PRELIMINARY HAZARDS ANALYSIS

OF THE

CHEMICAL PLATING WASTE TREATMENT PROCESS

Prepared for:
CHEMICAL SCIENCE AND TECHNOLOGY DIVISION
WASTE MANAGEMENT GROUP (CST-7)
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO
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by:
Santa Fe Engineering, Ltd.
Santa Fe, New Mexico

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1. INTRODUCTION

A Preliminary Hazards Analysis (PHA) of the Chemical Plating Waste Treatment Skid design is required by the Laboratory to assess the potential hazards associated with operation of the treatment skid in the processing of the Laboratory’s plating waste. The Chemical Plating Waste Treatment Skid design has been completed, but construction awaits permitting and selection of the fabricator. Conducting the PHA prior to construction enables potential hazards to be identified which could impact the operators or Laboratory employees, the public, or the environment, and will permit modification to the design and/or to the operating instructions prior to construction.

PHA is a semiquantitative method for identifying the broad range of potential hazards and accident scenarios, with corresponding estimated frequency and consequences. The more rigorous Probabilistic Risk Assessment (PRA) is beyond the scope of this report, but may be conducted for the most serious risks identified by this PHA. The PHA methodology involves the assessment of each step of the process for potential worst-case accident scenarios, then placing each conceived accident scenario into one of four predefined consequence categories. The consequence of each accident scenario is considered for the worker, the co-located worker, the public and/or the environment. Consequence likelihood, or frequency is then evaluated according to five predefined categories. Risk ranking then follows from the consequence and frequency classification. Section 4.1 of this report defines PHA methodology in greater depth.

Detailed processing steps were defined from the chemical plating waste treatment operating instructions prior to conducting the PHA. The process of defining accident scenarios and evaluating consequence and frequency categorization for each process step was conducted during a four-day intensive session with Lauren Ames, Dave Munger and Scott Carson of Santa Fe Engineering, and with Leo Beckstead representing Los Alamos National Laboratory (LANL) attending part-time.

This PHA is intended to provide insight into the potential hazards associated with operation of the process equipment during treatment of chemical plating waste. The PHA process was considered by the team members to provide a highly effective means of reviewing the safety of the design in conjunction with the operating instructions. By breaking the process down into discrete steps, and conceiving in group fashion all possibilities for hazard from malfunction and/or operator error, a degree of insight into potential hazards was achieved not otherwise possible.

The greatest hazard risk associated with treatment of chemical plating waste is considered to be the potential for exposure to toxic liquids and/or gases. Plating waste can contain cyanide complexes which, if acidified, will generate lethal hydrogen cyanide gas. Similarly, operator exposure to highly toxic hydrogen sulfide gas could occur with the use of sodium sulfide as a process reagent. Detailed operating instructions and equipment control interlocking have been designed to minimize inadvertent operator risk, however hazardous failure scenarios do exist and are evaluated in this report. This report is intended to identify potential hazards associated with the operation of the treatment skid, but it does not address hazards associated with transport and storage of chemical plating waste, chemical reagents and treatment products at the Hazardous Waste Treatment Facility (HWTF). The hazards associated with the Laboratory waste treatment, storage and handling facilities have been addressed by TSA-6 \(^{(1)}\). Similarly, industrial hazards associated with operation of the treatment equipment which are covered by LANL Standard Operating Procedures (SOPs) and which are not specific to the treatment of plating waste are considered outside this report’s scope.

\(^{(1)}\) Risk Assessment of CST-7 Proposed Waste Treatment and Storage Facilities, Volumes I & II, Kent Sasser. TSA-6, June 1994
The process is outlined in Section 2 to provide an overview of the operations associated with plating waste treatment, and the chemicals used and produced. Appendix A contains the flow diagrams showing the individual treatment steps which the PHA addresses. Section 4 summarizes the results of the PHA, and presents a discussion of the most serious risk rank scenarios. Recommendations for reducing risk are summarized in Section 5.
2. PROCESS

2.1. OVERVIEW

The Chemical Plating Waste (CPW) treatment system is intended to treat aqueous waste solutions primarily derived from metal plating operations to remove the hazardous components. The CPW will remove hazardous waste constituents to levels several orders of magnitude lower than the original feed by making use of the available EPA-approved Best Demonstrated Available Technology (BDAT) processes for electroplating wastes. These waste solutions are considered to be in one of three forms:

1. Listed Wastes -- These wastes are "listed" by the EPA as specifically hazardous wastes requiring specific handling. Special rules drive their treatment and disposal. Actions resulting from these rules will be pointed out in these Operating Instructions.

2. Characteristic Wastes -- These wastes possess one of several characteristics considered by the EPA to define "hazardous." These characteristics include corrosivity, reactivity, flammability and toxicity.

3. Mixed Wastes -- These wastes possess one of the characteristics above plus a radioactive component.

Typical waste solutions requiring treatment are cyanide plating wastes, chromic acid plating wastes, metals plating wastes and ammonia-bearing plating wastes; or solutions with similar compositions. Any of these wastes may be considered mixed wastes if a component of depleted uranium is present.

The general treatment process consists of reacting the waste solution with a variety of chemical reagents in order to convert the hazardous component into harmless byproducts or immobilized solid material. The treatment of choice and the order of treatment depends on the analysis of the solution mixture. Cyanide for instance will be decomposed into N₂ and CO₂ gasses while chromic acid is first reduced to chromous acid and then solidified as a hydroxide. Any liquid effluent is either low enough in hazardous component to be directly discharged through an outfall or will require further treatment in the Wastewater Plant. Figure 2.1 is a process overview, showing the CPW treatment components.

Figure 2.1 Chemical Plating Waste Treatment Process Overview
The CPW treatment unit is designed as a multi-functional process capable of treating several different types of wastes. At this time, the unit has been the designated treatment process for these wastes:

1. Destruction of free cyanide and metal-cyanide complexes from spent plating solutions;
2. Destruction of ammonia in solution from spent plating solutions;
3. Reduction of $\text{Cr}^{VI}$ to $\text{Cr}^{III}$ from spent plating solutions, precipitation, solids separation and immobilization;
4. Heavy metal precipitation from spent plating solutions, solids separation and immobilization; and
5. Acid or base neutralization from unspecified solutions.

A discussion of each waste type and the treatment basis is presented here separately. It is probable that one or all of these waste solutions will be mixed in the storage containers. Typically the wastes requiring multiple steps will follow a predefined order to minimize hazardous gas formation or to assure maximum treatment effectiveness.

2.2. CYANIDE TREATMENT

Conditions are set to first oxidize cyanides to cyanates. Calcium hypochlorite is metered to the reactor through the Dry Solids Feeder, as required, to maintain the desired oxidation-reduction potential and control temperature in the reactor. If needed, caustic soda is added to maintain a pH above 10. Maintaining this pH level is critical to avoid the formation of toxic CNCI or HCN gas. Following conversion to cyanates, conditions are adjusted to oxidize cyanate to carbon dioxide and nitrogen.

The rate for these reactions will be limited by controlling the reagent addition rate. Temperature control for the reaction will be accomplished by a combination of cooling water circulated through the reactor jacket and by controlling the reagent addition rate. By limiting the hypochlorite addition rate, pH control and oxidation-reduction potential will be more easily monitored and controlled. If necessary, sodium hydroxide solution is added to maintain a sufficiently high pH. If complexed cyanides are not present, the waste is processed until the total cyanide (as CN-) is below 0.2 mg/liter.

Cyanate oxidation is performed after the cyanide oxidation by the addition of additional hypochlorite if no excess exists and a lowering of the pH to 8.5. After a one hour time period, a check for cyanate is conducted. When the concentration decreases below ~0.2 mg/liter, the reaction should be considered complete. Excess hypochlorite is neutralized by adding dry sodium thiosulfate in stoichiometric amounts. Final pH adjustment to 6-7 pH is made by adding caustic.

Once these reactions have been completed, analyses for cyanide, cyanate and pH is made. Further chemical treatment is not necessary before discharge (assuming other waste types are not present). Discharge of the treated waste solution from the treatment process is through the recessed Plate Filter followed by polishing filtration as needed. Any solids recovered will be immobilized in a drum using cement, sand and water (or other solidification system), allowed to solidify and disposed in a landfill. The treated waste solution may be solidified in cement and landfilled, discharged to a Laboratory Outfall or sent to the Wastewater Treatment Plant. Determination of the fate of the liquid effluent depends on waste classification and whether it is radioactive.
If the waste solution contained ammonia it should have been destroyed by the oxidation treatment, but it should be checked for any remaining ammoniacal character. Chromium content or heavy metal content will require further processing as described in the following sections.

### 2.3. AMMONIA TREATMENT

At basic pH, free ammonia gas exists in equilibrium with aqueous solutions containing the ammonium ion. Free ammonia, which evolves from these ammoniacal solutions, is destroyed by oxidation with calcium hypochlorite. For solutions containing cyanide, this is done concurrently with cyanide oxidation. Ammonium solutions which do not contain cyanide will undergo oxidative treatment for ammonia destruction. This will free metals from their ammonia complexes, making them available for removal in subsequent processing. There is no EPA BOAT for ammonium solutions.

Ammonium metal complexes are in equilibrium with the ammonium ion. Potentially, these complexes interfere with the precipitation processes. Destruction of the ammonium ion results in an equilibrium shift away from the complex, eventually destroying all metal ammonium complexes.

Excess hypochlorite is removed using the same method as for cyanide. Chromium reduction and heavy metal removal follow ammonia destruction if they are present in the waste.

### 2.4. CHROMIUM TREATMENT

Hexavalent chromium (Cr\textsuperscript{VI}) must first be reduced to the trivalent (Cr\textsuperscript{III}) form before precipitation as trivalent chromium hydroxide. Since the pH is required to be in the acidic range, cyanide or sulfide solutions need to be pretreated to eliminate the possibility of toxic HCN or H\textsubscript{2}S gas formation. All reactions are carried out in the reactor.

The chromium is reduced to its Cr\textsuperscript{III} state before being precipitated for removal by filtration. Sulfuric acid is pumped to the reactor to reduce the pH of the chromium plating waste to the range 2-3. The reduction step is accomplished by using sodium sulfite at this pH. The chromium reduction process is operated in a batch mode. The amount of reducing agent is controlled by operator observation of oxidation-reduction potential and pH. When the correct oxidation-reduction potential and pH have been attained, the operator will analyze the reactor liquor for Cr\textsuperscript{VI} and then begin the precipitation step.

After the completion of the reduction step, precipitation is accomplished by adding caustic or calcium hydroxide until an 8 pH value is attained. The insoluble Cr\textsuperscript{III} hydroxide is filtered from the solution. Magnesium hydroxide may be added in varying degrees to aid in precipitate formation. Additionally, magnesium hydroxide hydrolyses to a pH of 9, which is substantially below that attained by calcium hydroxide, therefore allowing possible direct discharge without pH adjustment through a permitted NPDES outfall. Following precipitation, filtration is used to separate the solids from the waste water. It may be necessary to add filter aid or polymeric flocculating agents to help filter finely dispersed or gelatinous solids if formed. A recessed Plate Filter is used for primary filtration followed by a cartridge type Polishing Filter.

The solids are discharged from the plate filter into a 55-gallon disposal drum. Cement, sand and water are added to the drum, the top closed and the drum agitated using a tumbler type drum mixer. After agitation, the drum contents are allowed to solidify before disposal. The filtrate is either discharged to an acceptable recipient or recycled back to the reactor for further treatment. The treated waste solution may be solidified in cement and landfilled, discharged to a Laboratory Outfall or sent to the Waste Water Treatment Plant. Determination of the fate of liquid effluent depends on the waste classification and whether it is a low-level waste.
2.5. HEAVY METALS TREATMENT

Metals other than chromium contained in the plating waste solutions are precipitated, separated and immobilized in a cement matrix. A 50% solution of sodium hydrosulfide (NaHS) is used to precipitate metals because of its stabilizing effect upon reaction pH control. Dry addition of sulfide reagents to an acidic waste solution is not recommended because excessive amounts of hydrogen sulfide may be evolved.

