchanger column from where it passes through filtration prior to entry to the I-X column. The treated eluates are fed to an atmospheric evaporation plant and the saturated cartridges are regenerated, as previously. The evaporation plant concentrates the chromic acid up to levels which can be returned as solution to the users.

8.5.12 Effluent polishing

Decant from the reaction vessels, the SBR's and filtrate from the dewatering processes may still contain low concentration of heavy metals, in particular mercury and cadmium. Where the quality for discharge to sewer is stringent, residual pollutants may be reduced by passage through a microfiltration plant. The effluent from the microfilter is analysed and then discharged to sewer after confirmation of suitability. The metals removed in the microfilter are returned to the stock basin to undergo dewatering and so be incorporated in the chemically fixed material. Effluent failing to meet the "sewer discharge standard" is returned to one of the waste reception basins for reprocessing.

8.6 Siting the CWT

A suitable site for a Centralised Waste Treatment facility for the heavy metal concentrates and sludges would be at one of the sewage treatment works. This would then not only be on relatively cheap municipal land it would enable the municipality either to operate the facility itself as an extension of the normal sewage treatment practise, or to readily control and monitor the operation of the facility if run by contractors.

Location of the CWT at a Municipal site also allows the Municipality to monitor the reception of treated effluent entering the works, preventing the CWT becoming a source of pollution to the sewage works having moved the loads from the individual industries, and ensuring safe disposal of the concentrates and sludges generated, by co-disposal with municipal waste or other methods. The control of the effluent qualities generated by privatised CWT's has been a serious concern at a number of the sites in the USA, Europe and RSA.

8.7 CWT Facility Administration

To establish an effective CWT management approach the Municipality may require direct involvement in the CWT business or provide assistance to the private CWT industry. This assistance would serve to supplement the resources.

It would also be advantageous to administer the CWT either by the Municipality or under contract to the Municipality and through a combined board of directors. With a limited number of companies that could operate a CWT facility there is the possibility that charges may be levied in excess of market requirements and thereby penalise the industries further and encourage disposal via alternative less controllable routes, and control over the operation of the facility may not be as effective as if the municipality has overall control.

8.8 Financial Implications and Tariffing for Metals Handling Service

The costs of implementing a CWT facility and a pretreatment programme should be recovered from the industries utilising the facility. As the industries have not historically been required to undertake such programmes the implementation costs are escalated and possibly could be subsidised by central government in assisting in the economic advantages of the industries entering into the scheme, and the municipality/community at large having a controlled facility for the treatment and disposal of heavy metal wastes. These considerations are likely to outweigh the potential to recover some of the investment in the processing and recovery of metals from the wastes.

It is possible that a Municipality may collect the wastes and transport them to the CWT for processing and disposal either free of charge or at a nominal charge. The practical costs of the waste handling could then be recovered from the Municipal rates and the effluent discharge tariff system, or some subsidised system, in accepting that the metal penalty in the tariff is not a "treatment' cost, and that should the metal levels in the sewage significantly decrease the costs of handling and disposing of the sludges by the Municipality will become substantial and require recovery by some means from the industries and ratepayers.

If the Municipality cannot render a subsidised collection and handling service it may be necessary to control the basis of charges from appointed contractors in order to ensure that a fair charge is levied which will encourage the industries to routinely utilise the service, rather than alternatives and/or continue dumps to sewer.

The viability of recovering metals from the concentrates is largely related to the volumes and qualities of the wastes generated. The rate of Return on Investment in a metal recovery system improves rapidly as the amount of waste available for recovery increases. In order to take maximum advantage of scale economics, the CWT services should be provided to a broad range of industries and, where economical, accept wastes from a large service area.

If local industry is reluctant to purchase the recovered metals due to concerns over purity that can economically be guaranteed, the metals can be sold, at a lower return, to refining companies.

Where there are I-X columns that are to be regenerated and returned as a service to the individual Metal Finishing users, the CWT service is able to apportion a charge directly related to the costs of regeneration, and then to sell the recovered metal back to the user directly or to alternative users. It is estimated that the regeneration of individual I-X columns would cost of the order of R250/column, with recovery of metals an additional R250/column at a CWT facility servicing 50 users and 150 individual columns with regeneration on a monthly basis. The collection of rinsewater I-X columns alone would not recover the direct cost of operating the service nor ensure that discharge to sewer from non-rinse waters is in compliance. The handling and non rinse waters and collection and treatment of combined wastes received by the CWT is more difficult to account for. It is possible to charge the users in relation to the quality and quantity of the wastes collected and disposed of, which requires the ability to individually sample and measure loads from each user, or there is the opportunity to standardise the treatment costs relative to the total volume of wastewater treated or loads received and apportion a general charge relative to the volumetric contribution of each user, similar to conventional sewage charges.

Based upon a projected operational cost of R1 500 000/month for the service to 57 users and a wastewater production of 180 000 m^3/month it is possible to standardise the service charges at R8.5/kl wastewater, irrespective of size or loads derived from each individual user or whether I-X columns are utilised. This assists the smaller users who would be penalised by the economies of scale if they have to install individual pretreatment facilities and handle the wastes produced.

If it is necessary to determine the charges relative to the metals load handled, using the projected monthly operational cost of R1 500 000 and a total metals load of 37 350 kg/m the relative charge per kg metals can be equated to R40.16/kg.

However, this requires an ability to account for all the metal load being generated by each users and discharges to sewer from extraneous sources. In practise it would be necessary to charge at least R120/kg to account for the discrepancies identified in the industrial effluent sampling protocols, and to account for the handling of non-metals pollutants in the form of cyanide, acids, alkalies, cleaning chemicals and solvents generated by the Metal Finishers in addition to metals contained in defined rinsewaters and plating baths.

A further tariffing option is to charge in relation to the specific metals, cyanide and additional pollutant loads (acid, alkali and cleaning baths etc.) and their associated treatment and disposal costs. This would require the ability to define in detail the chemistry of wastes received from each user and to quantify treatment and disposal costs relative to each component, as a more extensive development of the existing sewage costs apportioned to COD, N and P.

Table 21: Central Industrial Wastewater Treatment Facility Construction Cost

ITEM	CAPITAL COST EST. (R)
Arrivals Holding Tanks	300 000
Equalization Tanks	500 000
Storage Tanks	350 000
Batch Physical/Chemical Treatment Equipment	2 500 000
Ion-Exchange Column Regeneration and Metals Recovery Equipment	6 000 000
Bath Recovery and Replenishment Equipment	1 500 000
Sequencing Batch Reactors	1 500 000
Sludge Thickening and Dewatering Equipment	2 500 000
Buildings (including offices and laboratory)	2 500 000
Effluent Polishing Equipment	350 000
Total Estimated Construction Cost	**R 18 000 000**

Table 22: Centralised Industrial Wastewater Treatment Facility Annual Operating Cost

ITEM	OPERATING COST EST. (R)
Vehicle Maintenance	250 000
Equipment Maintenance	500 000
Civils Maintenance	500 000
I-X Column Replacement (@ 10%/annum)	500 000
Electricity	1 000 000
Chemicals	2 000 000
Labour	2 500 000
Sludge Disposal	500 000
Total Estimated Annual Operating Cost	**R 7 750 000**

Notes: 1. Operating costs are based on regenerating 10-20 I-X columns/day, treating 10 000 ℓpd of mixed wastewaters and recovering 10 000 ℓ/month bath liquors.

2. Labour costs are based on 3 collection drivers, 3 operators for 8 hours/d, 5 days/week, one chemist, 3 administrative staff.

A WOOD PhD
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