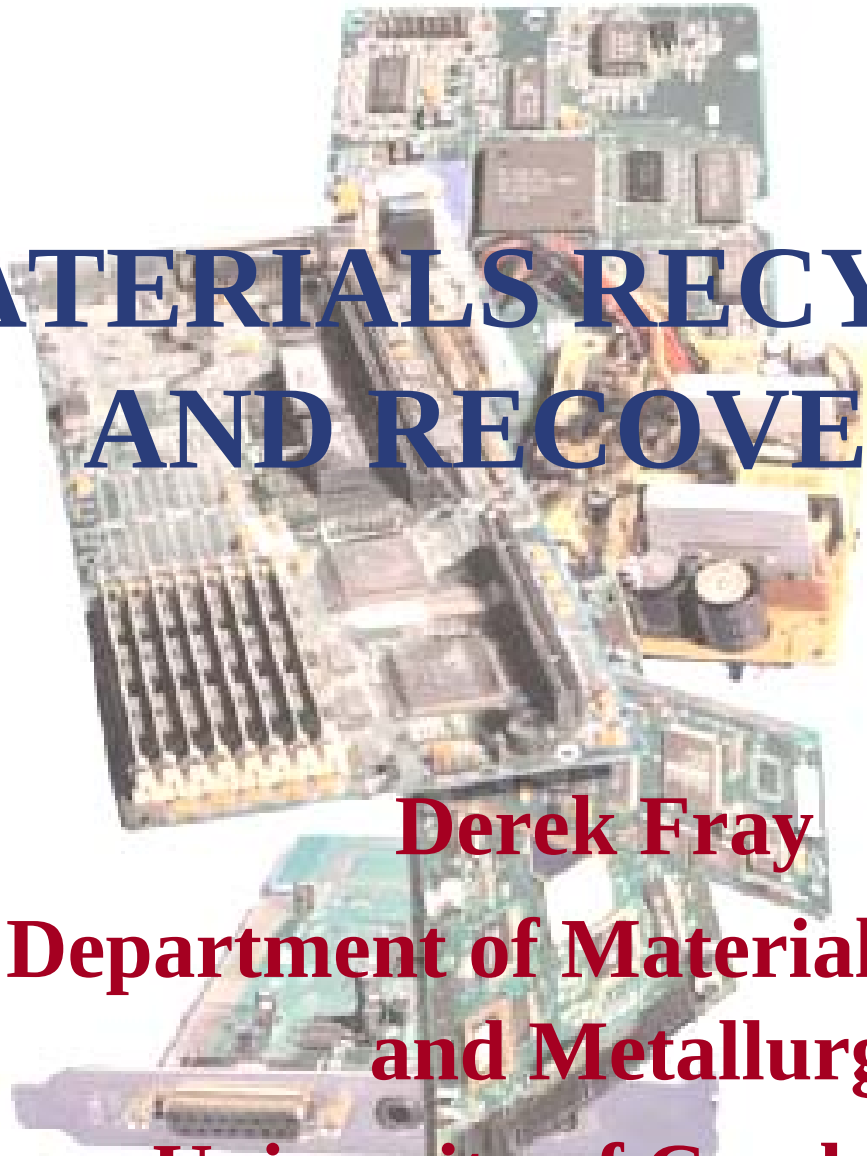
MATERIALS RECYCLING AND RECOVERY



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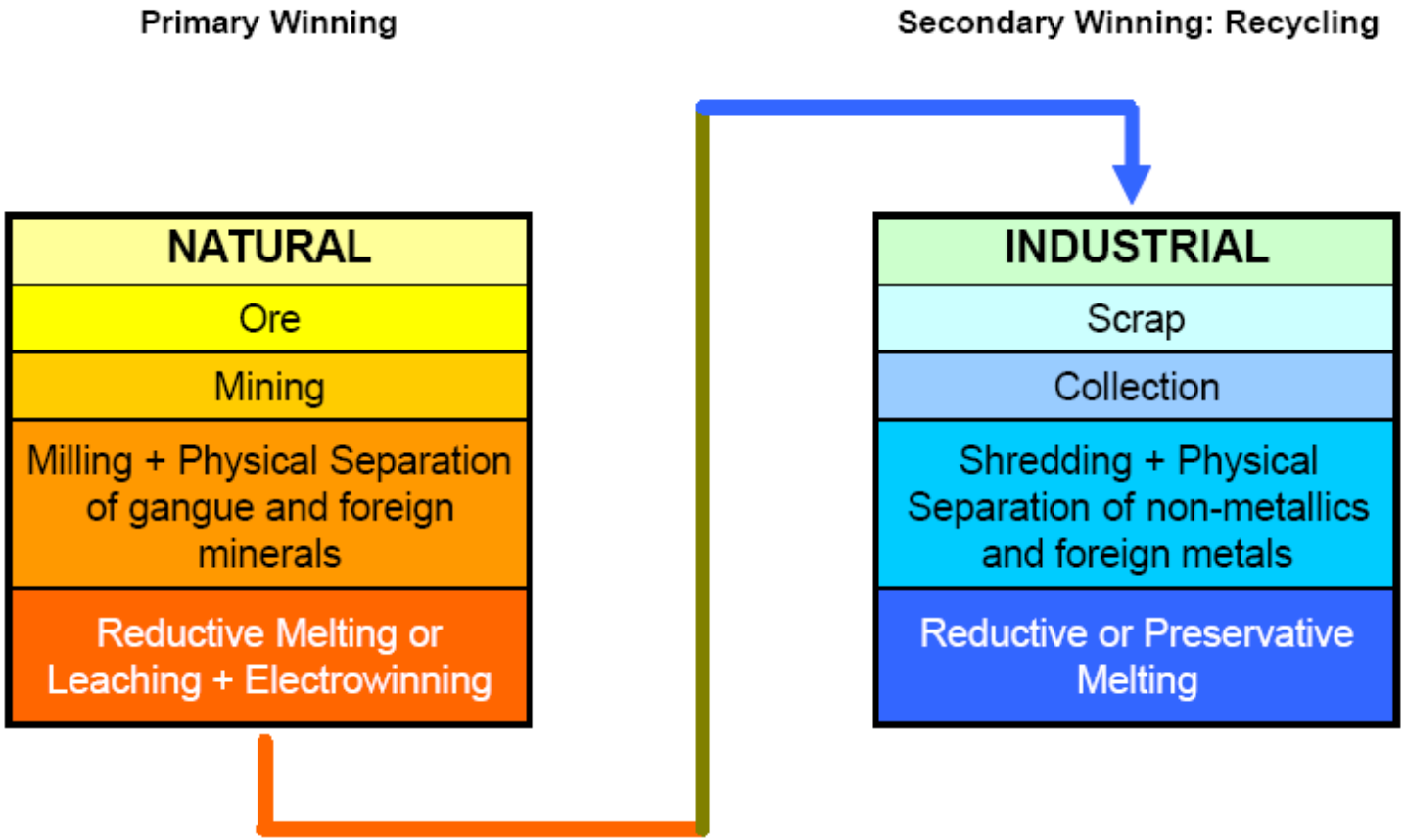
TOPICS TO BE COVERED

- Physical separation of materials
- Treatment of Electronic Scrap to recover components and valuable constituents
- Use of scrap PVC to treat metallic residues

