CORPORATION

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INTERIM REPORT

FEASIBILITY STUDY FOR ON-SITE COPPER RECOVERY FROM COPPER CHLORIDE SOLUTION

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TABLES

1.0 INTRODUCTION

IBM Corporation produces approximately 250 tons of spent cupric chloride solution per month at their Austin, Texas manufacturing facilities. The spent solution contains 17.5 to 23.5% $CuCl_2$ and has other constituents such as CuCl, HCl, and heavy metals in lower concentrations. The spent solution is currently sold to a contractor who recovers copper at an off-site operation.

As an alternative to the sale of the spent cupric chloride solution, IBM is considering an on-site copper recovery operation. IBM has commissioned Radian Corporation to perform a feasibility study for on-site copper recovery. The elements of the feasibility study include:

- identify processes that are used in industry to recovery copper from concentrated solutions in the pure, salt, and hydroxide forms;
- determine the marketability of the recovery processes' products;
- screen candidate processes using criteria of capacity, recovery efficiency, operator attention, operating schedule, and other factors; and select two or more recovery processes that offer the "best" potential for application at IBM; and
- prepare conceptual designs and cost estimates for the processes selected above; and determine the technical and economic feasibility for the selected processes.

This interim report presents preliminary results of the first three work elements. Recovery processes that offer the "best" potential for application at IBM are recommended. The preliminary results and recommendations will be reviewed with IBM before work is initiated on the last program element.

2.0 SUMMARY AND RECOMMENDATIONS

This section presents interim results of engineering and market analyses of copper recovery processes. Recommendations of three processes for more detailed analysis are made based on the engineering and market analyses results.

2.1 Engineering Analysis

The engineering analysis involves the identification and characterization of candidate copper recovery processes that have potential application at IBM. The engineering analysis results are summarized in Table 2-1. Nine (9) different copper recovery technologies have been identified. The primary products from these technologies include metallic copper, copper salt/hydroxide precipitates, concentrated copper-containing solution, and aqueous sludges composed of copper precipitates. Specific process variations within a given copper recovery technology determine the form of the primary copper product.

The applicability of the recovery technologies also varies widely. Many of the processes can only be applied to dilute copper solutions. Such technologies include UV radiation and magnetic field, paper chromatographic separation, and reverse osmosis. These processes are more suitable as pretreatment steps for copper removal and find limited application for IBM's spent copper chloride solution.

Many technologies such as ion exchange and precipitation are pH sensitive and would require pH adjustment of IBM's acidic spent copper chloride solution with alkaline reagents such as caustic or lime to achieve optimum pH ranges for efficient copper recovery. Specific ion exchange or precipitation processes requiring neutral to high pH values for copper recovery will find limited application at IBM due to the high reagent costs for pH adjustment.

TABLE 2-1. SUMMARY OF COPPER REMOVAL/RECOVERY TECHNOLOGIES

Technology	Primary Products	Applicability
Liquid Ion Exchange (Extraction)	Copper sulfate solution	Multistep process (i.e., extraction and solvent regeneration with H_2SO_4) required to produce concentrated solution (extraction pH range = 4 to 6).
UV Radiation and Magnetic Field	Concentrate copper-containing brine	Not efficient for single compound removal.
Paper Chromotagraphic Separation	Segregated metals on cellulose	Applicable only to low (ppb range) copper concentrations.
Membrane Cell Electrowinning	Metallic copper	Proven technology for metal recovery from ore heap leaching.
Rotating Electrodes	Concentrated copper-containing brine.	Technology applicable for metal recovery.
Electrolytic cell (Sulfuric Acid)	Metallic copper	Proven technology for metal recovery from ore heap leaching. Requires IBM replace H_2SO_4 for HCl in etching process (pH range = 1.5 to 2.5).
Ion Exchange	Copper salts (copper sulfate or copper chloride depending on process)	Resin capacity low at stream pH (optimum pH range is from 2.0 to neutral).
Precipitation	Copper precipitates (i.e., copper chloride, copper sulfide, copper hydroxide, organo-copper complexes, or metallic copper depending on specific precipitation process)	With exception of precipitation by evaporation/crystallization, alkaline pH's are required.

The technologies that are most applicable to IBM's stream characteristics include liquid ion exchange, membrane cell electrowinning, sulfuric acid electrolytic cells, low pH ion exchange processes, and precipitation via evaporation/crystallation.

2.2 Market Analysis

The task involves the determination of marketability of copper products. The products considered in detail include metallic copper, copper chloride, and copper sulfate. These products are produced by most viable copper recovery technologies discussed in the section above. These products also represent copper products of highest market value and offer the strongest markets for recovered copper at IBM.

Table 2-2 summarizes the market analysis results. In general, the copper market is depressed, and this situation affects the price of metallic copper, copper sulfate, and copper chloride. The prices of all three products could be expected to increase as the market improves. Although depressed, markets for all three products exist within Texas. The sale of metallic copper appears to generate the largest revenue. The metallic copper market also represents the widest market in terms of the number of local purchasers interested in IBM's recovered copper. Of the copper chemicals, copper sulfate offers the strongest market in-state, while copper chloride solution can readily be sold to a Mexican firm.

2.3 Process Selection and Recommendations

Process selection involves the determination of those copper recovery processes that are most applicable to treat spent copper chloride solution at IBM. Process selection takes basic engineering and market information discussed in the sections above and applies screening criteria to determine the most applicable processes. The selected processes are

TABLE 2-2. MARKET ANALYSIS RESULTS

Product	Demand	Quoted Purchase Prices	Remarks
Metallic copper	Competitive local market exists. Interest exists for purchasing all of IBM's metallic copper production capacity by several Austin scrap metal buyers.	$0.45 to $0.60+ per pound. Upper price bound is $0.73 per pound.	The U.S. metallic copper market is currently depressed. However, numerous markets exist for the quantity of copper that can be recovered at IBM. The current copper price represents a "worst case" situation for copper sales. Copper demand is forecasted to improve by 1987 and beyond. This forecast will further strengthen the demand for IBM copper and will improve copper prices.
Copper chloride	Demand for copper chloride in the immediate Austin vicinity is non-existant. Local markets for copper chloride exist in the Houston and Dallas areas with copper chemical manufacturers. Potential purchasers of copper chloride are limited.	Potential purchasers of copper chloride were reluctant to quote prices. The upper price bound is $0.73 per pound of copper.	When compared to metallic copper, the strength of the copper chloride market is limited in terms of potential local purchasers and the quantities of material that can be sold to any one purchaser.
Copper sulfate	Demand for copper sulfate in the immediate Austin vicinity is non-existant. Potential purchasers include chemical recyclers, chemical formulators and distributors in the Dallas and Houston areas as well as localities beyond. Demand for copper sulfate is characterized as strong and is relatively constant.	Potential purchasers of copper sulfate were reluctant to quote prices. The 1984 published price is $0.45 per pound (100 pound bags). Higher prices were reported in isolated instances for commercial grade. Price would be based on copper content.	The price of copper sulfate is closely tied to metallic copper prices. The copper sulfate market appears stronger and more stable than that of copper chloride.
Copper chloride solution	Strong interest expressed by Mexican firm, with office in Houston.	$0.15 per pound of copper in solution, as is.	Purchaser will supply on-site rail car and arrange transportation to Mexican copper chemical production facility.

recommended for further analysis (i.e., conceptual design, cost estimates, and economic feasibility) in the next phase of this program.

Screening criteria applied during the selection process are summarized below:

Criteria specified by IBM

- High product recovery (i.e., 1.0 lb copper per gallon of solution),
- Processing capacity ⩾ 250 tons per month of cupric chloride solution,
- Process operability (one shift per day requiring no more than one operator's supervision), and
- Proven capability with wastes similar to that generated by IBM.

Criteria developed by Radian

- Number of processing steps required to produce a salable product,
- Secondary waste stream generation,
- Modification of waste stream chemistry (e.g., pH adjustment) prior to processing,
- Utility requirements,
- Potential for producing usable byproducts,
- Safety considerations, and
- Potential operating problems.