The pH of the batch is adjusted to a range of 2-2.5. A 45% solution NaHS is slowly added in the presence of a seed material to control sulfide particle growth and achieve a filterable precipitate. Excess sulfide must be carefully monitored and controlled using on-stream analysis for sulfide ion and hydrogen sulfide monitors in the vent. Because the sulfide ion is immediately tied up with metal ions thus removing sulfide from solution, the possibility of toxic hydrogen sulfide gas formation in acidic solutions is minimal as long as free metal cations are present.

When the last of the metal ions have been precipitated as sulfides, excess sulfide in solution will result in an equilibrium partial pressure hydrogen sulfide. Prior to operation the amount of NaHS to add is calculated based upon analysis of the batch feed. As the addition of this amount is approached, the operator looks for a rapid increase in sulfide concentration by taking samples and analyzing. By careful observation, the operator can minimize hydrogen sulfide evolution at the end of the process. Excess sulfide addition should be avoided, but any surplus sulfide can be oxidized with the addition of hydrogen peroxide.

Following full precipitation, pH is adjusted to 6-9 with sodium hydroxide. The solution of heavy metal sulfides is then filtered through the Recessed Plate Filter. It may be necessary to add filter aid or polymeric floculating agents to help filter finely dispersed or gelatinous solids if formed. Following filtration, the solids are discharged from the Plate Filter into a 55-gallon disposal drum. Cement, sand and water are added to the drum, the top closed and the drum agitated using a tumbler type drum mixer. After agitation, the drum contents are allowed to solidify before disposal.

Filtrate from the plate filter is further clarified using the polishing filter. The final filtrate is discharged to an acceptable recipient. The treated waste solution may be solidified in cement and landfilled, discharged to a Laboratory outfall or sent to the TA-50 Wastewater Treatment Plant. Determination of the fate of the liquid effluent depends on its waste classification and whether its radioactivity classifies it as a low-level waste.

2.6. CHROMIUM AND HEAVY METALS TREATMENT

An alternative to acidic sulfide precipitation is to use sulfide precipitation at a pH greater than 10. Using this alternative, hydrogen sulfide evolution potential is substantially reduced and all RCRA metals can be immobilized. The alternative techniques will require piloting to select the most effective and safe method.

If chromium is present, the reduction of Cr$^{IV}$ to its Cr$^{III}$ state with sodium sulfite, and the precipitation of chromium hydroxide will be required, as discussed in Section 2.4. The reduced waste must then be transferred from the reactor to Tuff-tanks so that a lime slurry [Ca(OH)$_2$] can be made up of CaO and water in the reactor. The acidic metal waste solution is then added to the calcium slurry until the pH has increased to around 10. This step forms a metal hydroxide precipitate and a calcium nitrate
byproduct. A 15% solution of sodium sulfide is then added to the slurry. Nitric acid is then added to neutralize the solution to a pH of 6.0-8.0.

Following full precipitation and pH adjustment to below 8.0, filtration through the recessed plate filter is performed. It may be necessary to add filter aid or polymeric flocculating agents to help filter finely dispersed or gelatinous solids if formed. Following filtration, the solids are discharged from the Plate Filter into a 55-gallon disposal drum. Cement, sand and water are added to the drum, the top closed and the drum agitated using a tumbler type Drum Mixer P-M1. After agitation, the drum contents are allowed to solidify before disposal.

The solution is filtered, and the filtered solids and the filtrate are handled as discussed in Section 2.5 above.

2.7. SAFETY FEATURES

Various safety features are incorporated into the design. Detailed operating instructions have been prepared which define step-by-step procedures for treatment of chemical plating waste. The operating instructions were developed from the detailed design package to ensure compatibility with the process equipment. The operating manual addresses safety considerations in each process section, and highlights potential hazards associated with each process step posing a potential threat. Administrative control is considered necessary but not sufficient to fully protect against operational hazards. Operating instructions are essential, and should be thoroughly understood and followed explicitly, however intrinsic safety features have been designed into the process to minimize risk to the workers, the public or the environment.

2.7.1. Process Interlocks

Several levels of process interlocks have been incorporated into the design to prevent inadvertent hazard in the event of operator error (disregard of operating instructions) or equipment malfunction. Both the chemical plating waste treatment design manual and the operating instructions include diagrams referencing safety interlocking, as follows:

1. Reagent Feed Control (Dry Chemical Feed and Liquid Chemical Feed Stations "A" & "B"):
   Potential hazards associated with reaction caused by continued reagent feed are controlled by shutting down reagent feed under the following conditions:
   a. Reactor High Level - Prevents overflow of reactor due to excessive feed or reagent addition;
   b. Reactor High Pressure - Prevents continued reaction (reagent addition) with ventilation failure;
   c. Reactor Circulation High Temperature - Prevents continued reaction (reagent addition) with cooling system failure;
   d. Reactor Circulation Low Flow - Prevents continued reaction (reagent addition) with circulation pump failure;
   e. Vent Hydrogen Cyanide High Level - Prevents continued reaction (reagent addition) when HCN is detected;
   f. Vent Hydrogen Sulfide High Level - Prevents continued reaction (reagent addition) when H₂S is detected;
   g. Scrubber Circulation Low Flow - Prevents continued reaction (reagent addition) without vent scrubbing;
   h. Dry Chemical Feed Running (Chem "A" only) - Prevents concurrent dry and liquid feed;
   i. Moisture High Level (Dry Feed only) - Prevents reagent addition if liquid enters dry chemical follower.
2. Latching Fail-Safe Valve - Liquid Chemical Feed to Filter Press:
Potential inadvertent reagent addition to filter press or backflow of reactor slurry to Chemical “A” feed system is prevented by interlocking:
   a. Liquid Chemical Feed to Filter “OPEN” - operator must select the valve and latch open; and
   b. Circulation Branch Flow Valves Closed - prevents opening if circulation line branch valves are open.

3. Latching Fail-Safe Valve - Chemical Plating Waste Feed to Reactor:
Potential inadvertent circulation line drain valve opening:
   a. Plating Waste Feed “OPEN” - operator must select the valve and latch open;

4. Latching Fail-Safe Valve - Filtrate Recycle:
Potential inadvertent circulation line branch valve opening, spilling reactor slurry:
   a. Filtrate Recycle “OPEN” - operator must select the valve and latch open;

5. Latching Fail-Safe Valve - Filter Feed:
Potential inadvertent circulation line branch valve opening, spilling reactor slurry:
   a. Filtrate Recycle “OPEN” - operator must select the valve and latch open; and
   b. Filter press must be closed

6. Vacuum Conveyor System:
Potential overfilling of dry feed hopper controlled by hopper level interlocking to vacuum conveyor.

2.7.2. Scrubber

The scrubbing system treats any vented off-gas from the reactor. Vapors are drawn through the scrubber by the process blower. The venturi in the scrubber also draws a slight vacuum on the reactor. The vent gases are contacted in the venturi throat with a caustic scrubber solution. The caustic solution absorbs and neutralizes any chlorine gas or cyanide (if the reactor pH is allowed to drop below 6 pH during cyanide treatment). The caustic solution reacts with the chlorine gas to form a weak solution of sodium hypochlorite and sodium chloride. The weak solution of sodium hypochlorite tends to destroy any cyanide gas since the absorbed cyanide gas forms a solution highly amenable to destruction. Additionally, if any CNCI is evolved from the reactor, the very high pH in the scrubber decomposes that toxic gas. The scrubber system immobilizes any hydrogen sulfide evolved from the reactor during precipitation of metals with NaHS. The scrubber solution maintained at a basic pH will prevent re-evolution of hydrogen sulfide gas. Following the scrubber is an air dilution inlet followed by a HEPA filter to control any radioactive particulate if present. Finally, the process blower vents the diluted gases to the atmosphere through the stack. The process is monitored by cyanide and chlorine gas monitors before and after the scrubbing system.

2.7.3. Cooling And Heating System Isolation

The cooling and heating system is set up to isolate the reactor cooling loop from the chiller or heater by use of an intermediate reactor heat exchange loop. This system is intended to eliminate the possibility of radionuclides (primarily depleted uranium) from escaping the process boundary limits. Monitoring of the system is possible by analytical means and by observing the system’s ability to hold pressure.
3. QUALITATIVE ANALYSIS

3.1. OPERATION

The chemical plating waste treatment operation is described in step-by-step fashion in Appendix A. A flow diagram is presented defining the following steps in the overall process:

1. Drum Sampling and reactor volume calculation;
2. Scrubber and Cooling System Start-up;
3. Chemical Plating Waste Transfer to the Treatment Skid;
4. Reaction (Six Treatment Schemes Depending upon Waste Composition);
5. Filtration;
6. Filtered Solids Processing;
7. Filtrate Processing;
8. Slurry Solidification; and

These steps are then presented as separate flow diagrams with the individual sub-steps associated with that particular operational step. The individual flow diagrams reference the process step(s) leading to that operation, and reference the next step in the process sequence. The sequence of operations and the steps involved are taken from the chemical plating waste treatment process operating manual (2), and in most cases, the operating manual provides the detail necessary to assess the potential failure scenarios possible for standard operation.

Figure 3.1 shows a flow diagram for start-up, operation and post-operational shutdown of the plating waste treatment equipment. Only the hazards associated with the actual treatment of plating waste will be considered in this report (third block in Figure 3.1). Transport of reagents and/or chemical plating waste to and from the process are also considered beyond the scope of this report. Similarly, industrial hazards associated with operation of the treatment equipment, not specific to treatment of plating waste (i.e. drum and gas cylinder pinching, fork lift and crane accidents, chemical exposure during removal of protective clothing, etc.) are considered outside this report's scope.

3.2. FAILURE MODES

Each stage of processing poses unique hazards to the operators, to the public or to the environment. As stated earlier, the risks associated with treatment of plating waste are minimized with the use of detailed operating instructions. Operators are expected to be trained in the use of all treatment equipment, and are expected to be thorough in following the operating instructions. As a pilot process, much judgment will be necessary in conducting the treatment processes, however treatment variations are well defined and should be followed as specified. Where possible, the design is intended to be intrinsically safe by incorporating fail-safe valves and control interlocks.

The hazards associated with treatment of chemical plating waste are great due primarily to the toxicity of the plating waste and the extreme toxicity of potential reaction gas products. The potential for generation of highly toxic hydrogen cyanide gas is considered to be the greatest risk to the operators, the co-located workers and to the general public. The simple addition of acid to a cyanide bearing plating waste solution will generate hydrogen cyanide gas, which is fatal in low concentrations. Administrative controls minimize the risk of worker exposure from inadvertent mixing of acid and cyanide plating waste, and design considerations minimize the potential for release outside of the treatment facility, however, specific combinations of operator and equipment failure can

result in death. Similarly, hydrogen sulfide, a colorless and odorless gas, can be generated during sulfide precipitation by inadvertent mixing of a sulfide reagent (ex. sodium sulfide) and an acidic solution. Specific hazard scenarios are discussed in detail in Section 4 of this report, and recommendations for risk reduction with design modification and/or administrative controls are made in Section 5. This section presents an overview of the potential hazards of operation by the various failure modes.

Figure 3.1 - Chemical Plating Waste Treatment Operating Flow Diagram
3.2.1. Human Error

Operator error is considered to present the greatest threat to human health. Operation of the chemical plating waste treatment process is intended to follow explicit operating instructions, which include identification of hazards and safety procedures. Plating waste treatment can be conducted safely if the operating instructions and the safety procedures are followed. Failure to set valves properly or to fail to operate the equipment as defined can result in operator exposure to plating waste or to reaction products. Simple mishandling of cyanide or sulfide bearing solutions can cause the release of highly toxic gases, resulting in operator fatality.

Operator error can be present in any number of minor injury hazards from exposure to chemical plating waste or reagents. In the event of an improper valve setting, or in the event that a reagent drum or drum of plating waste is accidentally dumped, the operator can be injured. If improper protective clothing is not worn, a relatively serious injury can occur. Safe operation depends upon the quality of the operator’s training, and the care with which they follow the operating instructions.