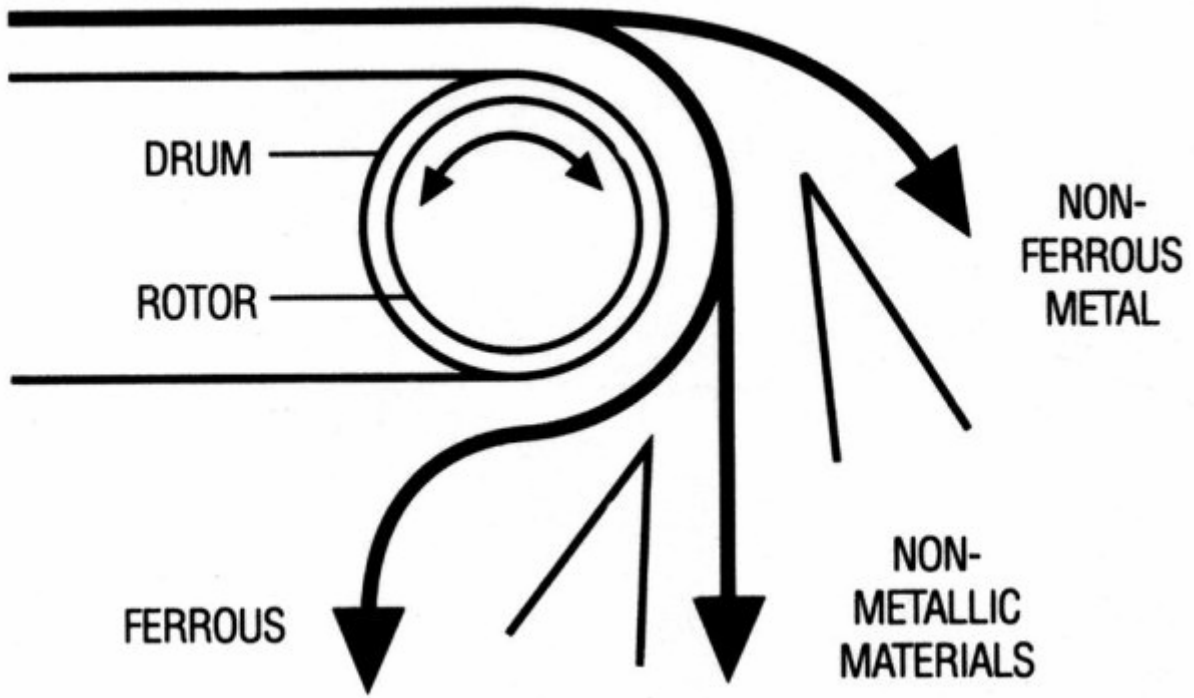
Similarities between Natural and Industrial Raw Material




Scrap

SORTING

Shaking tables



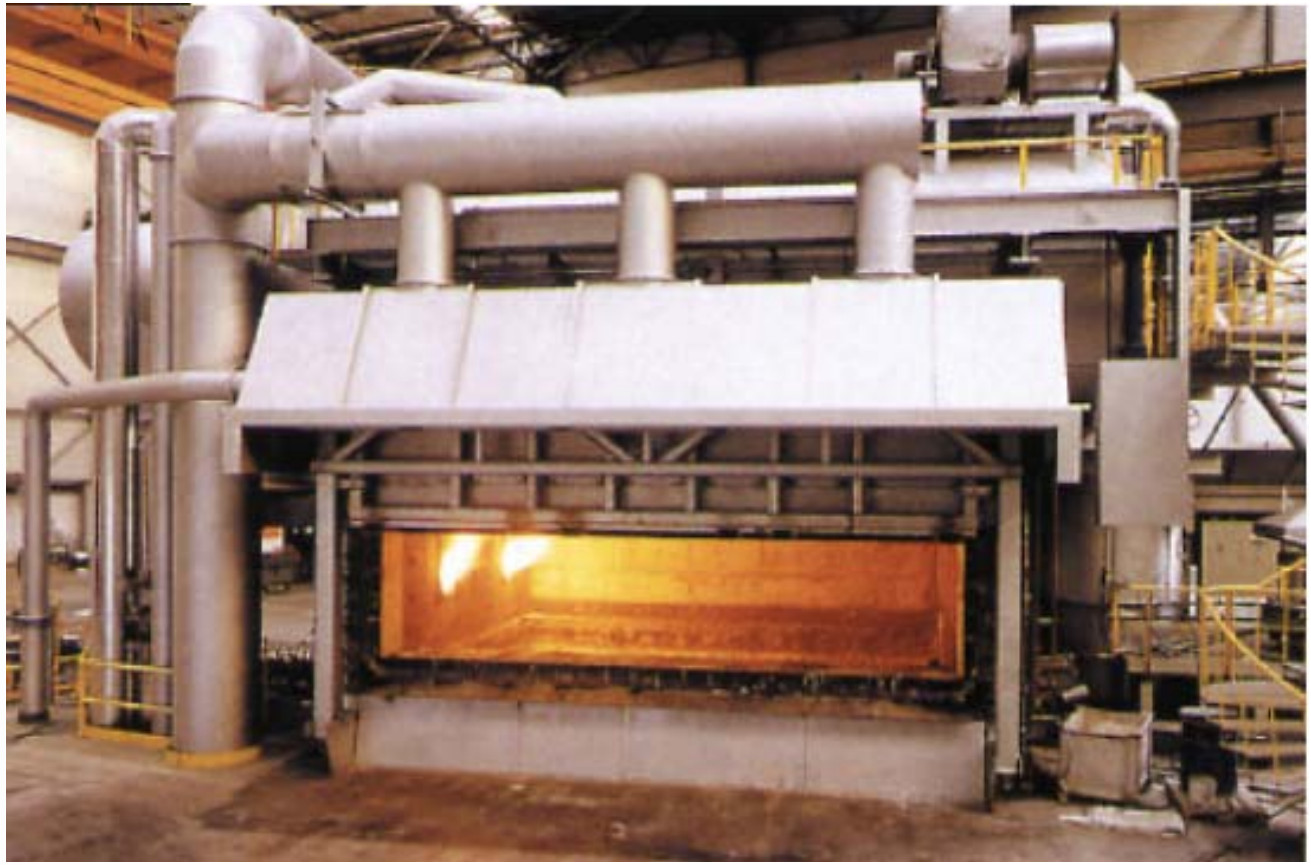
MAGNETIC SEPARATION

Eddy Current Sorting

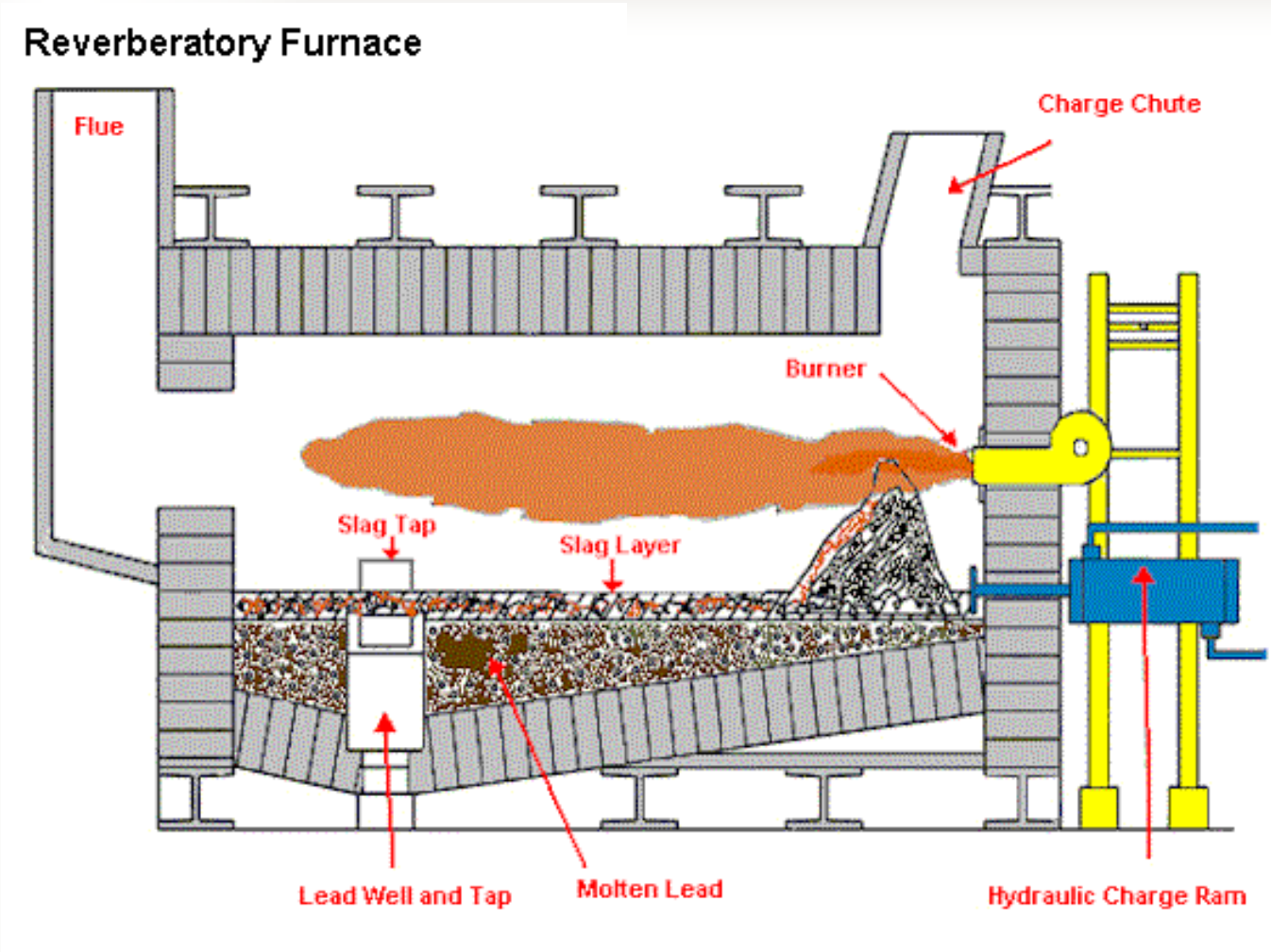
Hand Sorting at a Recycling Plant in Ningbo (China)