Table 2-3 compares the copper recovery technologies of liquid ion exchange, membrane cell electrowinning, sulfuric acid electrolytic cell, ion exchange, and crystallization when the screening criteria are applied.

TABLE 2-3. PROCESS SCREENING SUMMARY

Process	Product	Usable Byproduct(s)	Number of Processing Steps	Secondary Waste Streams	pH Adjustment Required	Utility Requirements	Potential Operating Problems/Advantages	Safety Considerations
Liquid Ion Exchange (Extraction)	Copper sulfate	None	2*	Brine solution	To pH 4 to 6	Electricity for pumping/mixing	Startup during 8-hour operating runs, loss of efficiency due to high chloride	Handling sulfuric acid
Membrane Cell Electrowinning	Metallic copper	Hydrochloric acid	1	Acid solution or sludge**	None	Electricity for electrowinning and pumping	Product contamination by other metals	Potential for chlorine gas evolution during upset
Sulfuric Acid - Electrolytic Cell	Metallic copper	Sulfuric acid	1	Acid solution or sludge**	None	Electricity for electrowinning and pumping	Product contamination by by other metals/possible etching process limitation	Handling of sulfuric acid solutions
Ion Exchange	Copper sulfate or chloride solution	None	1	Acidic brine solution	To pH 2 to 3.5	Electricity for pumping	Capacity loss in cold weather, loss of efficiency due to high dissolved solids background	Handling acid solutions
Crystallization	Copper chloride solution or solids	Dilute hydrochloric acid	2***	Overhead vapors, brine solution	None	Steam, cooling water, electricity for pumping	Startup/Shutdown with short operating runs	Handling dilute acid and solids. Evolution of gaseous HCl

* Requires sulfuric acid regeneration of solvent.

** Small purge stream may be required to avoid high metals concentration in recycled acid.

*** Requires scrubbing of evaporator/crystallizer overhead vapors to produce hydrochloric acid and vacuum filtration of concentrate to produce solids which may be considered a third processing step.

The table indicates that liquid ion exhange (LIX) and ion exchange would require pretreatment of the waste to increase the pH to the appropriate range. This would be accomplished by the addition of caustic soda (sodium hydroxide) or slaked lime (calcium hydroxide) to the waste. Due to the acid nature of the waste, which ranges from 1 to 6 weight percent hydrochloric acid, the neutralizing chemical demand would be high. Caustic requirements would range from 6 to 35 tons per month depending on the acid strength of the waste. Pretreatment with neutralizing chemicals may also impact the ionic balances in both processes. In the LIX process, mass transfer of copper may be inhibited by high chloride concentrations. Both processes will produce brines which will require disposal and are comparable in volume to the original waste stream. Thus, the limitations preclude the direct use of these technologies in the treatment of the IBM waste stream.

The three remaining technologies, membrane cell electrowinning, sulfuric acid electrolytic cell, and crystallization, appear to be similar with respect to the screening criteria presented in Table 2-3. Evaporation/crystallization has more diverse utility demands in that steam and cooling water are required for operation. Both electrolytic processes can be operated as single step treatments producing metallic copper and acid for recycle to the etching process. The major uncertainity with the sulfuric acid electrolytic cell is the use of sulfuric acid in IBM's etching process. All three processes produce a very low volume brine solution that will require disposal. Safety considerations appear to be comparable for all processes. The evolution of chlorine gas, noted under safety, is an extreme upset case for the membrane cell process and should not be construed as a frequent occurrence. Since these processes reasonably meet the IBM and other criteria established for the copper recovery system, they are recommended for more detailed analysis in the remainder of this program.

3.0 PROCESS SELECTION

This section presents information obtained during a literature search to identify options for copper recovery from IBM's copper chloride solution. The information on copper recovery processes is then compared and screened to determine the most viable recovery processes for more detailed analysis. Section 3.1 describes the chemistry of IBM's spent copper chloride solution. Section 3.2 identifies criteria used for recovery process selection and discusses candidate recovery process in light of these criteria. The most viable recovery approaches are described in more detail in Section 3.3.

3.1 Stream Characteristics

Spent solution from the processing plant is primarily cupric chloride ($CuCl_2$) with some free hydrochloric acid present. A chemical analysis for major and trace components, obtained from IBM, is shown in Table 3-1. A sample has not been analyzed by Radian to verify these values. For calculational purposes, it was assumed that one gallon of solution contains one pound of copper. Approximately 250 tons of solution (50,000 gallons) are generated per month.

TABLE 3-1. MAJOR AND TRACE COMPONENTS OF SOLUTION

$CuCl_2$	17.5 - 23.5% by weight
CuCl	0.1 - 0.3%
H_2O	63.4 - 75.5%
HCl	1 - 6%

Heavy Metals (with ppm ranges)
Worst Case Concentrations

Ag	4.9 - 0.4	Hg	0.04 - 0.004
As	13.0 - 0.28	Mn	0.24 - 0.01
Cd	0.03 - 0.006	Ni	3.2 - 0.02
Cr	4.7 - 0.06	Pb	0.07 - 0.06
Cu	195,000 - 419	Sn	0.03 - 0.03
Fe	12.2 - 0.18	Zn	411 - 1.0

This chemistry was used in the preliminary process screening to determine compatability with candidate recovery technologies.

The levels of trace contaminants present in any product is extremely important to any marketing effort and should be determined as accurately as possible.

There is also some question as to the actual ratio of cupric to cuprous ions in the solution. The analysis from IBM shows a proponderance of cupric ions. In an etching process, however, cupric ions in the acidic medium would react with metallic copper to produce cuprous ions as follows:

$$Cu^{++} + Cu(s) \rightarrow 2Cu^{+}$$

One might expect a spent etchant to contain elevated levels of cuprous rather than cupric ions. The cuprous ion can readily complex with chloride to form $CuCl_2^{-}$ and $CuCl_3^{=}$. Therefore, there is a question as to whether the analysis does indeed reflect the ionic distribution as would be seen by the process or whether the reported results are influenced by the analytical procedure used.

The implications for processing are that the cuprous ions are readily ~~oxidized~~ reduced in a membrane electrolytic cell to form elemental copper and oxidized to a cupric ion in a reversal of the above reaction sequence. A regenerated acidic etchant containing some cupric ions could then be recycled. Conversion of cupric ions to metallic copper may require different conditions to effect successful recovery of metallic copper without undesirable by-products. Final resolution of this question must be addressed in Task 4 of this study prior to a final process selection. For the purposes of this interim report, it is assumed that the chemical composition of the spent etchant presented in Table 3-1 is accurate.

3.2 Candidate Recovery Processes

There are numerous recovery processes that are potentially available for the recovery of copper and copper salts. The rapid growth of the electronics industry has spurred the development of new approaches and treatment equipment for the wastes generated. A literature search was conducted at the start of the program to ensure that the latest proven technological developments for copper and copper salt recovery were considered. The results of this search are compiled in Table 3-2. This table identifies candidate processes, products, and typical applications. Remarks pertinent to the application of each candidate process are also presented.

Table 3-2 indicates that a variety of techniques are available for copper recovery, removal, or salt production; however, most techniques are applicable to only dilute copper bearing solutions. Many processes such as reverse osmosis, the rotating electrode process, and ultra violet radiation techniques are not compound specific removal techniques. The processes that are most applicable to the stream characteristics presented in Section 3.1 include liquid ion exchange (extraction), membrane cell electrowinning, sulfuric acid electrolytic cell, ion exchange, and crystallization. The remainder of this section will focus on the details of each process in the context of IBM's application.