3.2.2. Equipment or Instrument Failure

Failure of process equipment or instrumentation alone is likely to disrupt the treatment process but is unlikely to pose a health or environmental hazard. A broken pipe or process vessel can expose an operator to plating waste or to a reagent, however protective clothing should mitigate the harmful impact of such inadvertent exposure. Instrument failure denies the operator process information, and can result in incomplete or improper waste treatment, but instrument failure alone would not typically be considered hazardous.

3.2.3. Combination Failure: Human and Mechanical

The combination of human error and protective interlock(s) or mechanical system(s) failure can pose a significant health hazard not posed by either failure alone. Workers are isolated from potential hazardous gases evolved in the reactor from specific improper treatment scenarios, but the gases are captured in the scrubber, if operated correctly. It is the combination of operator error, inadvertently producing a toxic gas, and failure of the scrubber and/or blower which could result in public or worker exposure to toxic gas with potentially fatal consequences. Most of the severe accident scenarios discussed in Section 4 are the result of a combination of operator error and equipment malfunction.

3.3. CONSEQUENCES OF FAILURE

A failure during the treatment of plating waste, by any mode discussed above, can have a wide range of consequences, from no harmful impact to operator fatality, or even fatality outside of the treatment facility in the worst case scenario. Due to the extreme toxicity of hydrogen cyanide, a potential off-gas from improper treatment of cyanide bearing plating waste, the consequences of a catastrophic failure can be great. The treatment skid design incorporates interlocks for minimization of risk due to operator error, and to mitigate the effects of inadvertent mixing of cyanide and acid. Control interlocks are utilized to prevent release of harmful gases.

The consequences of failure are evaluated for the following:

The Worker - The consequences of failure upon the worker, or operator, can vary between minor injury from exposure to plating waste or chemical reagents, to fatality from inhalation of toxic reaction gases caused by improper treatment of chemical plating waste and vent system failure.
The Co-Located Worker - Other workers in the vicinity are more prone to serious injury from the low probability failures resulting in release of toxic gas into the work space. In addition to operator error and the failure of process equipment, such a consequence would require the failure of room monitors warning of the presence of toxic gases.

The Public - The general public would have a very low probability of exposure to toxic gasses due to the combinations of failures required for such an occurrence. Toxic gasses could be emitted from the treatment facility stack in the event of concurrent operator error, failure of control interlocks and failure of the scrubber system, however an additional protection to the public is provided with the dilution of the gasses that would generally render the gasses innocuous beyond the facility boundary.

The Environment - The environment should experience no threat from the treatment of chemical plating waste. The possible pathways are 1) the discharge of liquid effluents, 2) the discharge of treated solids, and 3) the discharge of gasses from the process. Liquid and solid byproducts shall all be carefully analyzed prior to disposal. Liquid effluents are intended to be handled in existing treatments facilities (i.e. TA-50 Liquid Radioactive Waste Plant) if not suitable for direct discharge to a Laboratory outfall, and the solids shall be evaluated for disposability according to all necessary regulatory criteria before disposal. Gasses represent little or no threat to the environment, even in the event of a worst case failure scenario.
4. QUANTITATIVE ANALYSIS

4.1. PHA METHODOLOGY

The PHA method is endorsed by various Federal agencies, including the U.S. Department of Energy (DOE), the chemical and nuclear industry, and professional organizations, and is based upon techniques outlined in AIChE (3), the California Risk Management Prevention Program (RMPP) (4), and the Process Safety Management (PSM) (5) rule.

The PHA method entails step-by-step analysis of the operation, with an assessment of potential failure scenarios associated with each step. The risk to the workers, co-located workers, public, and to the environment are then evaluated, with regard to severity and estimated frequency. Table 4.1 shows the severity categories for which each failure scenario is evaluated. The category assigned is based upon the expected worst case consequence of the failure, for either the worker, the co-located worker, the public or the environment.

Table 4.1 CONSEQUENCE SEVERITY CATEGORIES

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>MAXIMUM POSSIBLE CONSEQUENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PUBLIC</td>
</tr>
<tr>
<td>A</td>
<td>Immediate health effects</td>
</tr>
<tr>
<td>B</td>
<td>Long-term health effects</td>
</tr>
<tr>
<td>C</td>
<td>Irritation or discomfort but no permanent health effects</td>
</tr>
<tr>
<td>D</td>
<td>No significant off-site impact</td>
</tr>
</tbody>
</table>

The frequency of the failure scenario is then evaluated, according to the categories outlined in Table 4.2. Frequency is estimated for a unit operation resulting in the accident scenario, or if the accident scenario is dependent upon a series of operator and/or equipment failures, the frequency is estimated as the sum of frequency exponents. For example, consider the following failure scenario treating a cyanide plating waste solution, in which the following events must all occur in order to release toxic hydrogen cyanide gas out the vent stack:

1. Operator must mistakenly add acid instead of caustic, reducing the pH (est. Frequency - 1 in 10 years = $10^{-1}$);
2. The vent hydrogen cyanide interlock must fail, failing to shut down the reagent pump (est. Frequency - 1 in 10 years = $10^{-1}$); and
3. The scrubber must either be overwhelmed or fail to remove cyanide from the vent stream (est. Frequency - 1 in 10 years = $10^{-1}$).

The resulting frequency for concurrent failures is considered to be $10^{-1} + 10^{-1} + 10^{-1}$ or $10^{-3}$ (once in 1,000 years). This method was used to evaluate scenarios requiring multiple failures.

Table 4.2 CONSEQUENCE LIKELIHOOD CATEGORIES

<table>
<thead>
<tr>
<th></th>
<th>Likelihood Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal operations; frequency as often as once in 10 operating years or at least once in 10 similar facilities operated for 1 year.</td>
</tr>
<tr>
<td>II</td>
<td>Anticipated events; frequency between one in ten years and one in 100 operating years or at least once in 100 similar facilities operated for 1 year.</td>
</tr>
<tr>
<td>III</td>
<td>Unlikely; frequency between one in 100 years and one in 10,000 operating years or at least once in 10,000 similar facilities operated for 1 year.</td>
</tr>
<tr>
<td>IV</td>
<td>Very unlikely; frequency between one in 10,000 years and once in 1 million years or at least once in a million similar facilities operated for 1 year.</td>
</tr>
<tr>
<td>V</td>
<td>Improbable; frequency of less than once in a million years.</td>
</tr>
</tbody>
</table>

4.2. RISK RANKING OF FAILURE MODES

Appendix A contains the operational flow diagrams used for PHA evaluation of the chemical plating waste treatment process. The flow diagrams were prepared from the operating instructions and are intended to diagram each step in the treatment of plating waste at the Laboratory. Possible failure scenarios are evaluated for each step in the process, and the consequence and probability of each failure is categorized as defined in Section 4.1. Risk ranking can then be assigned according to the Table 4.3 matrix below. Risk rank 1 and 2 scenarios are considered unacceptable, requiring mitigation by design modification or administrative control.

Table 4.3 MATRIX FOR ASSIGNMENT OF RISK RANK

<table>
<thead>
<tr>
<th>SEVERITY OF CONSEQUENCE</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
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<td>3</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Forty-four hazard scenarios were identified by the PHA team during the investigation, as shown in Appendixes A and B. Included in the definition of each scenario are its description, its likely cause, a description of the consequences, an estimate of the scenario likelihood, and recommendations that could reduce the likelihood and/or consequences:

**Step** - The step in the process, as shown in the Appendix A process flow diagrams, which poses a potential hazard;

**Cause/Scenario** - The potential worst case hazard scenario;

**Consequences** - The consequences of the failure scenario;

**Protective Features** - Design features and/or administrative controls which would tend to minimize the probability or the consequence of the failure scenario;

**Actions** - Recommended design and/or administrative control modifications to reduce the probability of the failure scenario; and

**R-F-C** - Risk Rank (Table 4.3), Frequency (Table 4.2), and Consequence (Table 4.1)
Risk Rank 1 and 2 scenarios should be mitigated to Risk Rank 3 or lower. These scenarios are discussed in Section 4.2, with their potential consequences and probabilities of occurrence. Recommendations for reduction of risk are discussed in Section 5. Risk Rank 3 scenarios are considered acceptable with controls, if procedures, controls and safeguards are verified to be in place. Risk Rank 4 scenarios are considered acceptable, with no further action necessary.

4.2.1. Discussion of Risk Rank 1 Scenarios

Risk Rank 1 scenarios can be, by definition, relatively frequent and severe, which could be expected to result in a severe injury or loss of life at least once in 100 years. Such a scenario requires a design or administrative control modification which would reduce the Risk Rank to three or four. Recommendations for modifications for risk reduction are addressed in Section 5.

Two basic Risk Rank 1 scenarios were deemed possible in the treatment of chemical plating waste. Each scenario could result in operator death from hydrogen cyanide, and the probability of each is considered frequent (greater than once in 100 years) due to insufficient operating instruction guidance and/or warning. Since the hazard scenarios each result in local release of toxic gas, no impact is expected on co-located workers, the public or the environment. All of the Risk Rank 1 scenarios are listed in Appendix C.

Improper Handling of Cyanide Bearing Samples (Steps 4A6 and 4A10)
Samples taken during treatment of cyanide plating waste could generate lethal concentrations of hydrogen cyanide if added to an acidic solution. Since no provision for handling process samples is made in the operating instructions, and no convenient method is provided in the design for reintroducing sample solutions to the process, the opportunity exists for accidental mixing of cyanide bearing samples with an acidic solution in a "slop bucket". Since hydrogen cyanide is extremely toxic, the results of such an accident could result in operator death.

Acid Neutralization of a Cyanide or Sulfide Bearing Scrubber Solution - (Step 91)
Operating instructions direct the operator to neutralize the scrubber solution with sulfuric acid at the end of each plating waste treatment program, if cyanide and sulfide are not present. The blower is not required to be on during this neutralization, so hydrogen cyanide or hydrogen sulfide generated from acid addition would not be ventilated through the building stack, and would enter the treatment space. Since this scenario would occur with a single erroneous sample analysis, or through misinterpretation of a single operating instruction or operator inattention, such an error is not considered improbable, and the risk is unacceptable. If the blower was on during this scenario, the public could be exposed to toxic gases in potentially hazardous concentrations.

4.2.2. Discussion of Risk Rank 2 Scenarios

Risk Rank 2 scenarios are considered either less severe or less probable than Risk Rank 1 scenarios, however Risk Rank 2 scenarios are considered undesirable, and require mitigation within a reasonable time period. A Risk Rank 2 scenario can result in loss of life, or severe injury or disability, however severe consequences of such a failure would be considered infrequent.

Five distinct Risk Rank 2 scenarios were conceived during investigation by the PHA team, as shown in Appendix C. The consequences of these accident scenarios range from severe injury to death of an operator or co-located worker, and in one scenario results in exposure of toxic gas to the public.
Operator Exposure to Plating Waste at the Sample Valve (Step 3D)
The sample valve on the process circulation line is manually operated for sample collection during waste treatment. In the event that the sample valve is left open during charging of the reactor and circulation of plating waste, the plating waste could be sprayed through the open valve at the pump discharge pressure. Operator exposure to highly acidic or basic solutions, or to toxic solutions, can result in relatively severe injury. The valve is not a self-closing design, and no direction is provided in the operating manual to verify that the valve is closed.

Drum Dropped on the Operator While Removing From the Drop Chute (Steps 6L & 8H)
No provision is made in the design for removal of the full drum of filter solids or treatment slurry dumped into the 55-gallon drum through the filter hopper. The space underneath the chute is too tight to permit crane or forklift access, and no ramp is provided for removal with a dolly. As designed, the operator would be required to work the drum out manually, risking back injury and exposure of potentially radioactive and/or cyanide bearing waste from tipping.

Acidic Reactor Solution Flows to Cyanide Waste Drum During Feed Operation (Step 3D)
The plating waste is introduced into the reactor by the circulation pump which takes suction from the reactor drain piping. The operating instructions direct the operator to close the reactor drain valve and to start the circulation pump prior to opening the plating waste feed valve to initiate pumping from the plating waste drum. During transfer of cyanide plating waste to the reactor, in the event that the reactor contains an acidic solution from a prior operation, and a concurrent failure of the reactor drain valve and the circulation occurs, then the acid solution can flow through the transfer line into the plating waste drum. Such a scenario would likely result in operator death, and possible death of co-located workers, due to the rapid production of hydrogen cyanide gas inside the treatment room.