Industrial Dimension of Han
Sorting (China)

Melting of Aluminium Scrap



STEELMAKING



MELTING OF LEAD SCRAP

TREATMENT OF ELECTRONIC SCRAP

KEY POINTS

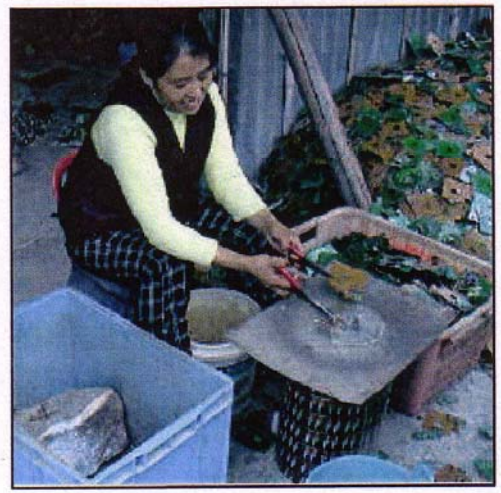
- Exponential demand for electronic equipment
- Short – life of computers
- Small percentage of computers find re-use
- Most electronic scrap is either land-filled or melted
- Legislation is likely to require manufacturers to take back equipment

QUANTITIES OF AVAILABLE SCRAP

- 50,000 tonnes of PCB scrap generated in the UK
- 300,000 tonnes of PCB scrap generated in Europe

PERCENTAGE RECYCLED

- Only 15% of the 50,000 tonnes per annum is subjected to any form of recycling, the remainder being consigned to landfill
- Approximately 60% of the 42,500 tonnes per annum is landfilled within the total redundant equipment package
- A significant proportion is exported illegally



APPROXIMATE COMPOSITION OF PCB ASSEMBLIES

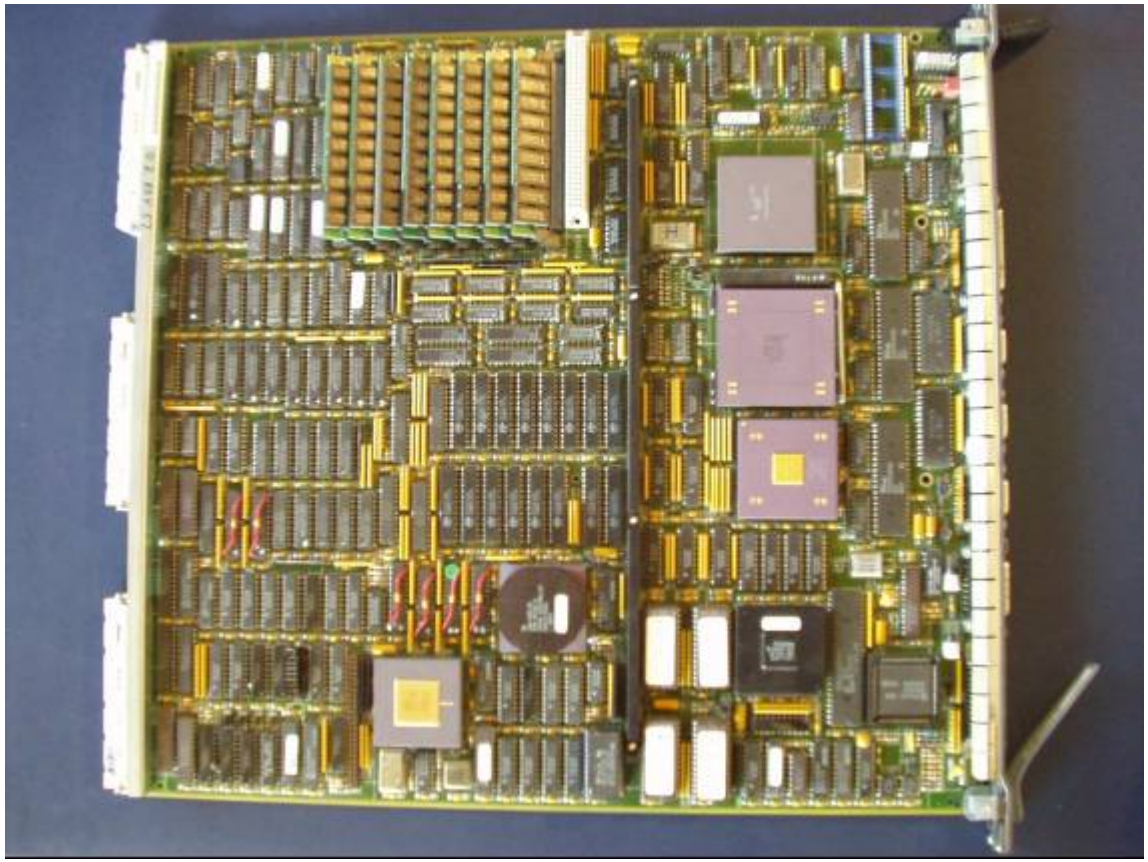
Glass-reinforced polymer	70%
Copper	16%
Solder	5%
Iron, ferrite (from transformer coils)	5%
Nickel	1%
Silver	0.1%
Gold	0.025%
Palladium	0.01%
Other (bismuth, antimony, tantalum, etc)	<0.01%

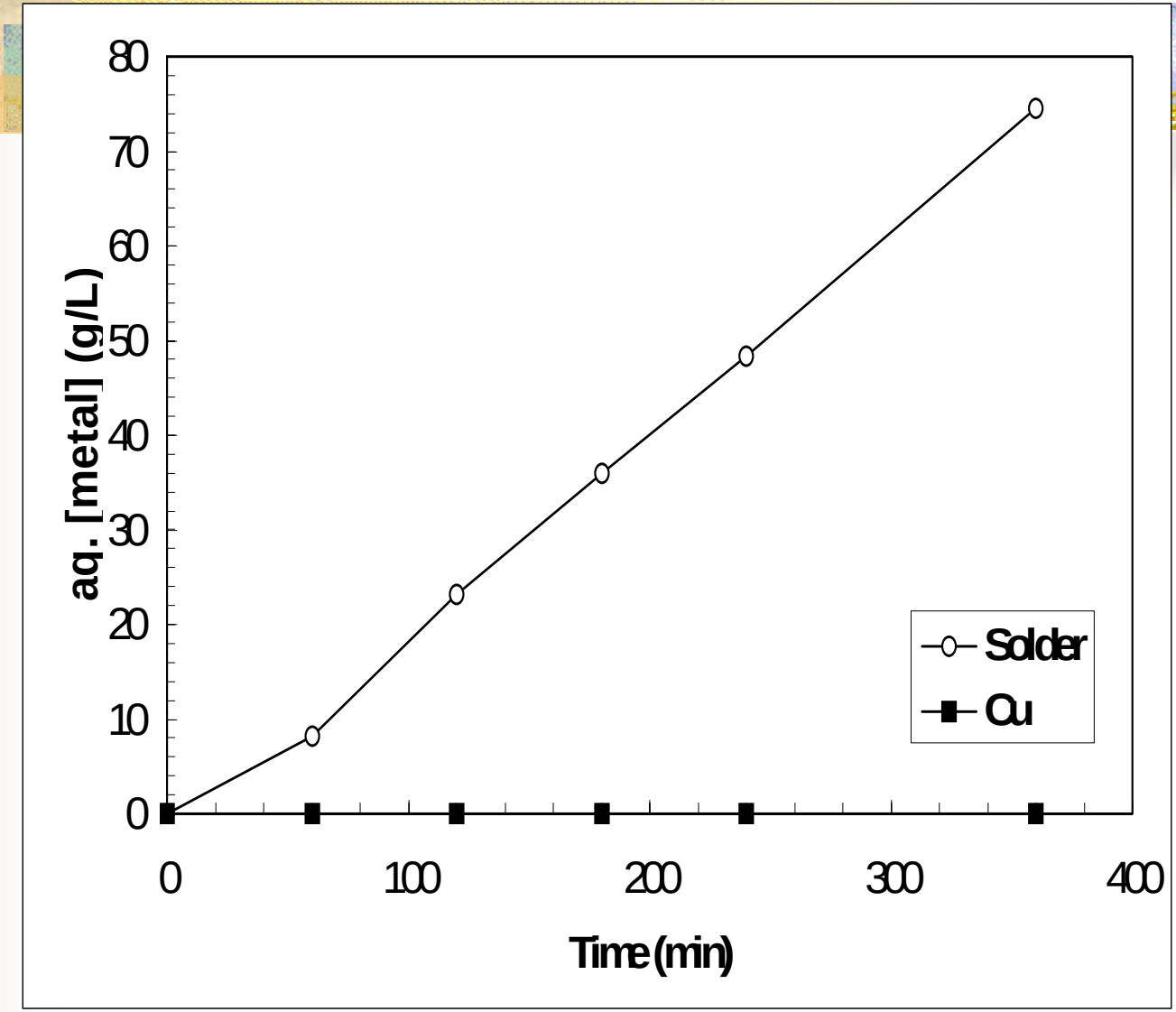
Component	Wt. (by%)	Value (£) (by kg)	Intrinsic Value (£ per kg)
Gold	0.025	12509	3.13
Palladium	0.01	26961	2.70
Silver	0.1	253	0.252
Copper	16	4.093	0.655
Tin	3	5.101	0.153
Lead	2	0.669	0.014
Nickel	1	10.815	0.108
Aluminium	5	1.538	0.077
Iron	5	0.208	0.01
Zinc	1	1.793	0.02
Total			£7.12/kg