3.2.1 Process Screening

All the recovery processes that are the most applicable to the IBM copper chloride stream were screened according to the following criteria:

- high product recovery, (i.e., 1.0 lb copper per gallon of solution),
- processing capacity $\geq$ 250 tons per month of cupric chloride solution,

TABLE 3-2. PROCESSES FOR REMOVING/RECOVERING SOLUBLE COPPER FROM SPENT ETCHANT SOLUTION

Method	Description/Reagents	Products	Applications	Remarks
Liquid Ion Exchange (Extraction)	Chelation with organics-ammonium pyrrolidine, dithiocarbamate, etc.	Copper sulfate solution	Metals concentration prior to processing with other techniques (e.g., electrowinning)	pH required is in the 4 to 6 range, and multistep processing is required to obtain a concentrated solution as metallic copper.
UV Radiation and magnetic field	Radiation ionizes elements, magnets cause diffusion, purifying water	Pure water and brine	Water, sea water	Not efficient for single compound removal
Paper chromato-graphic separation	Mixture of organic solvents causes differential migration of cations	Segregated metals on cellulose	Analytical technique	Copper removal at low concentrations (ppb).
Membrane Cell Electrowinning	Electrowinning of elemental copper	Metallic copper	Metal recovery from ore heap leaching	Byproduct hydrochloric or chlorine gas production is also feasible.
Rotating electrodes	Similar to UV/Magnetic, cations and anions migrate toward electrodes	Pure water and brine solution	Metals recovery	Unknown separation efficiency and energy requirement
Electrolytic Cell: sulfuric acid	Electrowinning of elemental copper	Metallic copper	Acid purification	Byproduct sulfuric acid production feasible.
Ion exchange resins	DOW XF 4195 Resin - selective copper removal by resin	Copper sulfate	Heap leaching (pH 1.5-2.5)	10 normal H_2SO_4 used for resin regeneration which is too concentrated for direct electrowinning
	DOW XF 4196 Resin - selective copper removal by resin	Copper sulfate	Heap leaching	Resin capacity too low at stream pH. Optimum pH range is 2.0 to 3.5.
	Chelex - 100 Resin - selective copper removal by resin	Copper chloride	Heap leaching	Resin capacity too low at stream pH. Optimum pH range is 5.0 to 6.0.
	Permutit-51005 Resin - selective copper removal by resin	Copper chloride	pH 5.0 - 6.0	Resin capacity too low at stream pH.
Precipitation	Evaporation/Crystallization	Dry cake, concentrated copper chloride solution	Waste volume reduction	Concentrates other contaminants, hydrochloric acid production is feasible.
	Thioacetamide	Copper sulfide	Wastewater treatment	Copper removal at low concentrations (ppm). Ammonium acetate formed in HCl solution.
	Dibromo-oxine	Solid complex	Wastewater treatment	Copper removal at low concentrations (ppb). Optimum pH of 8.
	Dialkydithiocarbamates	Solid complex	Wastewater treatment	Copper removal at low concentrations (ppm). Optimum pH of 4.2.
	Polyelectrolytes	Solid complex	Purifying solvents	Copper removal at low concentrations (ppm). Optimum pH of 6.8 - 7.2.
	Aluminum sulfate	Sludge	Wastewater treatment	Copper removal at low concentrations (ppm). Optimum pH of 6.8 - 7.2.

(continued)

TABLE 3-2. (continued)

Method	Description/Reagents	Products	Applications	Remarks
Precipitation (continued)	Insoluble starch xanthate	Sludge	Wastewater treatment	Copper removal at low concentrations (ppm). Alkaline pH required.
	Hydroxide (calcium or sodium)	Sludge	Wastewater treatment	Copper removal at low concentrations (ppm). Optimum pH of 9.
	Hydrogen sulfide	Copper sulfide	Wastewater treatment	Copper removal at low concentrations (ppm). Optimum pH of 8.5.
	Zinc	Metallic copper	Copper solutions	Results in zinc solution requiring disposal.
Reverse osmosis	Selective membrane separation under pressure.	Copper chloride solution	Water recovery	Membranes are chlorine and pH sensitive. Recovery limited by solution concentrations.

- process operability (one shift per day requiring no more than one operator's supervision), and
- proven capability with wastes similar to that described in Section 3.1.

These criteria were established by IBM at the start of the program. Since all the processes considered appear to meet the IBM criteria, Radian developed additional criteria for process screening. These criteria include:

- Number of processing steps required to produce salable product,
- Secondary waste stream generation,
- Modification of waste stream chemistry (e.g., pH adjustment) prior to processing,
- Utility requirements,
- Potential for producing usable byproducts,
- Safety considerations, and
- Potential operating problems.

The results of the screening of each process by these criteria are presented in Table 3-3. From the comparison table, it is apparent that liquid ion exchange (LIX) and ion exchange would require pretreatment of the waste to increase the pH to the appropriate range. This would be accomplished by the addition of caustic soda (sodium hydroxide) or slaked lime (calcium hydroxide) to the waste. Due to the acid nature of the waste, which ranges from 1 to 6 weight percent hydrochloric acid, the neutralizing chemical demand would be high. Caustic requirements would range from 6 to 35 tons per month depending on the acid strength of the waste. Pretreatment with neutralizing chemicals may also impact the ionic balances in both processes. In the LIX process, mass transfer of copper may be inhibited by high chloride concentrations. Both processes will produce brines that will require disposal and are comparable in volume to the original waste stream. Thus,

TABLE 3-3. PROCESS SCREENING SUMMARY

Process	Product	Usable Byproduct(s)	Number of Processing Steps	Secondary Waste Streams	pH Adjustment Required	Utility Requirements	Potential Operating Problems/Advantages	Safety Considerations
Liquid Ion Exchange (Extraction)	Copper sulfate	None	2*	Brine solution	To pH 4 to 6	Electricity for pumping/mixing	Startup during 8-hour operating runs, loss of efficiency due to high chloride	Handling sulfuric acid
Membrane Cell Electrowinning	Metallic copper	Hydrochloric acid	1	Acid solution or sludge**	None	Electricity for electrowinning and pumping	Product contamination by other metals	Potential for chlorine gas evolution during upset
Sulfuric Acid - Electrolytic Cell	Metallic copper	Sulfuric acid	1	Acid solution or sludge**	None	Electricity for electrowinning and pumping	Product contamination by by other metals/possible etching process limitation	Handling of sulfuric acid solutions
Ion Exchange	Copper sulfate or chloride solution	None	1	Acidic brine solution	To pH 2 to 3.5	Electricity for pumping	Capacity loss in cold weather, loss of efficiency due to high dissolved solids background	Handling acid solutions
Crystallization	Copper chloride solution or solids	Dilute hydrochloric acid	2***	Overhead vapors, brine solution	None	Steam, cooling water, electricity for pumping	Startup/Shutdown with short operating runs	Handling dilute acid and solids. Evolution of gaseous HCl

* Requires sulfuric acid regeneration of solvent.

** Small purge stream may be required to avoid high metals concentration in recycled acid.

***Requires scrubbing of evaporator/crystallizer overhead vapors to produce hydrochloric acid and vacuum filtration of concentrate to produce solids which may be considered a third processing step.

these limitations preclude the direct use of these technologies in the treatment of the IBM waste stream.

The three remaining technologies, membrane cell electrowinning, sulfuric acid electrolytic cell, and crystallization appear to be similar with respect to the screening criteria as presented in Table 3-3. Evaporation/crystallization has more diverse utility demands in that steam and cooling water are required for operation. Both electrolytic processes can be operated as single step treatments producing metallic copper and acid for recycle to the etching process. All three processes produce a very low volume brine solution that will require disposal. Safety considerations appear to be comparable for all processes. The evolution of chlorine gas, noted under safety, is an extreme upset case for the membrane cell process and should not be construed as a frequent occurrence. Since these processes reasonably meet the IBM and other criteria established for the copper recovery system, they are recommended for more detailed analysis in the remainder of this program. The three selected processes are described in more detail in the following section.