Acid is Added to Cyanide Plating Waste in the Reactor (Steps 4C3 & 4F2)
If acid is added to cyanide plating waste in the reactor, hydrogen cyanide would be generated and removed by the ventilation system. The operating instructions clearly warn of the consequences of adding acid to cyanide plating waste, however if the plating waste is being erroneously treated as chromium waste, through faulty labeling or simple operator error, initial acid neutralization is called for. If operated properly, the scrubber will remove hydrogen cyanide gas from the vent stream. Control interlocks will shut down the acid pump in the event of hydrogen cyanide detection in the vent system, however concurrent failure of the scrubber system and the hydrogen cyanide interlock to the feed pump would result in public exposure. If the vent blower failed at the same time as the scrubber and the pump interlock, the hydrogen cyanide gas could enter the work space, threatening the operator. A power failure at the control computer would result in the shutting down of the feed pump, but would not shut down the blower and the scrubber.

Acid is Transferred to Sodium Hydrosulfide (Steps 4D3 & 4F14)
Acid and sodium hydrosulfide are two reagents required for the precipitation of heavy metals. Acid can inadvertently be mixed with sodium hydrosulfide if both are present at their respective pumping stations and three valves are incorrectly set while either is being pumped. The consequence of mixing these two reagents is the generation of highly toxic hydrogen sulfide gas into the treatment room, which can be fatal to exposed workers.
4.2.3. **Risk of Public Exposure**

The only hazard scenario posing a public risk is the release of hydrogen cyanide or hydrogen sulfide during inadvertent acid addition to a cyanide or sulfide solution, either in the reactor or in the scrubber. Either scenario would require an operator failure, disregard of the operating instructions, and failure of control interlocks on the reagent feed pump. The consequence of discharge of either hydrogen cyanide or hydrogen sulfide from the vent stack is likely to be small due to the potential for mixing with air, however dispersion modeling would be necessary to determine whether the threat to the public would be real. The more quantitative analysis associated with a Probabilistic Risk Assessment (PRA) may be required to determine whether the modifications suggested, reduce the risk to the public to suitably low levels.
5. RECOMMENDATIONS FOR RISK REDUCTION

Risk Rank 1 and 2 scenarios require modification of administrative procedures and/or modification to the design to reduce the Risk Rank to level 3 or 4. Suggestions for modifications to the operating instructions and to the equipment design are made:

MODIFICATIONS TO THE PROCESS DESIGN

1. Modify the two sample valves from ball valves to self-closing valves (Steps 2C & 3D);
2. Redesign the plating waste feed system to prevent inadvertent drainage from the reactor to the plating waste feed drum, by either re piping to prevent reactor drainage or by adding an independent pump to introduce the waste to the spare nozzle at the top of the reactor (Step 3D);
3. Design a portable or attached ramp for the removal of drums from under the filter press chute (Steps 6L & 8H);
4. Interlock the vent hydrogen cyanide and hydrogen sulfide alarms after the scrubber to the reagent feed pumps to provide secondary back-up to the primary interlocks before the scrubber (Step 4C3 & 4F2);
5. Add a 3-way valve at the intersection of the Chemical "A" and Chemical "B" feed stations to prevent accidental reagent flow from one drum to another (Step 403); and
6. Add pH alarm to program logic to warn the operator of hazardous pH reduction during cyanide oxidation (Step 4A5).

MODIFICATIONS TO ADMINISTRATIVE CONTROLS

1. Revise the procedure to require oxidation of samples prior to combining with other solutions for later disposal to prevent the generation of hydrogen cyanide (Steps 4A6 & 4A10);
2. Revise operating instructions to require all scrubber solutions be transferred to the reactor and that the blower be turned on prior to treatment to prevent accidental HCN or H2S release into the treatment room;
3. Revise the operating instructions to require the operator to place the vent connection at the drum bung when the drum is opened;
4. Require head space be maintained in the drum, verified during drum sampling, to prevent overflow or spillage during insertion of the suction stinger;
5. Revise operating instructions to prevent connection of drum to system when cyanide solution is present, to prevent inadvertent mixing of cyanide plating waste with acid outside the reactor;
6. Verify operator training in occupational hygiene to prevent plating waste or reagent contact with skin;
7. Revise operating instructions to define the P-T1 mix tank as the preferred method for introducing sodium thiosulfate, to prevent inadvertent mixing of thiosulfate and calcium hypochlorite in the dry feed hopper;
8. Revise the operating instructions to prevent the presence of sodium hydrosulfide in the operation, during heavy metals treatment, until the acid has been removed and the drum sealed (to prevent accidental mixing of hydrosulfide and a acid);
9. Revise operating instructions to assure Y-strainers are capped before operation and during pumping at both Chemical "A" and "B" feed stations;
10. Revise operating instructions to emphasize verification of proper valve settings during wastewater transfer to through either P-F1 or P-F2; and
11. Replace 35% hydrogen peroxide with 20% peroxide to provide greater intrinsic safety.

Appendix D summarizes recommended actions for all scenarios which the evaluation team considered capable of mitigation through modification to the design or to administrative controls. The table shows the Risk Rank and the operation step of the defined hazard scenario, and revised Risk Rank if the modification(s) was implemented.
Figure 1. Sample drum and calculate reactor volume increase

1. Sample drum and calculate reactor volume increase

1A. Open bung and sample selected drum - submit sample for analysis

1B. Group drums into classes

1C. Weigh the drums

1D. Calculate treatment volume increase
Chemical Plating Waste Treatment Flow Diagram

Figure 2. Start Up Scrubber and Cooling System

1. Start Up Scrubber and Cooling System

2. Start the Process Blower (UT-B11) and Establish Dilution Air Flow Across P-F4

2A. Start the Process Blower (UT-B11) and Establish Dilution Air Flow Across P-F4

2B. Fill the Scrubber to 80% with Process Water, as Necessary

2C. Start the Scrubber Pump P-P3

2D. Sample the Scrubber Solution to Determine Caustic Strength (1.5-2.0% Desired)

2E. Pump Required NaOH to the Scrubber Using Either P-P1 or P-P5

2F. Set Valves for Proper Cooling Water and Chilled Water Operation

2G. Start Cooling System Pumps U-P4 and UT-P12 (Verify UT-CH11 Compressor Heaters On)

2H. Set Thermostat to Maintain 4 Deg C Outlet at 10 Deg C Inlet

3.
FIGURE 3. TRANSFER CPW TO TREATMENT SKID

1. Transfer CPW to Treatment Skid
2. Set valves for CPW transfer
3. Open and ventilate the CPW drum
4. Insert suction stinger
5. Pump CPW to reactor until drum is empty
6. Rinse the empty drum
7. Repeat until reactor is loaded

Insert suction stinger and pump CPW to reactor until drum is empty.

Rinse the empty drum.

MSC 9/7/94
CPW1.VSD
**CHEMICAL PLATING WASTE TREATMENT FLOW DIAGRAM**

**FIGURE 4A. REACTION -- CYANIDE TREATMENT**

1. **LOAD DRY FEED HOPPER WITH CALCIUM HYPOCHLORITE (CaOCl)**
2. **SAMPLE SOLUTION AT RECIRCULATION LINE SAMPLE VALVE**
3. **ADJUST pH TO 10 OR HIGHER**
4. **CONTROL ADDITION OF SODIUM HYDROXIDE TO MAINTAIN pH AT 8.5**
5. **ADJUST pH TO 6.5-8.5 USING H2SO4 OR NAOH**
6. **SAMPLE SOLUTION AT RECIRCULATION LINE SAMPLE VALVE**
7. **ADJUST pH TO 10 OR HIGHER, IF NECESSARY**
8. **CONTROL ADDITION OF SODIUM HYDROXIDE TO MAINTAIN pH AT 8.0**
9. **SAMPLE SOLUTION AT RECIRCULATION LINE SAMPLE VALVE**
10. **SAMPLE SOLUTION AT RECIRCULATION LINE SAMPLE VALVE**
11. **EMPTY DRY FEED HOPPER, THEN LOAD WITH SODIUM THIOSULFATE (Na2S2O3)**
12. **ADD Na2S2O3 TO REDUCE EXCESS CaOCl**
13. **ADD CaOCl TO OXIDIZE TO < 0.2 mg/L**
14. **CONTROL ADDITION OF SODIUM HYDROXIDE TO MAINTAIN pH AT 8.5**
15. **LOAD DRY FEED HOPPER WITH CALCIUM HYPOCHLORITE (CaOCl)**
16. **START RECIRCULATION PUMP**
17. **SET VALVES FOR CIRCULATION**
18. **REATION CYANIDE TREATMENT**

**Flow Diagram Instructions:**
- **Step 1:** Adjust pH to 10 or higher, if necessary.
- **Step 2:** Adjust pH to 6.5-8.5 using H2SO4 or NAOH.
- **Step 3:** Control addition of sodium hydroxide to maintain pH at 8.5.
- **Step 4:** Control addition of sodium hydroxide to maintain pH at 8.0.

**Flow Diagram Notes:**
- The flow diagram illustrates the steps involved in treating chemical plating waste, specifically the reaction process for cyanide treatment.
- Each step is connected to the next, showing the continuous process of adjusting pH, oxidizing cyanides, and maintaining pH levels to ensure proper treatment.

**Flow Diagram Symbols:**
- **Square Box:** Represents a process step.
- **Arrow:** Indicates the flow of the process from one step to another.
- **Text:** Provides specific instructions or descriptions for each step.
Figure 4B. Reaction -- Ammonia Treatment

1. Load dry feed hopper with calcium hypochlorite (CaOCl).
2. Start recirculation pump.
3. Adjust pH to 8.5-10.5 using H2SO4 or NaOH.
4. Remove excess calcium hypochlorite from the solids feed system.
5. Add Na2S2O3 to reduce excess hypochlorite.
6. Sample solution at recirculation line sample valve.
7. Load dry feed hopper with sodium thiosulfate (Na2S2O3).
8. Start recirculation line.
9. Add Na2S2O3 to reduce excess hypochlorite.
10. Load dry feed hopper with calcium hypochlorite (CaOCl).
11. Control to maintain T < 120 deg F.

Add CaOCl to oxidize to NH3 < 10 mg/L; control to maintain T < 120 deg F.

Adjust pH to 6.5-8.5 using H2SO4 or NaOH.

Chromium and/or heavy metals.