Value of components ~ £1.5 /kg

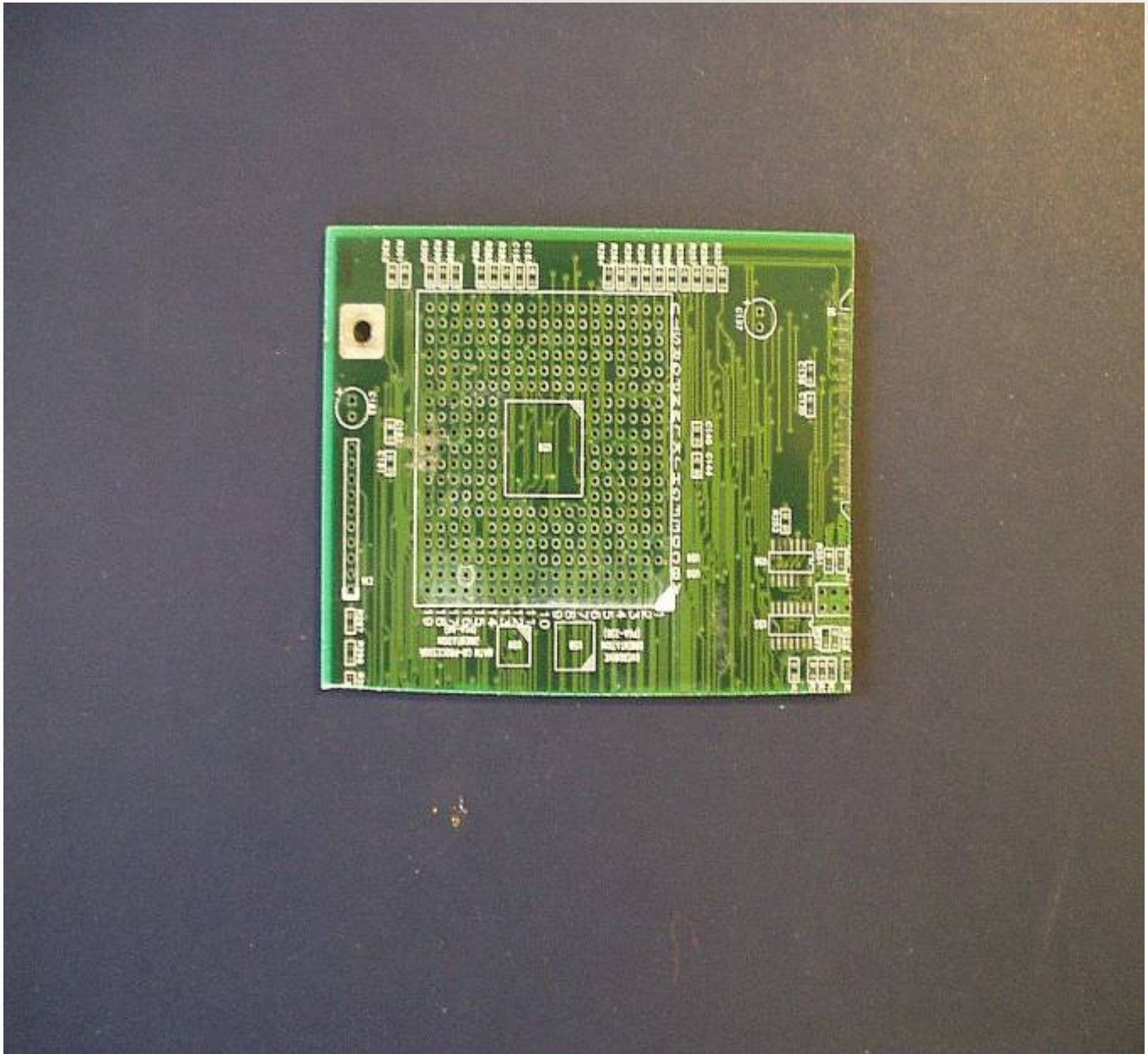
OVERALL AIM

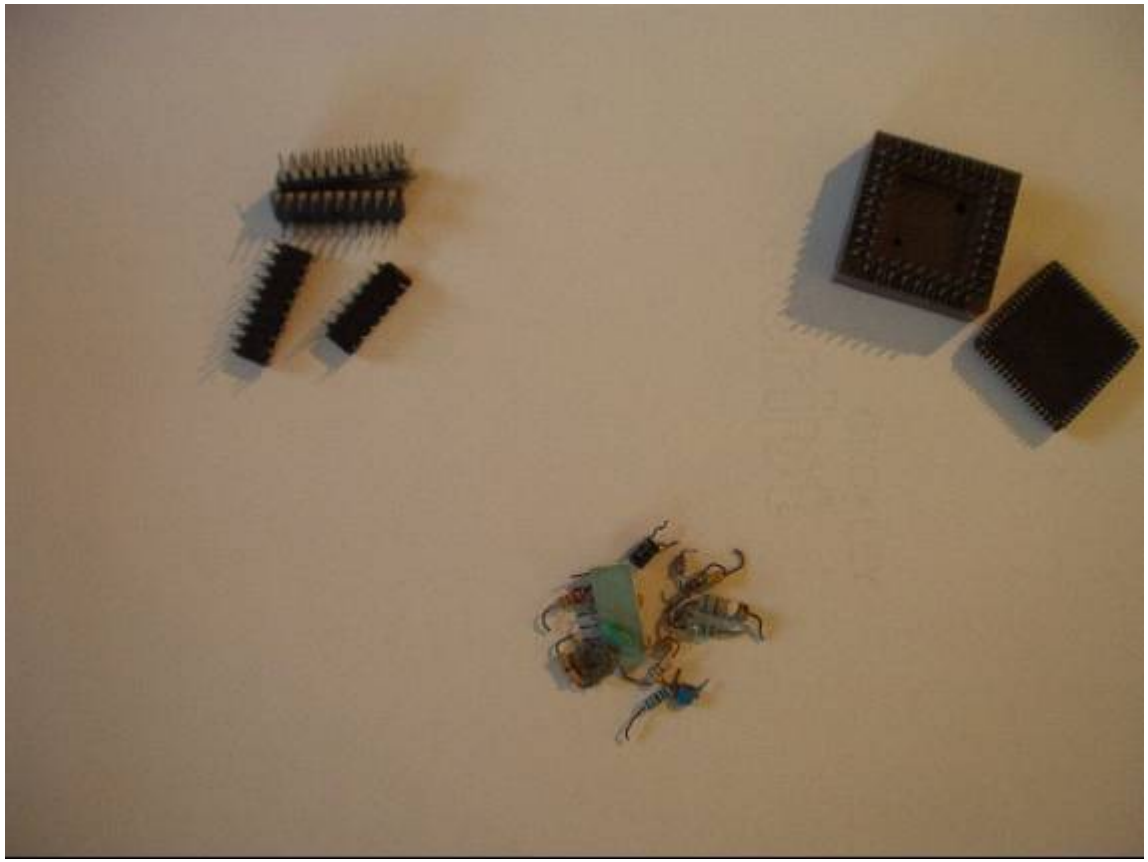
1. Recover value of components
2. Minimise chance of loss of precious metal
3. Recover solder
4. Recover copper
5. Recover bromine
6. Predominantly low temperature process- high energy efficiency
7. Low waste volume
8. Environmentally friendly