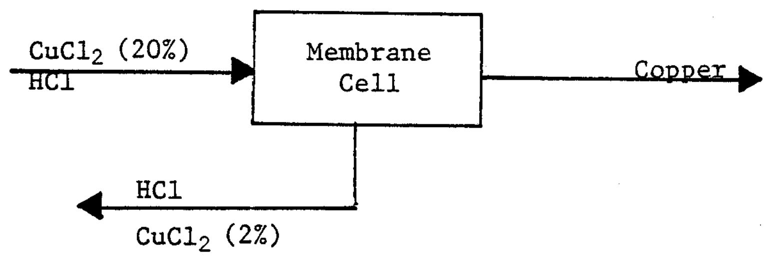
3.3 Potential Recovery Processes

Three processes have been identified as potentially applicable for the treatment of the IBM copper chloride solution. These processes are shown schematically in Figure 3-1. A discussion of the technical aspects, advantages/disadvantages, and relative cost of each of these processes is presented in this section. Pertinent remarks about each process were presented in Table 3-3. The processes are presented in descending order of desirability, based upon our current knowledge of the technologies and IBM's objectives.

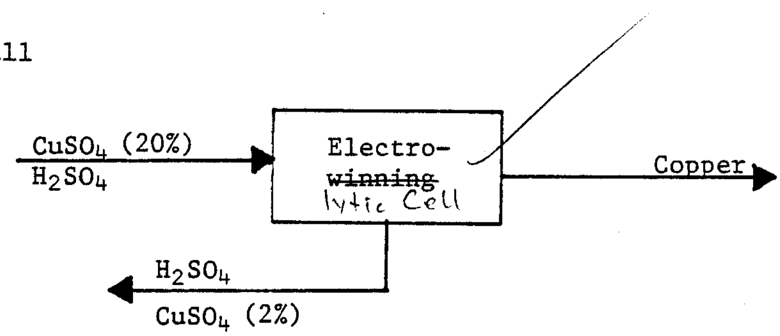
3.3.1 Membrane Cell Electrowinning

The most feasible treatment option for the copper chloride solution involves the use of an electrowinning cell to produce elemental copper. Electrowinning is the process of removing a dissolved metal from solution

1) Membrane Cell Electrowinning



2) Sulfuric Acid Cell Electrolytic



3) Crystallization

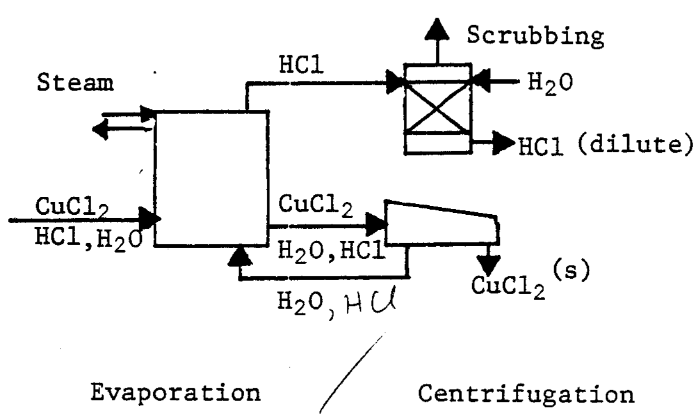


Figure 3-1. Schematic Treatment Options

and plating it on a elemental metal cathode, not necessarily of the same metal. A similar process, electrolytic refining, uses impure metal anodes which are dissolved in the bath solution and redeposited on the cathode of the same metal in the purer state. In primary copper production, electrolytic cell refining is used to produce wire grade product. Ninety-five percent copper anodes are dissolved in a sulfuric acid electrolyte and redeposited on 99.99 percent copper cathodes. In a sulfuric acid medium, the anode generates gaseous oxygen and protons which concentrate the acid, while cupric ion is removed at the cathode. In a hydrochloric acid solution, chlorine gas, rather than oxygen is released because of a lower half-cell voltage potential. This technique is the basis of chlorine and caustic production from salt brines.

Because of the potential for chlorine liberation, and the relative abundance of sulfuric acid available at copper plants, the great majority of electrowinning experience has been with copper sulfate solutions. Heap leaching of low grade copper ore with sulfuric acid produces the electrolyte for most electrowinning operations. Often, this liquid is fairly dilute with respect to copper, containing 2 to 20 grams per liter. The sulfate solution is processed in an electrowinning cell, producing copper and sulfuric acid (3-2, 3-3).

3.3.1.1 Process Description

There has been a recent increase in interest in treating etchant wastes from circuit board production because of increasing production volumes. Several companies have developed systems for treating copper chloride solutions without generating chlorine gas (3-4, 3-5). These systems use a semi-permeable membrane to separate the anolyte and catholyte solutions. Copper ions can migrate through a membrane. Spent solution from the etching bath is circulated through the anolyte section of the electrolytic cell which regenerates hydrochloric acid. The copper ions migrate to the cathode and are deposited in sheets which are periodically removed. Depending on final disposition of the recovered copper, special organic additives can be used in the catholyte to produce a smooth metal deposit (3-6).

3.3.1.2 Advantages/Disadvantages

The major advantage of a membrane cell is that a very pure metallic copper can be produced, with nearly 100 percent recovery. Anolyte from the cell might be recycled to the etchant bath which would reduce the amount of makeup hydrochloric acid required. The operation of the cells requires very little operator attention and the process can be automatically controlled based on the strength of the etching solution. Every 2 to 3 days the cathodes will be lifted from the cell and the recovered copper removed in 1/4 - 3/8" sheets. Impurities in the solution will generally not be removed in the copper plate but will form a sludge in the bottom of the cell over a rather long period of time. This secondary waste will require appropriate disposal. Its volume is far smaller, however, than the existing copper solution.

The major disadvantage of this process is its lack of wide-spread commercial use. Only three companies were identified which manufacture these units (one each in England, Canada, and the U.S.) (3-4, 3-5, 3-7). Very few literature references exist in the Chemical Abstracts or Metals Index. Computer searches of these data bases for a variety of combinations of keywords, such as copper chloride, electrowinning, recovery, copper salts, etc., produced about 100 abstracts of which only 2-3 were applicable to the present problem.

3.3.1.3 Design Considerations

The most process information has been obtained from ERC/Lancy Co. in Zelienople, Pennsylvania. Three of their largest standard models would be required to process IBM's quantity of solution. Each unit is about 3' x 14' x 7' high and contains 108 ft^2 of cathode area. Deposition rates of 0.36 $lb/hr\text{-}ft^2$ have been obtained by Lancy with a similar etching solution (3-5). Each batch of coated electrodes would weigh about 1000 pounds, requiring a hoist for removing the copper. Electrical consumption has not been determined yet for this present application, but should be between 50-150 Kw per 100 lbs of copper, depending on the cell current density required, which is a function of the solution composition. The cells can be automated by monitoring the redox potential of the anolyte solution. A redox value of 510-540 milliVolts is used, and the cell could operate until the redox potential reached 800 mW (3-6). The temperature of the cell liquor is monitored so that if circulating pumps fail, the rectifiers can be turned off before higher temperatures liberate chlorine gas.

3.3.1.4 Relative Costs

Preliminary costs from Lancy indicate that the purchase cost of 3 of their large model standard units, with rectifiers, would cost about $150,000. Costs of facility design, engineering, and installation will be estimated in Task 4 of this study. Electrical costs (based on the energy consumption values presented above) would be about $2.50-$7.50 per 100 lbs of copper at $0.05/KWh. Electrical and labor costs together would be about $60,000 per year. Copper sales, at 50,000 pounds per month at $0.60 per pound would generate revenues of $360,000/year. More accurate estimates of revenues and whether they are sufficient to justify implementation will be determined in the economic evaluation in Task 4.

3.3.2 Sulfuric Acid Electrolytic Cell

As discussed in the previous section, most industrial electrowinning experience has been with acidic copper sulfate solutions. If sulfuric acid could be substituted for hydrochloric acid in the etching process, copper metal could be recovered using a proven commercial process. Radian is not in a position to judge the feasibility of switching acids, and recognizes the potential difficulties with attempted changes in established manufacturing procedures. However, the process is technically viable from a copper recovery perspective and is, therefore, recommended for more detailed analysis in Task 4.

3.3.2.1 Process Description

This process is very similar to the chloride cell system described previously except that a membrane is not used. The electrolyte solution is reduced to a concentration 10 to 15 g/L of copper with a corresponding increase in the acid strength. Metallic copper would be obtained as product, and the regenerated acid solution recycled to the etching baths. Standard lead oxide anodes are used rather than the membrane coated anodes in the chloride process. As with the chloride system, the cell could be tied in directly with the etching bath and the cell operation controlled by the copper concentration.