No chromium or heavy metals.
CHEMICAL PLATING WASTE TREATMENT FLOW DIAGRAM
FIGURE 4C. REACTION -- CHROMIUM TREATMENT

1. SET VALVES FOR CIRCULATION
2. START RECIRCULATION PUMP
3. LOAD DRY FEED HOPPER WITH SODIUM SULFITE (Na₂SO₃)
4. ADJUST pH TO 2-2.5 USING CONCENTRATED H₂SO₄
5. ADD Na₂SO₃ TO REDUCE CHROMIUM (VI) TO < 2.0 mg/L; KEEP T < 49 DEG C
6. MAINTAIN H₂SO₄ ADDITION TO CONTROL pH AT 2-2.5
7. WHEN ORP < 0, SHUT DOWN SULFITE & SULFURIC ACID ADDITIONS

8. SAMPLE SOLUTION AT SAMPLE VALVE V-20
9. EMPTY EXCESS SODIUM SULFITE FROM FEED SYSTEM
10. ADD HYDRATED LIME Ca(OH)₂ TO DRY FEED HOPPER
11. ADD Ca(OH)₂ TO PRECIPITATE 2Cr(OH)₃; CONTROL FEEDRATE FOR 7.5 < pH < 10.0
12. CONTINUE ADDITION OF Ca(OH)₂ UNTIL TOTAL CHROMIUM IS BELOW 5.0 mg/L
13. EMPTY EXCESS Ca(OH)₂ FROM FEED SYSTEM
CHEMICAL PLATING WASTE TREATMENT FLOW DIAGRAM

FIGURE 4D. REACTION -- HEAVY METALS TREATMENT

3 5

4D 1

REACTION
HEAVY METALS TREATMENT

4D 2

SET VALVES FOR CIRCULATION

4D 3

START RECIRCULATION PUMP

4D 4

ADJUST pH TO 2-2.5 USING NITRIC ACID OR SODIUM HYDROXIDE

4D 5

SEED SOLUTION IF NECESSARY TO PROMOTE LARGE PARTICLE GROWTH

4D 6

CONTROL NaOH ADDITION (P-P5) TO MAINTAIN pH AT 2-2.5

4D 7

CONTINUE SODIUM HYDROXIDE ADDITION UNTIL THE pH REACHES 5.5

4D 8

SAMPLE SOLUTION AT THE RECIRCULATION LINE SAMPLE VALVE

4D 9

LET THE SYSTEM STABILIZE FOR 5 MINUTES

4D 10

IF pH HAS DROPPED BELOW 5.5 REPEAT SODIUM HYDROXIDE ADDITION

5

4E

msc 9/4/94
cpw4d.vsd
CHEMICAL PLATING WASTE TREATMENT FLOW DIAGRAM

FIGURE 4E. REACTION -- NEUTRALIZE WITH ACID/BASE

1. REACTION
   NEUTRALIZE WITH ACID/BASE

2. CALCULATE REAGENT REQUIREMENTS FOR 6.0 < pH < 8.0

3. SET VALVES FOR CIRCULATION AND START PUMP P-P2

4E. TRANSFER 50% NaOH IF pH < 6.0 (P-P1)

4E. TRANSFER 93% H2SO4 IF pH > 8.0 (P-P5)

5. TERMINATE REAGENT ADDITION WHEN pH IS WITHIN 6.0 - 8.0 RANGE

msc 9/4/94
cpw4e.vsd
FIGURE 4F. REACTION -- HEAVY METALS & CHROMIUM TREATMENT

1. LOAD DRY FEED HOPPER WITH SODIUM SULFITE
2. ADJUST pH TO 2-2.5 USING CONCENTRATED H2SO4
3. REDUCE WITH SODIUM SULFITE TO Na2SO3 < 2 mg/L, KEEPING T < 49 DEG C
4. MAINTAIN H2SO4 ADDITION TO CONTROL pH AT 2-2.5
5. LOAD DRY FEED HOPPER WITH Ca(OH)2
6. ADJUST pH TO 8.0 USING Ca(OH)2 OR NaOH TO PRECIPITATE Cr(OH)3 TO Cr < 5 mg/L
7. TRANSFER SOLUTION TO TUFF-TANK(S) THROUGH POLISHING FILTER
8. TRANSFER Ca(OH)2 OR WATER AND CaO TO REACTOR
9. TRANSFER WASTE FROM TUFF-TANK(S) WITH P-P5, (pH TO 10); KEEP T < 40 DEG C
10. MAKE UP Na2S SOLUTION AND TRANSFER (P-P1) UNTIL SULFIDE RISES ABOVE 50 mg/L
11. TRANSFER Ca(OH)2 OR WATER AND CaO TO REACTOR (20% OF TOTAL REQUIRED)
12. TRANSFER WASTE FROM TUFF-TANK(S) WITH P-P5
13. TRANSFER Ca(OH)2 TO KEEP 10<pH<11
14. FLUSH THE LINES AND SEAL THE Na2S DRUM
15. TRANSFER NITRIC ACID (P-P5) TO pH 7.0-8.0; RINSE LINES

ALTERNATE TREATMENT METHODS

CALCULATE REAGENT REQUIREMENTS AND FEED RATES; SET VALVES

MAINTAIN H2SO4 ADDITION TO CONTROL pH AT 2-2.5

LOAD DRY FEED HOPPER WITH SODIUM SULFITE

ADJUST pH TO 2-2.5 USING CONCENTRATED H2SO4

REDUCE WITH SODIUM SULFITE TO Na2SO3 < 2 mg/L, KEEPING T < 49 DEG C

LOAD DRY FEED HOPPER WITH Ca(OH)2

ADJUST pH TO 8.0 USING Ca(OH)2 OR NaOH TO PRECIPITATE Cr(OH)3 TO Cr < 5 mg/L

TRANSFER SOLUTION TO TUFF-TANK(S) THROUGH POLISHING FILTER

TRANSFER Ca(OH)2 OR WATER AND CaO TO REACTOR

TRANSFER WASTE FROM TUFF-TANK(S) WITH P-P5, (pH TO 10); KEEP T < 40 DEG C

MAKE UP Na2S SOLUTION AND TRANSFER (P-P1) UNTIL SULFIDE RISES ABOVE 50 mg/L

FLUSH THE LINES AND SEAL THE Na2S DRUM

TRANSFER NITRIC ACID (P-P5) TO pH 7.0-8.0; RINSE LINES

TRANSFERSolution TO TUFF-TANK(S) THROUGH POLISHING FILTER

TRANSFER Ca(OH)2 OR WATER AND CaO TO REACTOR

TRANSFER WASTE FROM TUFF-TANK(S) WITH P-P5, (pH TO 10); KEEP T < 40 DEG C

MAKE UP Na2S SOLUTION AND TRANSFER (P-P1) UNTIL SULFIDE RISES ABOVE 50 mg/L

FLUSH THE LINES AND SEAL THE Na2S DRUM

TRANSFER NITRIC ACID (P-P5) TO pH 7.0-8.0; RINSE LINES
CHEMICAL PLATING WASTE REATMENT FLOW DIAGRAM

FIGURE 5A. FILTRATION - POLISHING FILTER (P-F2)

5A

FILTRATION POLISHING FILTER

5A 1
PLACE EMPTY TUFF-TANK AT WASTEWATER DISCHARGE FROM POLISHING FILTER

5A 2
SET VALVES FOR FLOW DIVERSION THROUGH POLISHING FILTER, WITH P-P2 PUMPING

5A 3
IF REACTOR EMPTIES BEFORE TUFF-TANK FILLS, FLUSH REACTOR AND LINES

5A 4
IF TUFF-TANK FILLS BEFORE REACTOR EMPTIES, SHUT VALVE V-32

5A 5
IF PRESSURE DROP INCREASES TO GREATER THAN 5 psig, SHUT V-32

5A 6
CHANGE OUT CARTRIDGES AND DISPOSE PROPERLY

TO HWTF OR OTHER

6
CHEMICAL PLATING WASTE REATMENT FLOW DIAGRAM

FIGURE 5B. FILTER PRESS FILTRATION (P-F1)

1. Verify Filters P-F1 and P-F2 are closed and prepared for filtration.
2. Precoat filter or add filter aid as deemed necessary.
3. Verify recirculation pump operation (P-P2) initiate as necessary.
4. Recycle method.
5. Set valves to transfer contents of reactor through P-F1 and P-F2.
6. If pressure rises to the set pressure (50 psig) before the reactor is empty, stop circulation.
7. Reactor empties before the filter pressure rises to set pressure (50 psig).
8. Rinse reactor and lines.
9. Set valves to pump reactor contents through P-F1 back to reactor.
10. Sample filtrate at V-20 to check clarity (ensure line is flushed).
11. Sample reactor at V-20 continue until filtration is complete.
12. If filtrate is not clear, stop circulation, open press and diagnose problem.
FIGURE 6. FILTERED SOLIDS PROCESSING

6
FILTERED SOLIDS PROCESSING

6A
PROCESS COMPLETE
NO RINSE REQUIRED

6B
INTERMEDIATE PROCESS
RINSE REQUIRED

6C
STRAIGHT THROUGH
SET VALVES TO WASH CAKE, AS NECESSARY

6D
RECYCLE
SET VALVES TO WASH CAKE, AS NECESSARY

6E
WASH CAKE THROUGH P-F1 & P-F2 TO TUFF-TANK

6F
WASH CAKE THROUGH P-F1 TO REACTOR

6G
AFTER 5 MINUTES SAMPLE WASH WATER AND ANALYZE

6H
AFTER 5 MINUTES SAMPLE WASH WATER AT V-20

6I
SET VALVES TO BLOW FILTER CAKE WITH AIR TO REMOVE EXCESS FILTRATE

6J
SET TARED DRUM WITH SAND/CEMENT UNDER CHUTE

6K
OPEN FILTER PRESS AND DUMP FILTER CAKE SCRAPE AND CLEAN SURFACES, AS NECESSARY

6L
LOAD MIXER AND TUMBLE DRUM

6M
CLOSE FILTER PRESS FOR FURTHER FILTRATION

5B
7

msc 9/4/94
cpw6.vsd
FILTRATE PROCESSING

7

6

7B

FURTHER PROCESSING REQUIRED

PUMP THE CONTENTS OF THE TUFF-TANK TO THE REACTOR

REPLACE TUFF-TANK AT FILTRATE DISCHARGE

END

7A

FILTRATE FULLY TREATED

7C

NON-LISTED FILTRATE TO BE TRANSPORTED OR PUMPED TO THE TA-50 TREATMENT PLANT

END

7D

NON-RAD WASTE (INCLUDING CYANIDE < 0.2 mg/L) CAN BE PUMPED TO A LABORATORY OUTFALL

END

4

END
**CHEMICAL PLATING WASTE TREATMENT FLOW DIAGRAM**

**FIGURE 8. SLURRY SOLIDIFICATION**

1. **8A**
   - Place drum with sand/ce ment under the filter press chute

2. **8B**
   - Set valves to direct reactor slurry to filter press hopper (V-28 closed)

3. **8C**
   - Verify filter press is closed and P-P2 is operating

4. **8D**
   - Open V-28 to begin filling drum

5. **8E**
   - Adjust flow rate with pressure to P-P2 or pinching V-18

6. **8F**
   - Close V-28 when drum is approximately 75% full or reactor is empty

7. **8G**
   - If reactor is empty, rinse reactor and lines into drum

8. **8H**
   - Move full drum to scale, then to mixer - mix drum contents and move to storage

9. **8I**
   - If reactor is not empty, repeat steps above

**END**
CHEMICAL PLATING WASTE TREATMENT FLOW DIAGRAM

FIGURE 9. SCRUBBER PROCESSING

4

9A

SCRUBBER PROCESSING

9B

MONITOR ALL SCRUBBER INLET AND OUTLET ALARMS

9C

IF CAUSTIC STRENGTH FALLS BELOW 0.5 %, ADD MORE NaOH

9D

SAMPLE SCRUBBER SOLUTION AND ANALYZE FOR CYANIDE, SULFIDE AND RAD WHEN REACTOR EMPTY

9E

IF CYANIDE OR SULFIDE ARE DETECTED IN SCRUBBER, PUMP CONTENTS TO REACTOR

9F

IF THE SCRUBBER IS FULL, PUMP 20% SCRUBBER SOLUTION TO THE REACTOR (DURING PROCESS OK)

9G

9H

OXIDIZE SCRUBBER SOLUTION IN REACTOR WITH H2O2

9I

IF CYANIDE AND SULFIDE ARE NOT PRESENT, NEUTRALIZE WITH H2SO4 (P-P5)