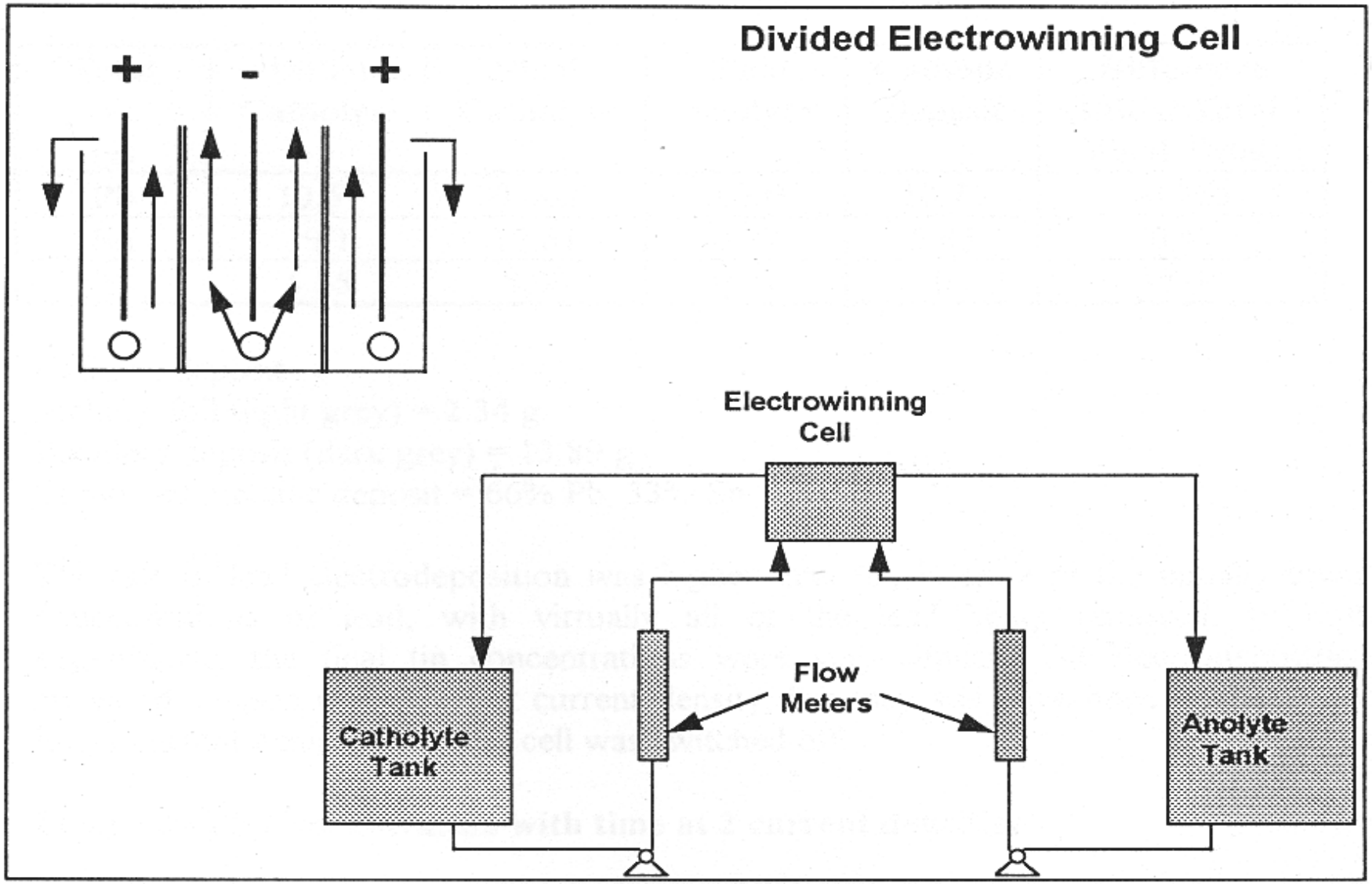
Dissolution of solder and copper with HBF_4/ 0.3 M Ti(IV) at 60 deg. C using oxygen sparge.



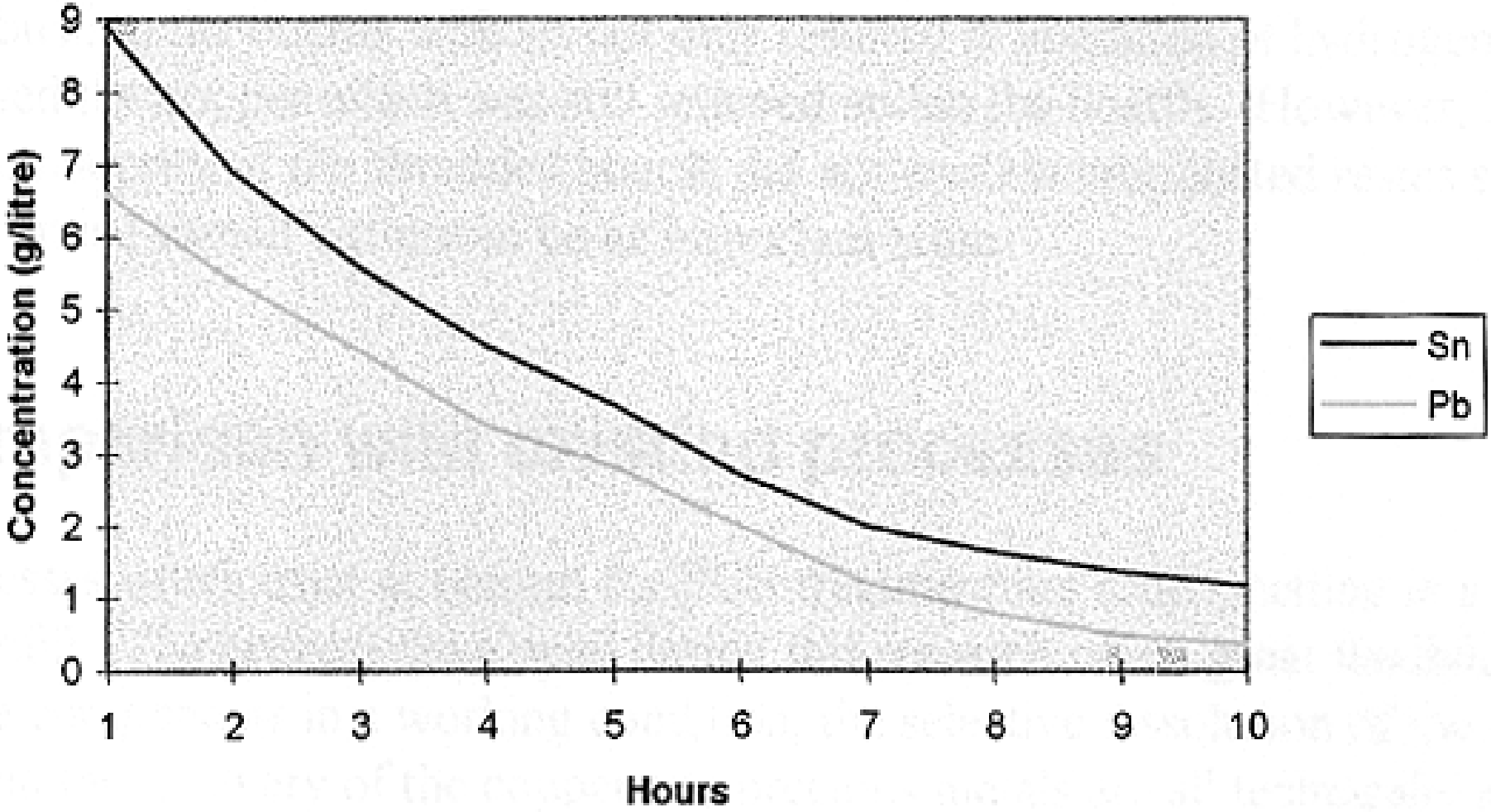


LEACHING RESULTS

- Lead and tin dissolved in the same ratio as in the solder
- About 70 g/l of metal was obtained in the fluoroboric acid
- Temperature of dissolution was 20 – 30^{o}C
- Dissolution of copper was negligible
- After dissolution of the solder, the components were simply removed and electronically tested