3.3.2.2 Advantages/Disadvantages

The primary advantage of this process is that its use for copper recovery is a standard commercial technique and well documented in other industries. Standard equipment and technical data from manufacturers are available. There is no possibility of chlorine gas generation with this system. The primary disadvantage may be the impracticality of using sulfuric acid in the etch bath. Another concern may be sulfate concentrations in the rinse tanks due to drag out. This may require changes in plant water treatment techniques or changes in the facility discharge permit.

3.3.2.3 Design Considerations

Space and power requirements for the sulfuric acid system are comparable to those for the chloride system. At this time, it is unknown what changes in the manufacturing process area would be required to use sulfuric acid in the etch bath. Any modifications required for rinse water treatment are also unknown. Should IBM concur with Radian's recommendation that the sulfuric acid electrolytic cell technology be evaluated in more detail, the substitution for sulfuric acid for hydrochloric acid in the etch baths must be addressed by IBM.

3.3.2.4 Relative Costs

Capital costs for the cells should be lower than the chloride system because less exotic anodes are required. However, there will be additional costs associated with manufacturing process modifications for using sulfuric acid, and costs associated with changes in rinse water treatment. Operating costs for the recovery process would be comparable to the chloride process.

3.3.3 Evaporation/Crystallization

A third technically feasible option for processing the solution produces a concentrated copper chloride solution or copper chloride crystals. The amount of spent etchant solution is too small and the one shift operating requirement preclude a continuous evaporator/crystallizer. It would be possible, however, to build a batch unit (3-8). This would be compatible with one shift per day operation.

3.3.3.1 Process Description

Evaporation/crystallization involves heating the solution to evaporate water and hydrochloric acid. Steam jacketed kettles (glass lined for corrosion protection) would be used to produce a slurry of copper chloride crystals which is intermittently withdrawn and centrifuged or filtered to produce a product containing 2 to 10 percent moisture. A dryer can be used to remove the remaining water if necessary. The vapor from the kettles is condensed, producing a HCl stream of about the same strength as the spent etchant. The stream could be concentrated to yield a higher strength acid for recycle, however, it may not be economically justified. In that case, the stream would have to be neutralized prior to discharge. At this time the overall technical feasibility is uncertain due to vapor pressure considerations and the ability to drive off HCl from solution at reasonable operating temperatures. Resolution of this question will be addressed in Task 4 of this study.

3.3.3.2 Advantages/Disadvantages

It may be feasible to design a small system which could operate on a daily basis. Generally, these processes are operated continually due to heating requirements and potential problems associated with startup and shutdown. Larger processing capabilities would be more economical and could be run less frequently, but would require continuous attention during processing.

Major disadvantages include steam requirements of one pound per pound of water evaporated, additional mechanical complexity because of the several pieces of equipment required, and the dangers involved with evolving gaseous HCl. The operation of the unit may not conform easily to IBM's criteria of 8 hours per day. The dilute HCl solution may require concentration before recycle to the etch bath. If not recoverable, the HCl solution would require neutralization before discharge.

3.3.3.3 Design Considerations

Because of the small volume of solution to be processed, a custom design of small scale equipment might have to be assembled from individual components. The presence of HCl requires corrosion resistant materials, such as a glass lined tank. This could be steam jacketed and equipped with a condenser to cool the vapor. A pilot scale centrifuge or filter could be used to dewater the solids.

3.3.3.4 Relative Costs

The capital costs for the evaporator/crystallizer system should be in the range of the electrolytic processes. Operating costs will probably be significantly higher due to steam and cooling water requirements. Concentration or treatment of the acid vapor stream will also be a significant operating cost.

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4.0 MARKET ANALYSIS

This section discusses the end uses, prices, and potential purchasers of metallic copper and copper compounds which can be produced from a spent copper chloride solution. The products addressed in detail in this section are metallic copper, copper chloride, and copper sulfate. They were selected for indepth economic analysis on the basis of technical feasibility of recovery, high market value, or low recovery cost. Copper hydroxide and copper sulfide salts were also considered in the market survey. However, the demand for these compounds is low and no potential buyers were found. Thus, these compounds were not considered further.

Section 4.1 describes uses, prices and purchasers for metallic copper; Section 4.2 addresses the market potential for copper chloride; and Section 4.3 discusses the demand for copper sulfate. Section 4.4 explains the methodology used for the market analysis.

4.1 Metallic Copper

4.1.1 Prices and Purchasers

The current market for metallic copper is depressed. Nonetheless, there may be opportunities for recovered metallic copper sales.

The market for copper has been affected by the world-wide recession and decreased industrial activity since 1980. The domestic copper market suffered a sharp downturn in 1982, as demand, production, prices, and profitability all declined sharply. Demand for copper fell about 11 percent in 1982, to the lowest demand level since the 1975 recession (4-1).

One effect of the price drop in 1982 was the cutback and closure of U.S. production facilities. The 1982 domestic production level fell 24 percent, to 1.28 million tons of copper. This was the lowest production level in 15 years.

Principal mining states are Arizona, with 66 percent of production, and Utah, with 17 percent. Ten other states also have some copper mining activity. In 1983, of 35 principal mines, 14 were closed all year. Half of the remaining mines operated at reduced capacity (4-2). Domestic producers compete with foreign producers from countries which rely on exporting copper as a source of foreign exchange. Foreign producers increased production when prices fell, in order to generate revenues and increase foreign exchange (4-1). Exacerbating the problem for domestic producers is the competitive price of foreign produced copper. In 1984, Chilean and Peruvian companies have had production costs of $.55 to $.60/pound, whereas American companies' costs have been closer to $.85/pound. Thus, domestic companies are buying from exchanges, rather than producing the metal themselves (4-1).

Some U.S. producers incurred substantial losses in 1982 and were forced to increase their debt burden at high interest rates. Unless prices increase and appear to remain above production costs in the long term, it is expected that high cost facilities, closed in 1982, will remain shut down. Projections by the U.S. Department of Commerce show continued low prices for the near term, resulting in lost U.S. production capacity (4-1).

The U.S. Industrial Outlook projects spot shortages occurring in the copper market by 1987, if an economic recovery continues. Serious domestic copper shortages could occur by the mid-1990s if facilities close permanently or new mine development does not occur in the 1983-87 period. This is due to the long lead time required for mine development (4-1).

According to the U.S. Department of Commerce, the demand outlook for copper from 1984-87 is mixed. Demand is expected to increase to about 2.43 million tons, assuming increased economic activity (4-1). The price for electrolytic wire bars has dropped from $0.85/pound in 1981 to $0.74/pound in 1982, to $0.70/pound by December 1983 (4-3). Since the beginning of 1984, the average domestic price has remained at about $0.73/pound (4-4).

Spot prices are $0.66-0.67/pound (4-5). The drop in price in 1982 meant that domestic prices were below the cost of domestic production, which varied between $0.80 to $1.20 per pound in 1982.

4.1.2 Potential Purchasers

The domestic price for electrolytic wire bar affects the local price paid for scrap copper. Scrap purchasers' prices are determined by the price refiners are willing to pay. Thus, the $0.73/pound price, less refiner's profit, is a clear upper bound on the price local scrap dealers will be able to offer for recovered copper.

In a survey of Austin scrap dealers, prices in the $0.40s to $0.60s/pound were quoted. Purity and quantity are important factors in determining price. All prices quoted assumed Number 1 grade copper, which is a high purity copper. The quantity potentially for sale from IBM was perceived as a positive factor by those interviewed, as currently the scrap copper market is composed of infrequent sellers, such as plumbers, who offer small quantities. Two scrap dealers indicated an interest in negotiating a long-term contract. If this were done, the price could be tied to traded copper prices, such as the price on the London Metals Exchange (LME). All of the scrap purchasers contacted showed an interest in negotiating with IBM about the purchase of copper.