9J

PUMP NEUTRALIZED SCRUBBER WASTE TO REACTOR

9K

PUMP SCRUBBER WASTE FROM REACTOR TO TUFF-TANK THROUGH P-F2

9L

RINSE REACTOR AND LINES; PUMP THROUGH P-F2 TO TUFF-TANK

9M

NEUTRALIZE TO pH 6.0 - 8.0

9N

RADIOACTIVITY & CYANIDE PRESENT

9O

NO RADIOACTIVITY PRESENT

FILTER THROUGH POLISHING FILTER

5A

7

8

MSC 9/4/94

CWP9.VSD
<table>
<thead>
<tr>
<th>STEP</th>
<th>R-F-C</th>
<th>CAUSE/SCENARIO</th>
<th>CONSEQUENCES</th>
<th>PROTECTIVE FEATURES</th>
<th>ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>4 VC</td>
<td>V-63 LEFT CLOSED OR P-F4 PLUGGED</td>
<td>LOSS OF DILUTION AIR FLOW WITH RESULTANT LOSS OF VENT CAPACITY</td>
<td>HEPA OVER DESIGN; HCN ALARM</td>
<td>NONE.</td>
</tr>
<tr>
<td>2B</td>
<td>4 II D</td>
<td>OVER FILLING SCRUBBER SYSTEM AND RELEASE OF DILUTE CAUSTIC TO SECONDARY CONTAINMENT.</td>
<td>EMPLOYEE EXPOSURE TO DILUTE CAUSTIC.</td>
<td>LEVEL D CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>2C</td>
<td>3 I D</td>
<td>START SCRUBBER PUMP P-P3 SAMPLE VALVE LEFT OPEN.</td>
<td>CAUSTIC SPILL - EMPLOYEE EXPOSURE.</td>
<td>1. PROTECTIVE CLOTHING, and 2. SECONDARY CONTAINMENT.</td>
<td>INSTALL SPRING RETURN SAMPLE VALVE.</td>
</tr>
<tr>
<td>3A</td>
<td>N/A</td>
<td>OPENS UTILITY VALVE.</td>
<td>NO SIGNIFICANT IMPACT.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td>3 VA</td>
<td>HCN IS PRESENT IN DRUM HEAD SPACE.</td>
<td>RELEASE OF HCN; DEATH.</td>
<td>1. PACKAGED IN BASIC FORM; 2. PRESAMPLED DRUM; and 3. OPERATOR PROTECTIVE CLOTHING.</td>
<td>1. VERIFY PROPER OPERATION; and 2. MODIFY PROCEDURE TO INCLUDE VENT CAPTURE AT DRUM OPENING.</td>
</tr>
<tr>
<td>3B</td>
<td>4 VC</td>
<td>SODIUM CYANIDE PRESENT ON EXPOSED SURFACES DURING DRUM OPENING.</td>
<td>PATHWAY TO SKIN ABSORPTION.</td>
<td>1. RINSING SUCTION LANCE.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3C</td>
<td>4 VC</td>
<td>DRUM LIQUID FULL, LIQUID OVERFLOWS TO DRUM TOP.</td>
<td>PATHWAY TO SKIN ABSORPTION.</td>
<td>1. SECONDARY CONTAINMENT; and 2. DRUM TOP CONTAINMENT.</td>
<td>ASSURE HEAD SPACE DURING SAMPLING.</td>
</tr>
<tr>
<td>3D</td>
<td>2 III A (3 IV A)</td>
<td>ACID IN R-1 FLOWS TO FEED DRUM.</td>
<td>1. HCN FORMED; and 2. LOSS OF LIFE.</td>
<td>NONE.</td>
<td>REDESIGN FEED INTRODUCTION TO PREVENT BACKFLOW: 1. REPIPE; 2. 3-WAY VALVE TO PUMP P-P2; or 3. INDEPENDENT PUMP TO TOP OF P-R1.</td>
</tr>
<tr>
<td>3D</td>
<td>4 II D</td>
<td>UTILITY WATER FLOWS INTO FEED LANCE.</td>
<td>SPILL OF FEED FROM ANNULAR AREA AROUND STINGER.</td>
<td>SECONDARY CONTAINMENT.</td>
<td>NONE.</td>
</tr>
<tr>
<td>STEP</td>
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<tr>
<td>3D</td>
<td>3 IVA</td>
<td>WASTE INTRODUCED TO ACID REAGENT DRUM FROM: 1. WASTE DRUM. 2. REACTOR.</td>
<td>GENERATION OF HCN; DEATH.</td>
<td>TWO SERIES INTERLOCKS &amp; IMPOSSIBLE POSITION OF THREE VALVES.</td>
<td>REVISE OPERATING PROCEDURES TO PREVENT CONNECTION OF ACID DRUM TO SYSTEM WHILE CYANIDE SOLUTION IS PRESENT.</td>
</tr>
<tr>
<td>3D</td>
<td>3 III C</td>
<td>VALVES INCORRECTLY POSITIONED. WASTE FLOWS TO FILTER PRESS HOPPER.</td>
<td>EMPLOYEE EXPOSURE TO PLATING WASTE.</td>
<td>1. ONE INTERLOCK; and 2. LEVEL C WORKER OUTFITTING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3D</td>
<td>4 IV C</td>
<td>VALVES INCORRECTLY POSITIONED. WASTE FLOWS FROM POLISHING FILTER.</td>
<td>EMPLOYEE EXPOSURE TO PLATING WASTE.</td>
<td>1. ONE INTERLOCK; and 2. LEVEL C WORKER OUTFITTING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3D</td>
<td>2 I C</td>
<td>SAMPLE VALVE LEFT OPEN DURING WASTE TRANSFER TO REACTOR.</td>
<td>EMPLOYEE EXPOSURE TO PLATING WASTE.</td>
<td>NONE.</td>
<td>NEED TO CHANGE TO SELF-CLOSING SAMPLE VALVE.</td>
</tr>
<tr>
<td>3E</td>
<td>3 ID</td>
<td>SEVERAL PATHWAYS FOR LOW LEVEL SKIN CONTACT.</td>
<td>EMPLOYEE EXPOSURE TO SMALL AMOUNTS OF PLATING WASTE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>VERIFY OPERATOR TRAINING IN OCCUPATION HYGIENE.</td>
</tr>
<tr>
<td>4A3</td>
<td>4 III D</td>
<td>MISTAKENLY PUMP ACID RATHER THAN CAUSTIC TO REACTOR</td>
<td>HCN MAY GO OUT VENT STACK.</td>
<td>1. ADMINISTRATIVE PROCEDURE ON INTRODUCTION OF ACID TO SKID; and 2. VENT LINE INTERLOCK TO REAGENT FEED PUMP.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4A4</td>
<td>3 ID</td>
<td>INHALATION OF CALCIUM HYPOCHLORITE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4A5</td>
<td>3 ID</td>
<td>PH DROPS BELOW 10 DURING CALCIUM HYPOCHLORITE ADDITION.</td>
<td>RELEASE OF HCN OR CYANOCYANIDE TO VENT SYSTEM.</td>
<td>GOOD VENT SCRUBBER.</td>
<td>ADD pH ALARM TO PROGRAM LOGIC.</td>
</tr>
<tr>
<td>4A6</td>
<td>1 IA</td>
<td>INCORRECT SAMPLE DISPOSITION CAUSING HCN RELEASE.</td>
<td>RELEASE OF HCN; DEATH.</td>
<td>WASTE CONTAINER LABELING.</td>
<td>CHANGE PROCEDURE TO OXIDIZE SAMPLE PRIOR TO DISPOSAL OF WASTE; WASTE WILL BE CHARGED TO NEXT BATCH.</td>
</tr>
<tr>
<td>STEP</td>
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<tr>
<td>4A10</td>
<td>1 II A</td>
<td>INCORRECT SAMPLE DISPOSITION CAUSING HCN RELEASE</td>
<td>DEATH.</td>
<td>WASTE CONTAINER LABELING</td>
<td>CHANGE PROCEDURE TO OXIDIZE SAMPLE PRIOR TO DISPOSAL OF WASTE; WASTE WILL BE CHARGED TO NEXT BATCH.</td>
</tr>
<tr>
<td>4A11</td>
<td>3 I D</td>
<td>SODIUM THIOSULFATE INTRODUCED TO SOLIDS FEED HOPPER AND REACTS WITH SOLID CALCIUM HYPOCHLORITE RESIDUAL FROM PREVIOUS DRY FEED OPERATION.</td>
<td>HEAT GENERATION AND STEAM RELEASE IF WATER PRESENT.</td>
<td>MOISTURE DETECTOR PREVENTS WATER WHICH IS REQUIRED FOR REACTION.</td>
<td>CHARGE THIOSULFATE AS LIQUID FROM P-T1. CLEAN DRY FEED HOPPER.</td>
</tr>
<tr>
<td>4A11</td>
<td>3 I D</td>
<td>INHALATION OF SODIUM THIOSULFATE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4B4</td>
<td>3 I D</td>
<td>INHALATION OF CALCIUM HYPOCHLORITE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4B8</td>
<td>3 I D</td>
<td>SODIUM THIOSULFATE INTRODUCED TO SOLIDS FEED HOPPER REACTS WITH SOLID CALCIUM HYPOCHLORITE RESIDUAL FROM PREVIOUS DRY FEED OPERATION.</td>
<td>HEAT GENERATION STREAM RELEASE IF WATER PRESENT.</td>
<td>MOISTURE DETECTOR PREVENTS WATER WHICH IS REQUIRED FOR REACTION.</td>
<td>CHARGE THIOSULFATE AS LIQUID FROM P-T1. CLEAN DRY FEED HOPPER.</td>
</tr>
<tr>
<td>4B8</td>
<td>3 I D</td>
<td>INHALATION OF SODIUM THIOSULFATE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
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<tr>
<td>4C3</td>
<td>2 III A</td>
<td>OPERATOR FAILS TO REALIZE PRESENCE OF CYANIDE AND PROCEEDS TO ADD ACID FOR pH REDUCTION AS CALLED FOR IN CHROME PROCEDURE. SCRUBBER IS OVERTAXED AND HCN IS RELEASED TO ENVIRONMENT. BLOWER REMAINS ON. INTERLOCK FAILS. NO OPERATOR INTERDICTION.</td>
<td>RELEASE OF LARGE HCN TO SYSTEM VENT. IMMEDIATE CO-LOCATED HEALTH EFFECT OR DEATH.</td>
<td>NONE.</td>
<td>INTERLOCK SECOND HCN ALARM TO ACID ADDITION (BECOMES RANK 3 IV A).</td>
</tr>
<tr>
<td>4C3</td>
<td>3 V A</td>
<td>SAME AS ABOVE WITH BLOWER FAILURE AND NO WORKER INTERDICTION. SCRUBBER IS OVERTAXED. ALL HCN DETECTORS AND INTERLOCKS FAIL.</td>
<td>LARGE RELEASE OF HCN TO SYSTEM VENT. IMMEDIATE WORKER HEALTH EFFECT OR DEATH.</td>
<td>NONE.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4D3</td>
<td>2 III A</td>
<td>ACID IS TRANSFERRED TO SODIUM HYDROSULFIDE SOLUTION THROUGH 3 IMPROPERLY POSITIONED VALVES CREATING H₂S IN ROOM.</td>
<td>EMPLOYEE EXPOSURE; DEATH.</td>
<td>3 VALVES.</td>
<td>1. REVISE OPERATING INSTRUCTIONS TO PRECLUDE PRESENCE OF SODIUM HYDROSULFIDE IN OPERATION; and 2. ADD 3 WAY AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04, (BECOMES RANK 4 I A).</td>
</tr>
<tr>
<td>4E3</td>
<td>3 III B</td>
<td>ACID OR BASE IS BEING TRANSFERRED AND MIX WITH BASE OR ACID CAUSING ERUPTION OF REAGENTS; OPERATOR EXPOSURE DUE TO 3 IMPROPERLY POSITIONED VALVES.</td>
<td>WORKER INJURY AND DISABILITY.</td>
<td>1. PROTECTIVE CLOTHING; and 2. THREE VALVES.</td>
<td>ADD 3-WAY VALVE AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04, (BECOMES RANK 4 V B).</td>
</tr>
<tr>
<td>STEP</td>
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<tr>
<td>4F2</td>
<td>2 III A</td>
<td>OPERATOR FAILS TO REALIZE PRESENCE OF CYANIDE AND PROCEEDS TO ADD ACID FOR pH REDUCTION AS CALLED FOR IN METALS/CHROME PROCEDURE. SCRUBBER IS OVERTAXED AND HCN IS RELEASED TO ENVIRONMENT. BLOWER REMAINS ON. INTERLOCK FAILS. NO OPERATOR INTERDICTION.</td>