Divided electrowinning cell (flow cell, laboratory scale)

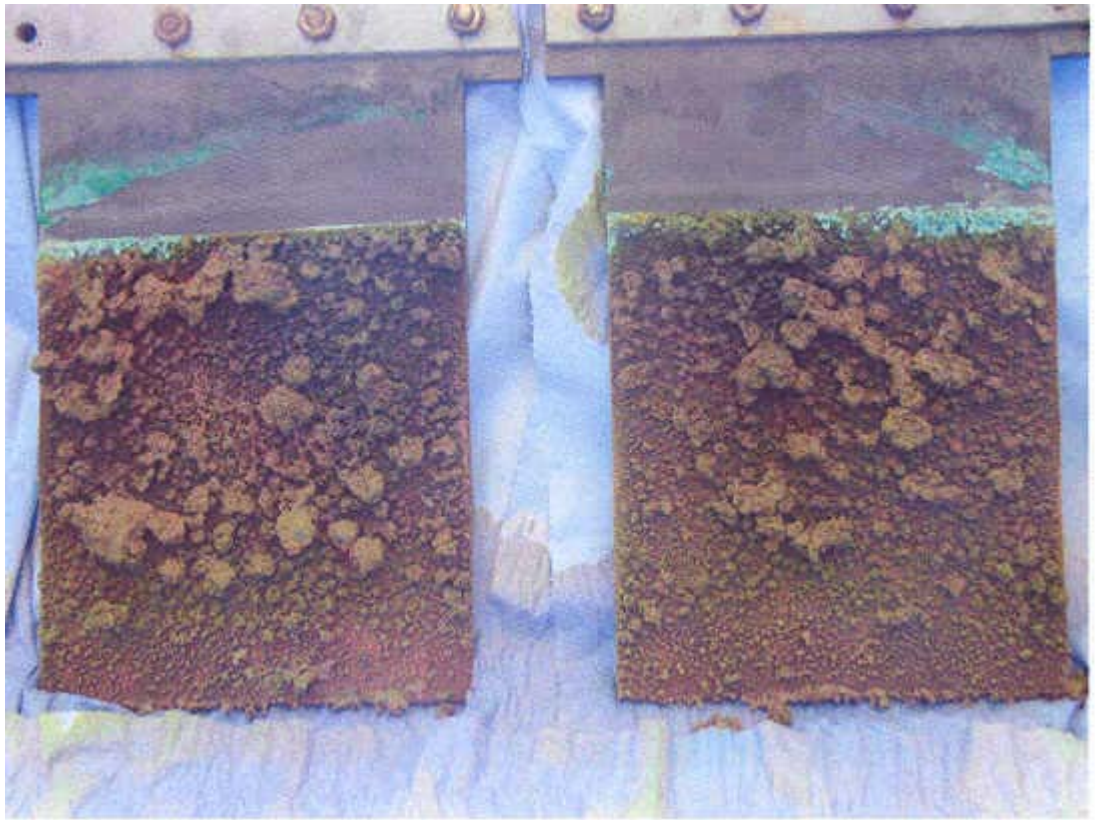


Variation of concentrations of Sn and Pb in electrolyte as a function of electrolysis time.

ELECTRODEPOSITED SOLDER

REMOVAL OF COPPER

- Boards are shredded
- Copper is leached in cupric solution
- Electrowon



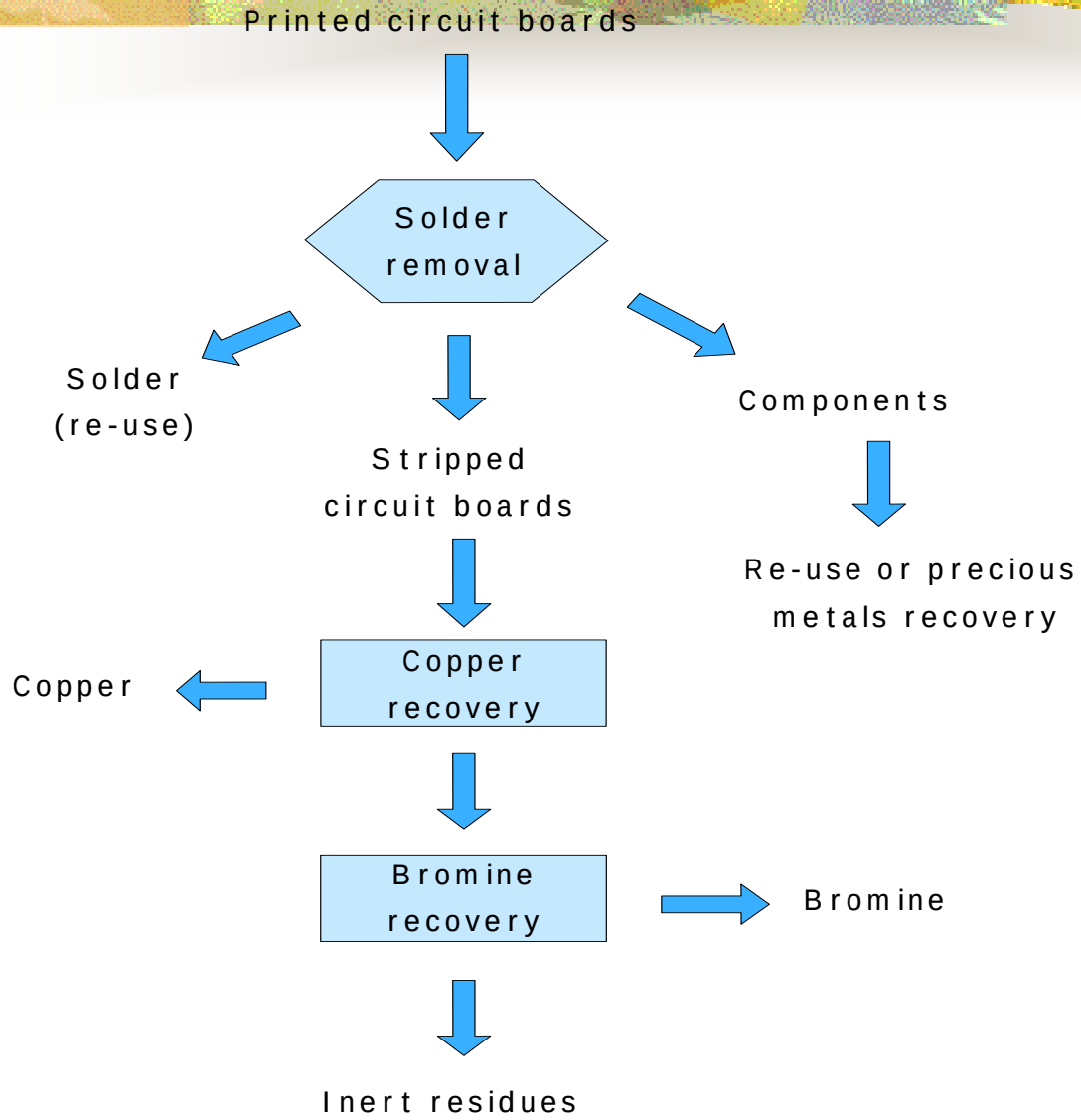
ELECTRODEPOSITED COPPER

LEACHING AND ELECTROWINNING OF PRECIOUS METALS

- Precious metals were leached with hydrochloric acid and nitric acid and then electrowon

RELEASE OF BROMINE

- Boards after leaching were simply combusted in air at 600^{o}C
- The bromine and hydrogen bromide were collected in caustic soda
- About 3.5% of the boards were bromine


Printed circuit boards
Solder removal
Solder (re-use)
Stripped circuit boards
Components
Re-use or precious metals recovery
Copper
Copper recovery
Bromine recovery
Bromine
Inert residues

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 159 467 B1

(12) **EUROPEAN PATENT SPECIFICATION**

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PCT/GB00/00116

(87) International publication number:
WO 00/043574 (27.07.2000 Gazette 2000/30)