The scrap purchasers contacted were selected at random from the Austin telephone directory. Their comments are presented on Table 4-1. Phelps-Dodge in El Paso was also contacted, as it is the closest of the large refiners. Phelps-Dodge was not interested in purchasing scrap copper.

TABLE 4-1. POTENTIAL PURCHASERS OF METALLIC COPPER

Company Name	Phone	Contact	Price Quoted	Comments
Southside Recycling	385-5735	John Weinstein	$0.45 - 0.55	Very interested in long term contract. Could offer higher price than that quoted, based on LME.
Newell Recycling	442-2384	N/A	∿$0.52/lb	Price quoted is for over 100 pounds, #1 grade.
Beaman Recycling	385-6935	Richard Beaman	upper $0.50's to $0.60's/lb	Assumed #1 grade, large quantities.
Gardner Recycling	477-3900	N/A	Unspecified	Required analysis of product before price could be quoted. Also depends on form (slag, solid).

4.2 Copper Chloride

4.2.1 Prices and Purchasers

Copper chloride is used in a wide variety of industrial and chemical applications. Important uses are in organic chemical synthesis, textile dyeing, paint pigmentation and wood preservation. It also can be used in pollution control, as a gasoline additive or to absorb nitrogen oxide gases.

Producers of copper chloride are listed on Table 4-2. The two companies of most interest on the list are Kocide and Southern California Chemical, since they are located in Texas.

The published price for copper chloride (dry solids) is $0.90/pound when purchased in carload quantities (4-5).

4.2.2 Potential Purchasers

The Austin/San Antonio area does not provide an outlet for recycled chemical products. Several area business people remarked that they were not aware of any companies in this area which handled bulk quantities of recycled chemicals (personal communication with employees at Southside Recycling, Stull Chemical Company, and Safeway Farm Products). To date, neither Austin nor San Antonio has had the kinds of industries, such as chemical formulators or manufacturers, which would support chemical recycling. Thus, Houston or Dallas will probably offer the best markets for recycled copper chemicals.

Table 4-3 lists the comments of company representatives who expressed an interest in purchasing copper chloride, in solution or salt form. Three of the companies, Kocide, Southern California Chemical, and Cuproquim, are copper chemical manufacturers; two companies are waste exchanges; and two of the companies are chemical recyclers.

TABLE 4-2. U. S. COPPER CHLORIDE PRODUCERS

Company	Location
Kocide Chemical	Houston, Texas
Harshaw/Filtrol Partnership	Elyria, Ohio
McGean Inorganic Division	Cleveland, Ohio
Southern California Chemical Co.	Garland, Texas Sante Fe Springs, CA Union, Illinois

Source: SRI 1984 Directory of Chemical Producers

TABLE 4-3. POTENTIAL COPPER CHLORIDE PURCHASERS

Company Name	Phone	Contact	Comments
Bayport Chemical Services	(713) 472-5081	Don Barnes	Indicated an interest. Price would be ∿$0.10/lb of copper in solution. Price for salts not quoted. Quantity available is probably too large for Houston market alone.
Southern California Chemical	Garland: (214) 272-4528; New York (201) 636-4300	Pete Fintschents Adam Feldman	Copper chloride must be 16 to 18 ounces/ gallon of solution. Company would like to talk with generator as they may already be in communication with the IBM and did not want to "underbid" themselves.
Custom Interchem	(713) 721-8084	Jim Turpin	Indicated interest. Price would be based on contaminants.
Midwest Industrial Waste Exchange	(314) 231-5555	Clyde Wiseman	Non-profit waste exchange services to 39 states, although most buyers/sellers are in Midwest.
Kocide	(713) 433-6404	Don Ingram	Interested. Currently they do not buy copper compounds, due to the price of copper. Would pay only scrap prices, as product is a sidestream, not a commodity.
Houston Waste Exchange	(713) 651-1313	Jack Westney	Non-profit waste exchange. Provides a listing service for buyers and sellers.
Cuproquim S.A.	(713) 827-1134	Jerry Mohn	Interested in purchase of copper chloride solution as is for $0.15/lb of copper. Would provide a tank car for client's site and arrange transportation. Indicated that processing to dry concentrated form would be of no greater interest and would pay approximately same price.

The primary purchasers of copper chloride appear to be the three copper chemical manufacturers. For example, recyclers or waste exchanges in the Houston area, although expressing some interest in handling the product, will most likely serve as an intermediary and will re-sell the product ultimately to Kocide. Thus, IBM's bargaining position is fairly limited. The market for copper chemicals is specialized, with only a few potential purchasers. Complicating the situation for IBM is the likelihood that potential buyers in one geographical area, such as Houston, are in communication with each other. Thus, the price received for the product will depend in large part upon IBM's negotiating skill. The market is not highly competitive, with many buyers and sellers, such as in the scrap copper market discussed in Section 4.2.1.

4.3 Copper Sulfate

4.3.1 Prices and Purchasers

Copper sulfate is one of the most important copper chemical products. Industrial applications include use as an activator in froth flotation of sulfide ores, wood preservation formulations, copper electroplating, azo-dye manufacture, textile dyeing mordant, petroleum refining, and in the manufacture of a variety of copper chemicals, such as copper carbonate and copper hydroxide (4-6).

Domestic demand for copper sulfate has been the same for 30 years, at approximately 40,000 tons per year. Higher production levels in the 1940's and 50's were the result of high foreign demand. Exports declined after the 1950's, due to changes in foreign agricultural usages. Generally, over the past 30 years, uses of copper sulfate have been evenly divided between the agricultural and industrial sectors. Until 1990 copper sulfate demand is expected to remain at 40,000-44,000 tons per year.

Producers of copper sulfate are distributed throughout the country. Table 4-4 lists the names and locations of producers. Two facilities, not on the list, closed from 1981 to 1983, while one, International Metals Recycling, started production. Although capacity estimates are not available, Phelps-Dodge and Tennessee Chemical Company reportedly account for 60-70 percent of output (4-6).

Published copper sulfate prices have remained the same since 1981 at $0.45/pound. Actual prices have fallen as low as the low $0.30s in 1982. Prices rose to the upper $0.30s in 1983. The quoted price in 1984 remains at $0.45/pound, when bought in 100 pound bags. The price of copper sulfate is tied to the price of copper and will increase when the metal's price rises (4-11). One small distributor of copper sulfate noted, however, that they paid $0.55/pound for half a truckload on a semi-annual basis (personal communication with Larry Copeland, Humco Lab). Thus, the prices quoted in publications may not represent the price which could be negotiated with a small, infrequent purchaser of copper chemicals.

4.3.2 Potential Purchasers

Purchasers of copper sulfate can be categorized as chemical recyclers, chemical formulators, distributors, and end-user industries, such as electroplaters or petroleum refiners. It was assumed that end users, such refineries, would not be interested in the quality of compound produced by the client. Potential buyers from all other categories were contacted to determine their interest. Table 4-5 lists the companies who acknowledged an interest in purchasing or listing copper sulfate. As discussed in Section 4.2.2, the Austin/San Antonio area does not provide a local market for copper compounds.

Southern California Chemical Company and Kocide are large manufacturers/distributors of copper compounds in the Texas area. Both companies

TABLE 4-4. COPPER SULFATE PRODUCERS
(CUPRIC)

Company Name	Location
Mallinkrodt Chemical Co. (subsidiary of Avon Products, Inc.)	St. Louis, MO
Chemtech Industry	Brooklyn, NY
C. P. Chems, Inc.	Sewaren, NY* Powder Springs, GA**
Kocide Chemical Co.	Houston, TX
Imperial West Chemical Co.	Antioch, CA
Liquid Chemical Corp.	Hanford, CA
Old Bridge Chemical Co. Inc.	Old Bridge, NJ
Phelps-Dodge	El Paso, TX
Philipp Brothers Chems. Inc.	Bowmanstown, PA Quancy, IL
J. T. Baker Chemical	Phillipsburg, NJ
Southern California Chemical	Garland, TX Santa Fe Springs, CA Union, IL
Tennessee Chemical	Copperhill, TN*
Van Waters and Rogers	Kent, WA Pinehurst, ID
International Metals Recycling	Casa Grande, AZ

*Also produce basic.
**Produce basic only.