<td>RELEASE OF LARGE HCN TO SYSTEM VENT. IMMEDIATE CO-LOCATED HEALTH EFFECT OR DEATH.</td>
<td>ADDITIONAL.</td>
<td>INTERLOCK SECOND HCN ALARM TO ACID ADDITION (BECOMES RANK 3 IV A).</td>
</tr>
<tr>
<td>4F2</td>
<td>3 VA</td>
<td>SAME AS ABOVE WITH BLOWER FAILURE AND NO WORKER INTERDICTION. SCRUBBER IS OVERTAXED. ALL HCN DETECTORS AND INTERLOCKS FAIL.</td>
<td>LARGE RELEASE OF HCN TO SYSTEM VENT. IMMEDIATE WORKER HEALTH EFFECT OR DEATH.</td>
<td>NONE.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4F7</td>
<td>3 IV B</td>
<td>PLUG LEFT OFF Y-STRAINER, VALVE LEFT OPEN. OPERATOR COVERED WITH CONCENTRATED NaOH.</td>
<td>SKIN &amp; EYE DAMAGE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>REVISE OPERATING INSTRUCTIONS TO ASSURE Y-STRAINER IS CAPPED.</td>
</tr>
<tr>
<td>4F8</td>
<td>4 IV C</td>
<td>POLISHING FILTER LID LEFT OFF.</td>
<td>OPERATOR EXPOSURE TO NEUTRALIZED CHEMICAL PLATING WASTE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>EMPHASIZE VERIFICATION OF VALVE CLOSURE IN OPERATING INSTRUCTIONS.</td>
</tr>
<tr>
<td>4F10 &amp; 4F12</td>
<td>4 IV C</td>
<td>VALVES V-28 &amp; FV-28 ARE INCORRECTLY OPEN AND MATERIAL IS PUMPED FROM TUFF-TANK THRU HOPPER (P-F1A) ONTO FLOOR.</td>
<td>OPERATOR EXPOSED TO NEUTRALIZED CHEMICAL PLATING WASTE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>EMPHASIZE VERIFICATION OF VALVE CLOSURE IN OPERATING INSTRUCTIONS.</td>
</tr>
<tr>
<td>4F14</td>
<td>2 III A</td>
<td>ACID IS TRANSFERRED TO SODIUM HYDROSULFIDE BY IMPROPERLY POSITIONED VALVES.</td>
<td>EMPLOYEE EXPOSURE: DEATH.</td>
<td>THREE VALVES.</td>
<td>ADD 3 WAY AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04, (BECOMES RANK 4 IV A).</td>
</tr>
<tr>
<td>STEP</td>
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<td>CAUSE/SCENARIO</td>
<td>CONSEQUENCES</td>
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<tr>
<td>5A2</td>
<td>411D</td>
<td>FILL LINE IS REMOVED FROM TUFF-TANK AND MATERIAL IS PUMPED TO FLOOR.</td>
<td>OPERATOR CONTACT WITH WASTE.</td>
<td>PERSONNEL PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>5A2</td>
<td>411D</td>
<td>TUFF-TANK OVERFLOWS INTO FLOOR.</td>
<td>OPERATOR CONTACT WITH WASTE.</td>
<td>PERSONNEL PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>5B5 &amp; 5B9</td>
<td>411D</td>
<td>LEAK AT FILTER PRESS COMES IN CONTACT WITH OPERATOR.</td>
<td>OPERATOR CONTACT WITH NEUTRALIZED WASTE.</td>
<td>PERSONNEL PROTECTION.</td>
<td>NONE.</td>
</tr>
<tr>
<td>5B12</td>
<td>41V D</td>
<td>OPERATOR OPENS FILTER PRESS DURING FILTRATION OPERATION.</td>
<td>OPERATOR CONTACT WITH NEUTRALIZED WASTE.</td>
<td>TWO LEVELS OF INTERLOCK.</td>
<td>NONE.</td>
</tr>
<tr>
<td>6K</td>
<td>31D</td>
<td>OPERATOR COMES IN CONTACT WITH FILTER CAKE DURING SCRAPING OF FILTER CAKE.</td>
<td>OPERATOR CONTACT WITH CAKE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>6L</td>
<td>21C</td>
<td>DRUM COULD BE DROPPED ON OPERATOR WHILE REMOVING IT FROM UNDERNEATH DROP CHUTE.</td>
<td>LOST TIME INJURY.</td>
<td>NONE.</td>
<td>INSTALL RAMP TO FACILITATE DRUM REMOVAL.</td>
</tr>
<tr>
<td>8F</td>
<td>31D</td>
<td>OVERFLOW SLURRY. OPERATOR CONTACT.</td>
<td>OPERATOR CONTACT WITH PROCESSED SLURRY.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>8H</td>
<td>21C</td>
<td>DRUM COULD BE DROPPED ON OPERATOR WHILE REMOVING IT FROM UNDERNEATH DROP CHUTE.</td>
<td>LOST TIME INJURY.</td>
<td>NONE.</td>
<td>INSTALL RAMP TO FACILITATE DRUM REMOVAL.</td>
</tr>
<tr>
<td>9H</td>
<td>311B</td>
<td>35% PEROXIDE REACTS WITH REDUCTANT CREATING HEAT &amp; HYDROGEN RESULTING IN EXPLOSION.</td>
<td>EXPLOSION; INJURY.</td>
<td>NONE.</td>
<td>REPLACE 35% PEROXIDE WITH 20% TO MAKE SYSTEM INTRINSICALLY SAFE.</td>
</tr>
<tr>
<td>9I</td>
<td>11A</td>
<td>WRONGLY DETERMINE PROCESS STEP NEUTRALIZING WITH ACID IN SCRUBBER. BLOWER OFF.</td>
<td>HCN RELEASE INTO OPERATING AREA; DEATH.</td>
<td>1. HCN PROCESS ALARM; 2. HCN ROOM ALARM; and 3. PRESSURE INTERLOCK.</td>
<td>1. MODIFY OPERATING PROCEDURE TO HAVE VERIFICATION; 2. TRANSFER SCRUBBER LIQUOR TO REACTOR; and 3. ALWAYS KEEP BLOWER ON. (BECOMES RANK 3 IV A).</td>
</tr>
<tr>
<td>R-F-C</td>
<td>STEP</td>
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<tr>
<td>1 II A</td>
<td>4A6</td>
<td>INCORRECT SAMPLE DISPOSITION CAUSING HCN RELEASE.</td>
<td>RELEASE OF HCN; DEATH.</td>
<td>WASTE CONTAINER LABELING.</td>
<td>CHANGE PROCEDURE TO OXIDIZE SAMPLE PRIOR TO DISPOSAL OF WASTE; WASTE WILL BE CHARGED TO NEXT BATCH.</td>
</tr>
<tr>
<td>1 II A</td>
<td>4A10</td>
<td>INCORRECT SAMPLE DISPOSITION CAUSING HCN RELEASE</td>
<td>DEATH.</td>
<td>WASTE CONTAINER LABELING</td>
<td>CHANGE PROCEDURE TO OXIDIZE SAMPLE PRIOR TO DISPOSAL OF WASTE; WASTE WILL BE CHARGED TO NEXT BATCH.</td>
</tr>
<tr>
<td>1 II A</td>
<td>9I</td>
<td>WRONGLY DETERMINE PROCESS STEP NEUTRALIZING WITH ACID IN SCRUBBER. BLOWER OFF.</td>
<td>HCN RELEASE INTO OPERATING AREA; DEATH.</td>
<td>1. HCN PROCESS ALARM; 2. HCN ROOM ALARM; and 3. PRESSURE INTERLOCK.</td>
<td>1. MODIFY OPERATING PROCEDURE TO HAVE VERIFICATION; 2. TRANSFER SCRUBBER LIQUOR TO REACTOR; and 3. ALWAYS KEEP BLOWER ON. (BECOMES RANK 3 IV A).</td>
</tr>
<tr>
<td>2 I C</td>
<td>3D</td>
<td>SAMPLE VALVE LEFT OPEN DURING WASTE TRANSFER TO REACTOR.</td>
<td>EMPLOYEE EXPOSURE TO PLATING WASTE.</td>
<td>NONE.</td>
<td>NEED TO CHANGE TO SELF-CLOSING SAMPLE VALVE.</td>
</tr>
<tr>
<td>2 I C</td>
<td>6L</td>
<td>DRUM COULD BE DROPPED ON OPERATOR WHILE REMOVING IT FROM UNDERNEATH DROP CHUTE.</td>
<td>LOST TIME INJURY.</td>
<td>NONE.</td>
<td>INSTALL RAMP TO FACILITATE DRUM REMOVAL.</td>
</tr>
<tr>
<td>2 I C</td>
<td>8H</td>
<td>DRUM COULD BE DROPPED ON OPERATOR WHILE REMOVING IT FROM UNDERNEATH DROP CHUTE.</td>
<td>LOST TIME INJURY.</td>
<td>NONE.</td>
<td>INSTALL RAMP TO FACILITATE DRUM REMOVAL.</td>
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<tr>
<td>2 III A (3 IV A)</td>
<td>3D</td>
<td>ACID IN R-1 FLOWS TO FEED DRUM.</td>
<td>1. HCN FORMED; and 2. LOSS OF LIFE.</td>
<td>NONE.</td>
<td>REDESIGN FEED INTRODUCTION TO PREVENT BACKFLOW: 1. REPipe; 2. 3-WAY VALVE TO PUMP P-P2; or 3. INDEPENDENT PUMP TO TOP OF P-R1.</td>
</tr>
<tr>
<td>2 III A</td>
<td>4C3</td>
<td>OPERATOR FAILS TO REALIZE PRESENCE OF CYANIDE AND PROCEEDS TO ADD ACID FOR pH REDUCTION AS CALLED FOR IN CHROME PROCEDURE. SCRUBBER IS OVERTAXED AND HCN IS RELEASED TO ENVIRONMENT. BLOWER REMAINS ON. INTERLOCK FAILS. NO OPERATOR INTERDICTION.</td>
<td>RELEASE OF LARGE HCN TO SYSTEM VENT. IMMEDIATE CO-LOCATED HEALTH EFFECT OR DEATH.</td>
<td>NONE.</td>
<td>INTERLOCK SECOND HCN ALARM TO ACID ADDITION (BECOMES RANK 3 IV A).</td>
</tr>
<tr>
<td>2 III A</td>
<td>4D3</td>
<td>ACID IS TRANSFERRED TO SODIUM HYDROSULFIDE SOLUTION THROUGH 3 IMPROPERLY POSITIONED VALVES CREATING H2S IN ROOM.</td>
<td>EMPLOYEE EXPOSURE; DEATH.</td>
<td>3 VALVES.</td>
<td>1. REVISE OPERATING INSTRUCTIONS TO PRECLUDE PRESENCE OF SODIUM HYDROSULFIDE IN OPERATION; and 2. ADD 3 WAY AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04, (BECOMES RANK 4 I A).</td>
</tr>
<tr>
<td>R-F-C</td>
<td>STEP</td>
<td>CAUSE/SCENARIO</td>
<td>CONSEQUENCES</td>
<td>PROTECTIVE FEATURES</td>
<td>ACTIONS</td>
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</tr>
<tr>
<td>2 III A 4F2</td>
<td>OPERATOR FAILS TO REALIZE PRESENCE OF CYANIDE AND PROCEEDS TO ADD ACID FOR pH REDUCTION AS CALLED FOR IN METALS/CHROME PROCEDURE. SCRUBBER IS OVERTAXED AND HCN IS RELEASED TO ENVIRONMENT. BLOWER REMAINS ON. INTERLOCK FAILS. NO OPERATOR INTERDICT.</td>
<td>RELEASE OF LARGE HCN TO SYSTEM VENT. IMMEDIATE CO-LOCATED HEALTH EFFECT OR DEATH.</td>
<td>ADDITIONAL.</td>
<td>INTERLOCK SECOND HCN ALARM TO ACID ADDITION (BECOMES RANK 3 IV A).</td>
<td></td>
</tr>
<tr>
<td>2 III A 4F14</td>
<td>ACID IS TRANSFERRED TO SODIUM HYDROSULFIDE BY IMPROPERLY POSITIONED VALVES.</td>
<td>EMPLOYEE EXPOSURE; DEATH.</td>
<td>THREE VALVES.</td>
<td>ADD 3 WAY AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04, (BECOMES RANK 4 I A).</td>
<td></td>
</tr>
<tr>
<td>3 I D 2C</td>
<td>START SCRUBBER PUMP P-P3 SAMPLE VALVE LEFT OPEN.</td>
<td>CAUSTIC SPILL - EMPLOYEE EXPOSURE.</td>
<td>1. PROTECTIVE CLOTHING, and 2. SECONDARY CONTAIN-MENT.</td>
<td>INSTALL SPRING RETURN SAMPLE VALVE.</td>
<td></td>