(54) **PROCESS FOR THE RECOVERY OF TIN, TIN ALLOYS OR LEAD ALLOYS FROM PRINTED CIRCUIT BOARDS**

VERFAHREN ZUR RÜCKGEWINNUNG VON ZINN, ZINNLEGIERUNGEN ODER BLEILEGIERUNGEN AUS LEITERPLATTEN

RECUPERATION DE L'ETAIN ET DES ALLIAGES D'ETAIN OU DE PLOMB DES CARTES DE CIRCUITS IMPRIMES

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **25.01.1999 GB 9901586**

(43) Date of publication of application:
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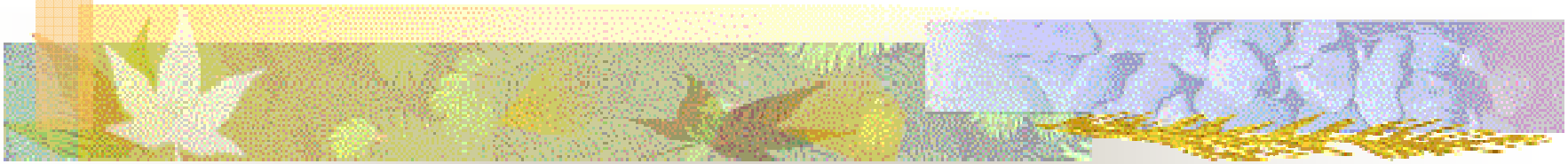
ECONOMIC ASSESSMENT

- Cost of plant to process 10000 tonnes/annum of PCBs is £3m
- Profit per tonne of material treated £90
- Value of recovered components has not be included as the value of components fluctuates considerably. It could be as high as £1500/tonne

COMBINATION OF PVC AND STEEL SCRAP AND RESIDUES

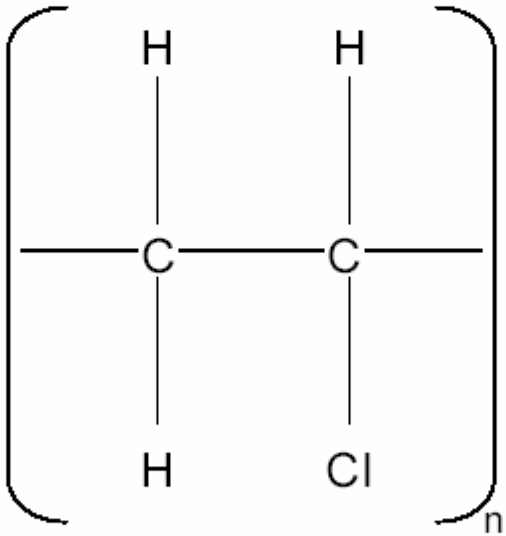


Interpro Zinc LLC

Treatment of Polyvinyl Chloride

US Patent 5,698,759 · D.J.Fray, 1997

PVC

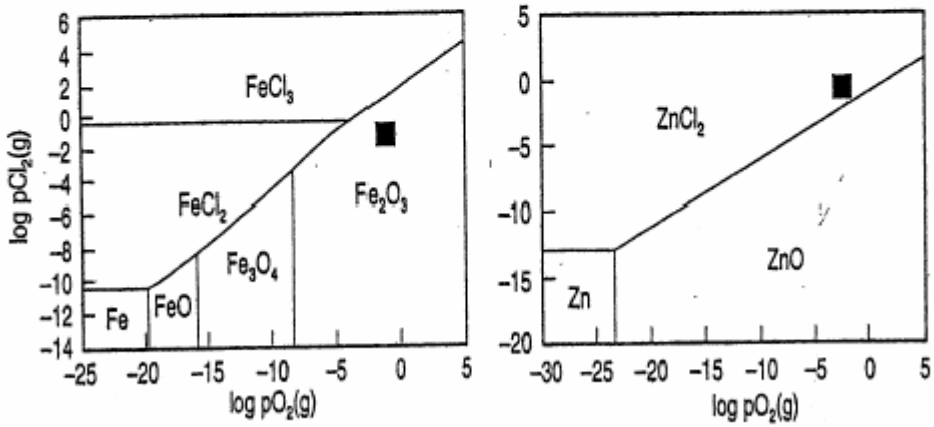


- 57% Cl
- 34 kJ/kg
  (15000 BTU/lb)

Interpro Zinc LLC

Thermodynamics at 800°C

Thermodynamics / Phase Stability Diagrams at 800°C



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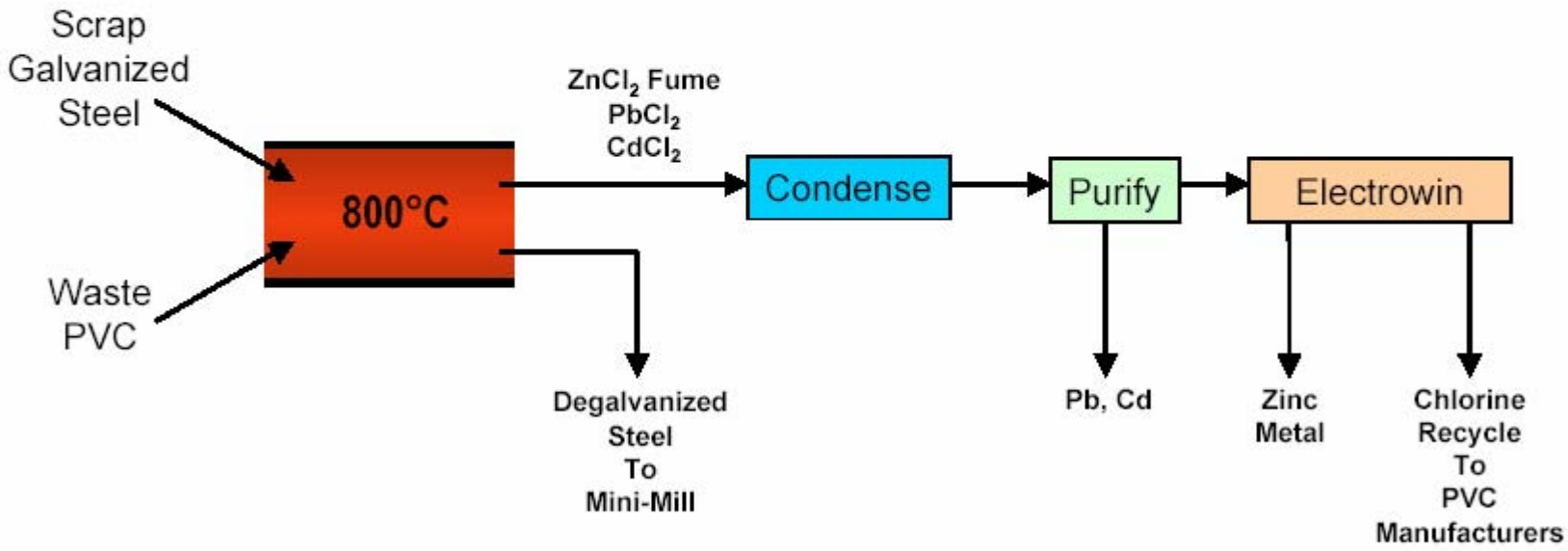


Interpro Zinc LLC

- EAF dust is the fume produced when scrap steel is melted in an electric arc furnace

- Every steel mini-mill produces 30-40 lbs of EAF dust per ton of liquid steel

- In North America:
  1 million tons @ 20% Zn, every year

  57% - goes to thermal treatment to produce zinc oxide
  43 % - goes to stabilization and landfill