Source: SRI 1984 Directory of Chemical Producers; Mannsville Chemical Products Synopsis

TABLE 4-5. POTENTIAL COPPER SULFATE PURCHASERS

Company Name	Phone	Contact	Price Quoted	Comments
Southern California Chemical Company	Garland: (214) 272-4528 New York (201) 636-4300	Pete Fintschenko Adam Feldman	None quoted	Interested, but would not give an estimate, as they were concerned that they may already be in communication with the client, and so may "underbid" themselves. Product needs to be in crystal form, with heavy metals under 5 ppm. Especially concerned about lead.
Custom Interchem	(713) 721-8084	Jim Turpin	None quoted	Interested, but did not seem familiar with copper compounds. Price would be based on copper content of solution or compound.
Midwest Industrial Waste Exchange	(314) 231-5555	Clyde Wiseman	None quoted	Functions as a listing service for 39 states, mostly in Midwest.
Kocide Chemical	(713) 433-6404	Don Ingram	Scrap prices, based on copper content	Interested in copper compounds, although currently they do not purchase any, due to the price of copper. Price would be well below $0.60-0.70/pound of copper
Houston Waste Exchange	(713) 651-1313	Jack Westney	See comments	Waste exchange run by Houston Chamber of Commerce. Provides a listing service to generators and sellers.
Bayport Chemical Services	(713) 472-5081	Don Barnes	None quoted	Interested. Price for salt not quoted. Would be value of copper content.

expressed an interest, but indicated that they would need to talk directly to the generator in order to negotiate.

Two other possible outlets for copper sulfate are waste exchanges, one in Houston and the other in St. Louis. Both function as listing services, whereby buyers and sellers are put in touch with each other and confidentiality is maintained.

The Metal Finishing Suppliers Association was contacted in order to determine the location of electroplaters and their demand for copper sulfate in the Texas area. Although there are electroplaters in the Texas area, they purchase specialty chemical formulations, rather than the copper compound alone. Companies producing the formulations are not generally located in this area (personal communication, King Rauhly, Metal Finishing Suppliers Association).

4.4 Market/Process Selection Methodology

The methodology combined engineering and economic analysis, with feedback from the engineering assessment to the market study. The steps in the market study included:

1) identification of possible products, based on engineering feasibility;

2) determination of end uses and prices for products identified in Step 1;

3) narrowing the range of products based on further engineering study of process feasibility and cost; and

4) determination of market and prices for final list of products from Step 3.

These steps are discussed in greater detail below.

4.4.1 Identification Possible Products

The initial list of products considered consisted of five copper compounds, metallic copper, hydrochloric acid, and chlorine. The five compounds included copper chloride, copper sulfate, copper oxide, copper hydroxide, and copper sulfide. It was assumed that IBM could use the hydrochloric acid in their production process.

4.4.2 Determination of End Uses

End use information was obtained from publications such as Chemical Products Synopsis, Encyclopedia of Chemical Technology, Minerals Facts and Problems, 1983 U.S. Industrial Outlook, Minerals Yearbook and the 1983 Thomas Register of American Manufacturers. In addition, copper, recycling, and electroplating trade associations were contacted. Trade associations contacted are listed in Appendix A.

Current prices for copper compounds and metallic copper are listed in the Chemical Marketing Reporter.

In addition, a literature search was conducted in 6 databases covering over 2900 publications for recent articles concerning the copper and copper chemical markets.

4.4.3 Establish a Range of Products

Based on additional engineering analysis of system design and cost, the range of products was reduced from the initial list. At this stage, the most attractive products appeared to be metallic copper and copper chloride solution or salt, with hydrochloric acid as a by-product.

4.4.4 Determination of Markets and Prices

Radian contacted over 20 different companies, in locations inside and outside of Texas, in order to determine if they were potential purhcasers of copper compounds or metallic copper. A list of the companies contacted appears in Appendix B. Companies were contacted for several reasons:

- they produced or sold copper chemicals, and so might use a copper-based feedstock;
- they functioned as waste exchanges, either commercial or non-profit; or
- they bought and sold metallic copper. Only companies in Austin were contacted. Because of the large number of buyers of scrap copper, it was assumed that price will not vary significantly from one city to the other, and selling to a local buyer will minimize transportation costs.

REFERENCES

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4-3 Chemical Marketing Reporter, Jan-March, 1984.

4-4 Survey of Current Business, Feb. 1984, Vol. 64, No. 2.

4-5 Chemical Marketing Reporter, March 12, 1984.

4-6 "Copper Sulfate", Chemical Products Synopsis, Jan. 1984, Mansville Chemical Products Corp.

APPENDIX A

COPPER, ELECTROPLATING AND RECYCLING TRADE ASSOCIATIONS CONTACTED

COPPER, ELECTROPLATING AND RECYCLING TRADE ASSOCIATIONS CONTACTED

National Recycling Coalition	(402) 277-5566
National Association of Recycling Industries	(212) 867-7330
Texas Solar Energy Society	(512) 472-1252
Copper Development Association	(212) 246-1201
American Electroplaters Society	(305) 647-1197
Metal Finishing Suppliers Association	(313) 646-2728

APPENDIX B

TELEPHONE CONTACT REPORTS WITH BUSINESSES

Contact reports are in alphabetical order by Company name. The company name is in the "Person Called" blank.

RADIAN CORPORATION

TELEPHONE CALL RECORD

- [ ] Incoming Call
- [ ] Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: Bayport Chemical Service	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Don Garns -

4/23 Indicated an interest in copper compounds and chlorine gas. No prices were mentioned; he said he would check around and see who might be interested in it.

Action: Will call back again.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: Bayport Chemical	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Don Barnes
Contact # 2
1) Definitely interested in Chlorine gas. Ballpark estimate is $150/ton. He would be able to sell the quantity available in Houston area.

2) Said he'd talked to people who said they thought the product is too dilute to be of interest. These people were looking at TI & IBM's waste streams. Also, was quite contaminated, they thought.
I told him the salt would be 99.5% pure copper chloride & this seemed to interest him much more.
He said the copper chloride solution would be worth about $.10/lb of copper. The copper content alone is worth $.80 ~~-~~ 1.00/lb of copper, but it is worth less since its got the chlorides ~~&~~ or sulfates present.
He did not know if copper chloride or sulfate was more valuable.
This much copper product would need to ~~be~~ be shipped elsewhere as it is too much for Houston to handle regularly. Costs $.10/lb to ship to East Coast. Product needs to be worth at least $.50/lb to cover handling. Definitely interested

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.		Distribution
Project Name		
Date	Time	
Person Calling: Kathey Ferland.	Activity	
Person Called: Beaman Recycling	Activity	
General Subject		

TOPICS DISCUSSED AND ACTION TAKEN

Richard Beaman

if #1 grade, would be willing to pay from ~~top~~ upper $.50s to .60s/pound of copper.

He was very interested.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ierland	Activity
Person Called: Chemical Exchange Inc.	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Ann Wayfer

they don't buy copper, only interested in sulphur

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

- [x] Incoming Call
- [ ] Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: Cuproquim	Activity
General Subject: 713-827-1134	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

5/22/84

Jerry Mohn - represents Cuproquim S.A. (a Mexican company) in the U.S. US company is called Chippenham Corp. in Houston

1) Very interested in copper chloride solution as is for $0.15 lb/copper. They will provide a rail tank car and arrange to haul it away periodically

2) He was not particularly more interested in a copper chloride salt & would not pay much more for it. He commented that the recovery process equipment is very expensive as one must use titanium alloy equipment due to corrosive nature of solution.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time

Distribution

Person Calling: Kathey Forland	Activity
Person Called: Custom Interchem Inc.	Activity
General Subject	

TOPICS DISCUSSED AND ACTION TAKEN

Jim Turpin 713 721-8084

is interested in copper compounds in solution or salt, although solution is difficult to ship.

Price would be based on copper content. He was very interested in knowing quality of product.