Interpro Zinc LLC

EAF Dust Composition

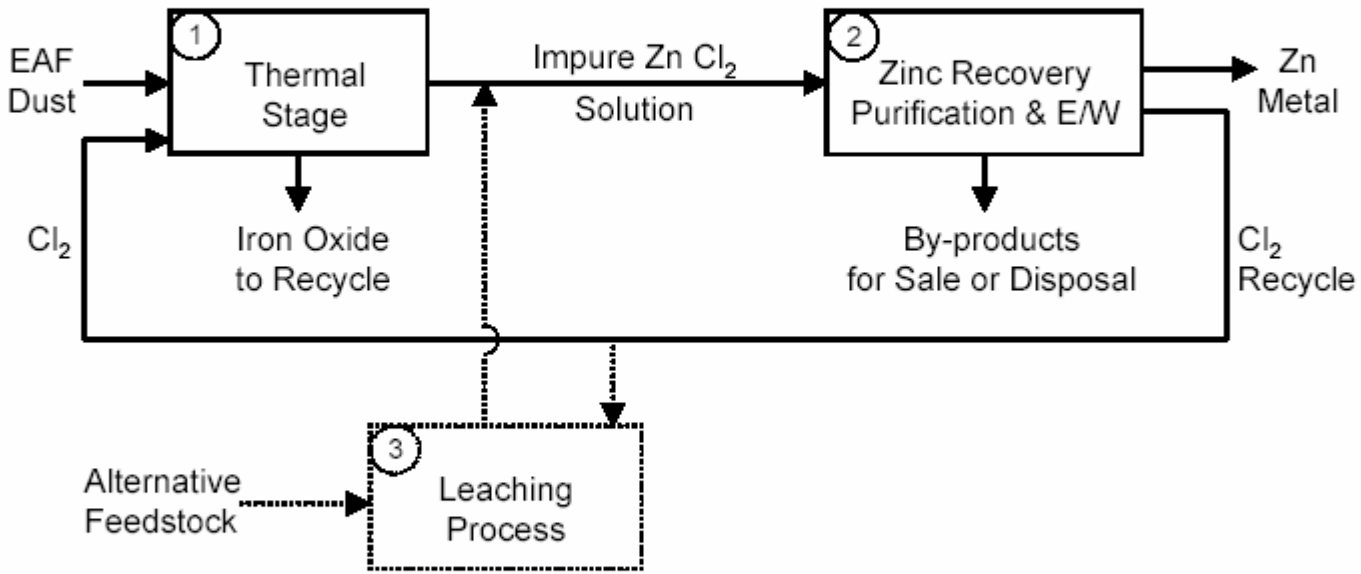
- Typical analysis:

Zn	20%	Cl	0.1 – 0.5%
Pb	1 – 2%	CaO	5 – 10%
Cd	0.1%	Fe_2O_3	30 – 60%

- Zinc occurs as ferrite $ZnO.Fe_2O_3$
- Forms by high temperature reaction of ZnO and iron oxide fumes
- Need thermal step to decompose the spinel structure
  (Technology to match the new material)

Interpro Zinc LLC

Zinc Recycling Process

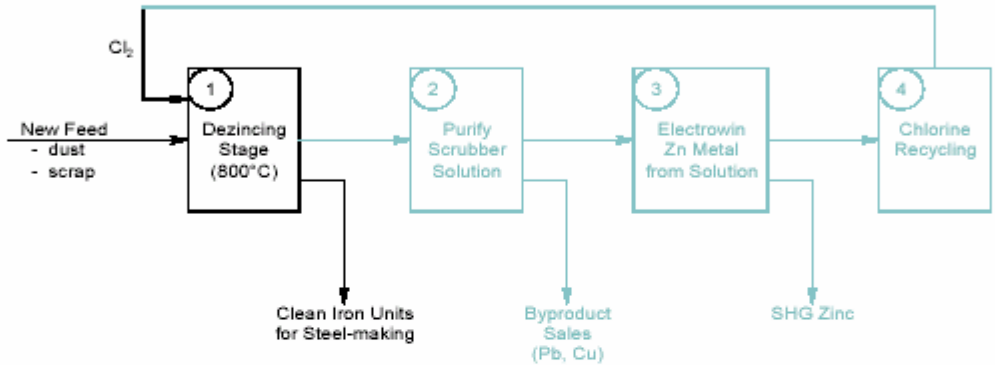


Alternative feedstock:

- Crude zinc oxide derived from EAF Dust
- Mined zinc concentrates ("dirty concentrates")
- Mined zinc oxide ores
- Brass dust

Interpro Zinc LLC

Zinc Extraction - Typical Results



- 98% zinc removal from galvanized steel scrap
- 93% zinc removal from steel furnace dust
- 95% zinc removal from brass dust
- 99% zinc removal from crude zinc oxide

Interpro Zinc LLC

Laboratory Kiln

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Pilot Plant Cell

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Washing Pilot Plant Cathodes

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E/W Pilot Plant generating Cl_2

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Ashes to Ingots!

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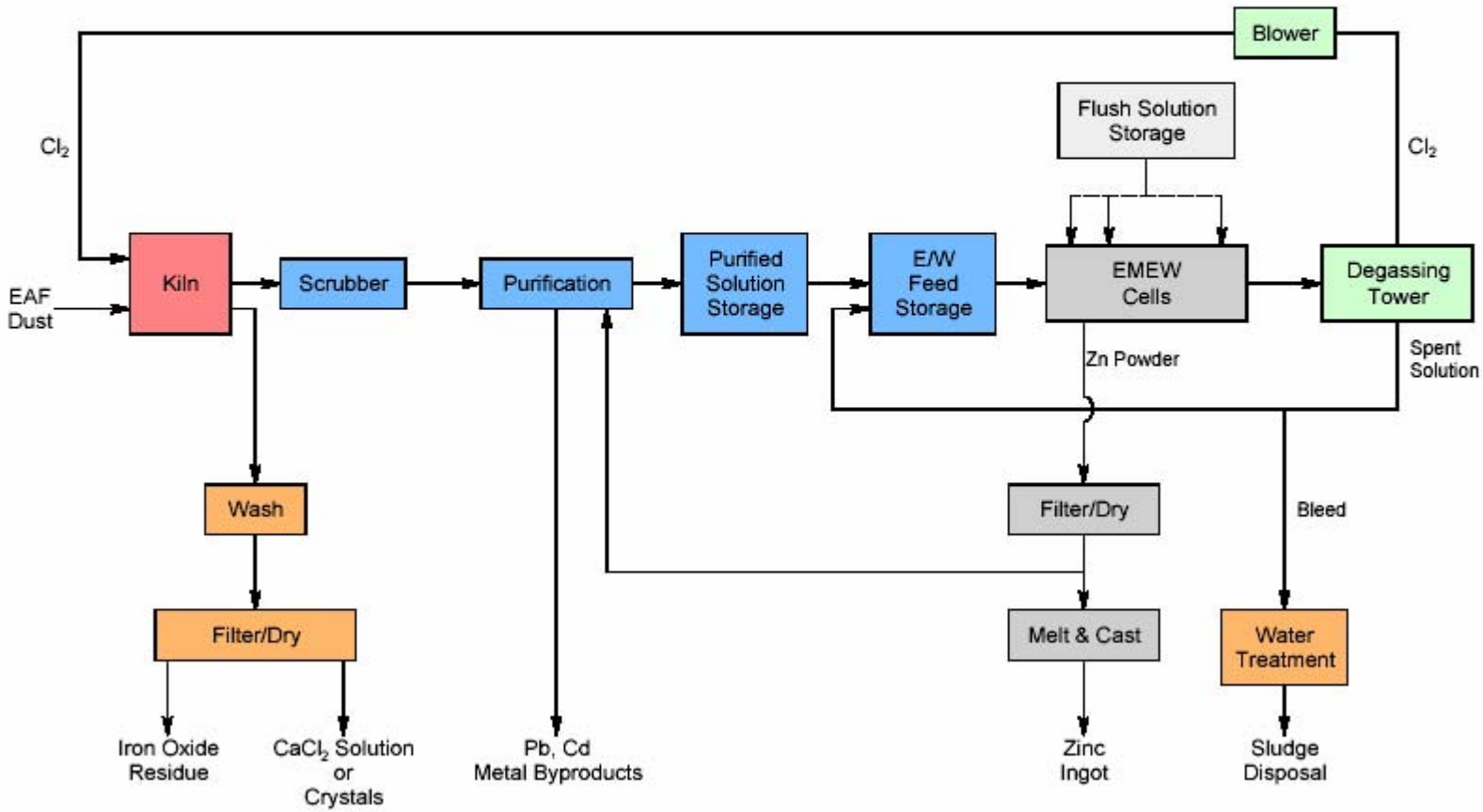
Commercial Flowsheet Concept



Business Opportunity

Produce SHG Zinc from EAF Dust

75% from zinc sales

20% from treatment fees

5% from reselling treated dust

Operating Costs: $0.20-$0.25 lb of zinc metal

Capital Costs:$2000 per annual tonne of zinc

Break-even Zinc Price: $600/tonne

GENERAL CONCLUSIONS

- Conventional and novel metallurgical extraction techniques can be applied to the recycling of a variety of wastes
- In some cases it is possible to combine two waste materials together to give useful products
- There are many other opportunities which can be investigated