He would need to call around to his contacts to see if anyone needed copper compounds.

(Note: he did not seem familiar with copper compounds)

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathy Terlard	Activity
Person Called: Gardner's Recycling	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Dale of Gardner's 477-3900

he said he needed to know the form (slag or solid) before he would know the price he could offer. Also, ~~was~~ would need to be analyzed before he could make estimate.

was interested, however.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: Great Gulf Minerals & Chemicals	Activity
General Subject: 713-799-9081	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

not interested in any of products mentioned

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	Distribution
Project Name	
Date	Time
Person Calling: Kathey Ierland	Activity
Person Called: Houston Waste Exchange	Activity
General Subject	

TOPICS DISCUSSED AND ACTION TAKEN

Jack Westney 713-651-1313

They publish an inventory list once a month, for buyers + sellers. It costs $15/yr to subscribe. $10 for an advertisement.

He referred me to Chemical Exchange, for commerical chemical recycling.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

- ☐ Incoming Call
- ☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: HUMCO Lab	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

214-793-3174
Larry Copeland

They repackage bulk copper sulfate (crystal & powder)

They pay $55/100 pound bag for a half truckload every 6 mths.

They buy from Tenessee Copper, & 2 distributors: Ashland & McKesson.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: KMCO, Inc.	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Randy Detmar ~~7++~~ 713-328-3507

Company does not use copper compounds.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date: 4/5/84	Time
Person Calling: Kathey Ferland	Activity
Person Called: KOCIDE	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Bill Greeny 713-433-6404

They do not currently purchase copper compounds but are considering how they might use them. They do not buy it due to price of copper. He said they had looked at TIs & IBMs byproducts, but currently had no plans to buy it. He referred me to:

Don Ingram - Industrial Products Manager. Said he was interested in most of the compounds, but would only pay scrap copper prices, based on copper content.

Copper chloride solution is difficult to deliver. Salts would easier to handle.

Cannot have any organics or heavy metals ~~[illegible]~~ impurities down to below 1% (Ex: aluminum)

Price they would pay would be well below $.60-.70/ pound copper. He would not be more specific than that. Remarked that we would be selling a sidestream, not a commodity, so must take a lower price.

(See comments on phone conversation with Bill McDonald of McHouston

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date: 4/25	Time
Person Calling: Kathey Ferland	Activity
Person Called: ~~Bo~~ McHouston Co.	Activity
General Subject:	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

4/16 Bob McDonald -
Contact #1 - ~~C~~Indicated a strong interest in electronic chemicals, which he assumed this was. Was interested in ~~all~~ copper sulfates or chloride, as well as chlorine gas. Would check around for prices.

He sent materials on his company, buying & selling of chemicals.

4/25 Contact #2 - he said he was not interested in the copper compounds as he had talked to Don Ingram at Kocide & Kocide was not interested as they had decided it was too low a value product for their interest. He asked if I was working for IBM, as Ingram had told him they were currently negotiating with IBM (unclear what for). I told him I could not discuss that with him. He also added that the chlorine gas would not be worth the trouble to handle.

Note: His attitude, after the discussion with Kocide, had changed considerably. From his comments, it appears that Kocide may not be interested, contrary to their statements when I contacted them. (See Kocide contact report)

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.		Distribution
Project Name		
Date	Time	
Person Calling: Kathy Ferland	Activity	
Person Called: Midwest Industrial Waste Exch.	Activity	
General Subject		

TOPICS DISCUSSED AND ACTION TAKEN

Clyde Wiseman - 314-231-5555
serves companies in 39 states, does have some listings near Gulf area.

His agency serves as a listing service. He sent materials on how to join, etc. They do list copper compounds.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathy Ireland	Activity
Person Called: Newell Recycling	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Austin 442 2384

	over 100 pds	under 100 pounds
#1 grade	$.52/pound	.50
#2 grade	.43	.40

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: Palmer House Chemical Corp.	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

713-672-2451

Does not use copper compounds or chlorine gas.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.		Distribution
Project Name		
Date	Time	
Person Calling: Kathey Ferland	Activity	
Person Called: Phelps-Dodge	Activity	
General Subject		

TOPICS DISCUSSED AND ACTION TAKEN

El Paso 915-778-9881

Shirley

~~they are a large refiner, they do not purchase copper,~~ etc.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.	Distribution
Project Name	
Date	Time
Person Calling: Kathey Ferland	Activity
Person Called: Safeway Farm Products	Activity
General Subject	

TOPICS DISCUSSED AND ACTION TAKEN

Jim Bolden 478-2554

They buy copper sulfate already packaged. They do not want to handle bulk copper sulfate.

He did not know of anyone in ~~town~~ Austin who handles bulk copper compounds. Said he would call back if he thought of something.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.			Distribution
Project Name			
Date	Time		
Person Calling: Kathey Ferland	Activity		
Person Called: Southern Calif. Chemical	Activity		
General Subject: See below -			

TOPICS DISCUSSED AND ACTION TAKEN

Pete Fintschenko, 214-272-4528

Company buys copper chloride. In principle, is interested in all copper compounds (sulfate, chloride, etc.)

Specifications: copper chloride: 16-18 ounces/gallon of copper chloride (liquid)

Copper sulfate: crystal form; absence of heavy metals, especially lead, under 5ppm.

Referred me to Adam Feldman in New York for prices.

Signature Kathey Ferland

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.		Distribution
Project Name		
Date	Time	
Person Calling: Kathey Ferland	Activity	
Person Called: Southern California Chemical	Activity	
General Subject: See below		

TOPICS DISCUSSED AND ACTION TAKEN

Prices for copper compounds:
Adam Feldman - 201-636-4300 New York

He asked if the solution byproducts were from a spent etchant. He preferred to deal directly with the seller, as he was concerned that his company may be in negotiations with the seller and he might undercut his bid.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.		Distribution
Project Name		
Date	Time	
Person Calling: Kathey Ferland	Activity	
Person Called: Southside Recycling Com.	Activity	
General Subject		

TOPICS DISCUSSED AND ACTION TAKEN

John Weinstein ~~444 2228~~ 385-5735

Asked him about copper compounds & metallic copper. He thought metallic copper was most marketable. He was interested in purchasing copper, quoted a price of $.50/pound (at this point he did not know the quantity involved.)

He did not think any refining capacity existed in Austin for copper solutions. No chemical recyclers in Austin.

Currently, the scrap market $.45 - .55 /pound, with the higher price paid to the larger sellers. Plumbers, small sellers, characterize Austin sellers.

His use for it would be to sell it to refiners, & they turn it into metallic copper.

He does not expect price to change dramatically or go up. He would offer a higher price than that quoted based on long-term contract for large amounts. Could tie contract to London Metals Exchange price. He thought the amount offered would be attractive to handle.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

- ☐ Incoming Call
- ☐ Outgoing Call

Project No.		Distribution
Project Name		
Date	Time	
Person Calling: Kathey Ferland	Activity	
Person Called: Stull Chemical Co.	Activity	
General Subject		

TOPICS DISCUSSED AND ACTION TAKEN

San Antonio

They do not buy copper compounds. Did not know of anyone in Austin / San Antonio area who handled bulk recycled chemicals or would be interested in them. Suggested trying Houston

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

- [ ] Incoming Call
- [ ] Outgoing Call

Project No.	
Project Name	
Date	Time
Person Calling: Katrey Ferland	Activity
Person Called: Tech Rad Waste Exchange, Oklahoma	Activity
General Subject	

Distribution

TOPICS DISCUSSED AND ACTION TAKEN

Bob Naylor - 405-528-7016

The waste exchange idea did not get off the ground.

Signature

RADIAN CORPORATION

TELEPHONE CALL RECORD

☐ Incoming Call
☐ Outgoing Call

Project No.		Distribution
Project Name		
Date	Time	
Person Calling: Kathey Ferland	Activity	
Person Called: Trinity Brass & Copper	Activity	
General Subject		

TOPICS DISCUSSED AND ACTION TAKEN

~~[illegible]~~ 214-742-5488

Not interested in copper or compounds.

Signature