</tr>
<tr>
<td>3 I D 3E</td>
<td>SEVERAL PATHWAYS FOR LOW LEVEL SKIN CONTACT.</td>
<td>EMPLOYEE EXPOSURE TO SMALL AMOUNTS OF PLATING WASTE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>VERIFY OPERATOR TRAINING IN OCCUPATION HYGIENE.</td>
<td></td>
</tr>
<tr>
<td>3 I D 4A4</td>
<td>INHALATION OF CALCIUM HYPOCHLORITE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
<td></td>
</tr>
<tr>
<td>3 I D 4A5</td>
<td>PH DROPS BELOW 10 DURING CALCIUM HYPOCHLORITE ADDITION.</td>
<td>RELEASE OF HCN OR CYANOGEN CHLORIDE TO VENT SYSTEM.</td>
<td>GOOD VENT SCRUBBER.</td>
<td>ADD pH ALARM TO PROGRAM LOGIC.</td>
<td></td>
</tr>
<tr>
<td>3 I D 4A11</td>
<td>SODIUM THIOSULFATE INTRODUCED TO SOLIDS FEED HOPPER AND REACTS WITH SOLID CALCIUM HYPOCHLORITE RESIDUAL FROM PREVIOUS DRY FEED OPERATION.</td>
<td>HEAT GENERATION AND STEAM RELEASE IF WATER PRESENT.</td>
<td>MOISTURE DETECTOR PREVENTS WATER WHICH IS REQUIRED FOR REACTION.</td>
<td>CHARGE THIOSULFATE AS LIQUID FROM P-T1. CLEAN DRY FEED HOPPER.</td>
<td></td>
</tr>
<tr>
<td>R-F-C</td>
<td>STEP</td>
<td>CAUSE/SCENARIO</td>
<td>CONSEQUENCES</td>
<td>PROTECTIVE FEATURES</td>
<td>ACTIONS</td>
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</tr>
<tr>
<td>3 I D</td>
<td>4A11</td>
<td>INHALATION OF SODIUM THIOSULFATE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3 I D</td>
<td>4B4</td>
<td>INHALATION OF CALCIUM HYPOCHLORITE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3 I D</td>
<td>4B8</td>
<td>SODIUM THIOSULFATE INTRODUCED TO SOLIDS FEED HOPPER REACTS WITH SOLID CALCIUM HYPOCHLORITE RESIDUAL FROM PREVIOUS DRY FEED OPERATION.</td>
<td>HEAT GENERATION STREAM RELEASE IF WATER PRESENT.</td>
<td>MOISTURE DETECTOR PREVENTS WATER WHICH IS REQUIRED FOR REACTION.</td>
<td>CHARGE THIOSULFATE AS LIQUID FROM P-T1 CLEAN DRY FEED HOPPER.</td>
</tr>
<tr>
<td>3 I D</td>
<td>4B8</td>
<td>INHALATION OF SODIUM THIOSULFATE DURING REAGENT TRANSFER.</td>
<td>RESPIRATORY IRRITATION.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3 I D</td>
<td>6K</td>
<td>OPERATOR COMES IN CONTACT WITH FILTER CAKE DURING SCRAPING OF FILTER CAKE.</td>
<td>OPERATOR CONTACT WITH CAKE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3 I D</td>
<td>8F</td>
<td>OVERFLOW SLURRY OPERATOR CONTACT.</td>
<td>OPERATOR CONTACT WITH PROCESSED SLURRY.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3 III B</td>
<td>4E3 or 4E4</td>
<td>ACID OR BASE IS BEING TRANSFERRED AND MIX WITH BASE OR ACID CAUSING ERUPTION OF REAGENTS; OPERATOR EXPOSURE DUE TO 3 IMPROPERLY POSITIONED VALVES.</td>
<td>WORKER INJURY AND DISABILITY.</td>
<td>1. PROTECTIVE CLOTHING; and 2. THREE VALVES.</td>
<td>ADD 3-WAY VALVE AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04, (BECOMES RANK 4 V B).</td>
</tr>
<tr>
<td>3 III B</td>
<td>9H</td>
<td>35% PEROXIDE REACTS WITH REDUCTANT CREATING HEAT &amp; HYDROGEN RESULTING IN EXPLOSION.</td>
<td>EXPLOSION; INJURY.</td>
<td>NONE.</td>
<td>REPLACE 35% PEROXIDE WITH 20% TO MAKE SYSTEM INTRINSICALLY SAFE.</td>
</tr>
<tr>
<td>3 III C</td>
<td>3D</td>
<td>VALVES INCORRECTLY POSITIONED. WASTE FLOWS TO FILTER PRESS HOPPER.</td>
<td>EMPLOYEE EXPOSURE TO PLATING WASTE.</td>
<td>1. ONE INTERLOCK; and 2. LEVEL C WORKER OUTFITTING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>R-F-C</td>
<td>STEP</td>
<td>CAUSE/SCENARIO</td>
<td>CONSEQUENCES</td>
<td>PROTECTIVE FEATURES</td>
<td>ACTIONS</td>
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<tr>
<td>3 IV A</td>
<td>3D</td>
<td>WASTE INTRODUCED TO ACID REAGENT DRUM FROM: 1. WASTE DRUM. 2. REACTOR.</td>
<td>GENERATION OF HCN; DEATH.</td>
<td>TWO SERIES INTERLOCKS &amp; IMPROPER POSITION OF THREE VALVES.</td>
<td>REVISE OPERATING PROCEDURES TO PREVENT CONNECTION OF ACID DRUM TO SYSTEM WHILE CYANIDE SOLUTION IS PRESENT.</td>
</tr>
<tr>
<td>3 IV B</td>
<td>4F7</td>
<td>PLUG LEFT OFF Y-STRAINER, VALVE LEFT OPEN. OPERATOR COVERED WITH CONCENTRATED NaOH.</td>
<td>SKIN &amp; EYE DAMAGE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>REVISE OPERATING INSTRUCTIONS TO ASSURE Y-STRAINER IS CAPPED.</td>
</tr>
<tr>
<td>3 VA</td>
<td>3B</td>
<td>HCN IS PRESENT IN DRUM HEAD SPACE.</td>
<td>RELEASE OF HCN; DEATH.</td>
<td>1. PACKAGED IN BASIC FORM; 2. PRESAMPLED DRUM; and 3. OPERATOR PROTECTIVE CLOTHING.</td>
<td>1. VERIFY PROPER OPERATION; and 2. MODIFY PROCEDURE TO INCLUDE VENT CAPTURE AT DRUM OPENING.</td>
</tr>
<tr>
<td>3 VA</td>
<td>4C3</td>
<td>SAME AS ABOVE WITH BLOWER FAILURE AND NO WORKER INTERDICTION. SCRUBBER IS OVERTAXED. ALL HCN DETECTORS AND INTERLOCKS FAIL.</td>
<td>LARGE RELEASE OF HCN TO SYSTEM VENT. IMMEDIATE WORKER HEALTH EFFECT OR DEATH.</td>
<td>NONE.</td>
<td>NONE.</td>
</tr>
<tr>
<td>3 VA</td>
<td>4F2</td>
<td>SAME AS ABOVE WITH BLOWER FAILURE AND NO WORKER INTERDICTION. SCRUBBER IS OVERTAXED. ALL HCN DETECTORS AND INTERLOCKS FAIL.</td>
<td>LARGE RELEASE OF HCN TO SYSTEM VENT. IMMEDIATE WORKER HEALTH EFFECT OR DEATH.</td>
<td>NONE.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 II D</td>
<td>2B</td>
<td>OVER FILLING SCRUBBER SYSTEM AND RELEASE OF DILUTE CAUSTIC TO SECONDARY CONTAINMENT.</td>
<td>EMPLOYEE EXPOSURE TO DILUTE CAUSTIC.</td>
<td>LEVEL D CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 II D</td>
<td>3D</td>
<td>UTILITY WATER FLOWS INTO FEED LANCE.</td>
<td>SPILL OF FEED FROM ANNULAR AREA AROUND STINGER.</td>
<td>SECONDARY CONTAINMENT.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 II D</td>
<td>5A2</td>
<td>FILL LINE IS REMOVED FROM TUFF-TANK AND MATERIAL IS PUMPED TO FLOOR.</td>
<td>OPERATOR CONTACT WITH WASTE.</td>
<td>PERSONNEL PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 II D</td>
<td>5A2</td>
<td>TUFF-TANK OVERFLOWS ONTO FLOOR.</td>
<td>OPERATOR CONTACT WITH WASTE.</td>
<td>PERSONNEL PROTECTIVE CLOTHING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>R-F-C</td>
<td>STEP</td>
<td>CAUSE/SCENARIO</td>
<td>CONSEQUENCES</td>
<td>PROTECTIVE FEATURES</td>
<td>ACTIONS</td>
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</tr>
<tr>
<td>4 II D</td>
<td>5B5 &amp; 5B9</td>
<td>LEAK AT FILTER PRESS COMES IN CONTACT WITH OPERATOR.</td>
<td>OPERATOR CONTACT WITH NEUTRALIZED WASTE.</td>
<td>PERSONNEL PROTECTION.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 III D</td>
<td>4A3</td>
<td>MISTAKENLY PUMP ACID RATHER THAN CAUSTIC TO REACTOR</td>
<td>HCN MAY GO OUT VENT STACK.</td>
<td>1. ADMINISTRATIVE PROCEDURE ON INTRODUCTION OF ACID TO SKID; and 2. VENT LINE INTERLOCK TO REAGENT FEED PUMP.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 IV C</td>
<td>3D</td>
<td>VALVES INCORRECTLY POSITIONED. WASTE FLOWS FROM POLISHING FILTER.</td>
<td>EMPLOYEE EXPOSURE TO PLATING WASTE.</td>
<td>1. ONE INTERLOCK; and 2. LEVEL C WORKER OUTFITTING.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 IV C</td>
<td>4F8</td>
<td>POLISHING FILTER LID LEFT OFF.</td>
<td>OPERATOR EXPOSURE TO NEUTRALIZED CHEMICAL PLATING WASTE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>EMPHASIZE VERIFICATION OF VALVE CLOSURE IN OPERATING INSTRUCTIONS.</td>
</tr>
<tr>
<td>4 IV C</td>
<td>4F10 &amp; 4F12</td>
<td>VALVES V-28 &amp; FV-28 ARE INCORRECTLY OPEN AND MATERIAL IS PUMPED FROM TUFF-TANK THRU HOPPER (P-F1A) ONTO FLOOR.</td>
<td>OPERATOR EXPOSED TO NEUTRALIZED CHEMICAL PLATING WASTE.</td>
<td>PROTECTIVE CLOTHING.</td>
<td>EMPHASIZE VERIFICATION OF VALVE CLOSURE IN OPERATING INSTRUCTIONS.</td>
</tr>
<tr>
<td>4 IV D</td>
<td>5B12</td>
<td>OPERATOR OPENS FILTER PRESS DURING FILTRATION OPERATION.</td>
<td>OPERATOR CONTACT WITH NEUTRALIZED WASTE.</td>
<td>TWO LEVELS OF INTERLOCK.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 VC</td>
<td>2A</td>
<td>V-63 LEFT CLOSED OR P-F4 PLUGGED</td>
<td>LOSS OF DILUTION AIR FLOW WITH RESULTANT LOSS OF VENT CAPACITY</td>
<td>HEPA OVER DESIGN; HCN ALARM</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 VC</td>
<td>3B</td>
<td>SODIUM CYANIDE PRESENT ON EXPOSED SURFACES DURING DRUM OPENING.</td>
<td>PATHWAY TO SKIN ABSORPTION.</td>
<td>1. RINSING SUCTION LANCE.</td>
<td>NONE.</td>
</tr>
<tr>
<td>4 VC</td>
<td>3C</td>
<td>DRUM LIQUID FULL, LIQUID OVERFLOWS TO DRUM TOP.</td>
<td>PATHWAY TO SKIN ABSORPTION.</td>
<td>1. SECONDARY CONTAINMENT; and 2. DRUM TOP CONTAINMENT.</td>
<td>ASSURE HEAD SPACE DURING SAMPLING.</td>
</tr>
<tr>
<td>N/A</td>
<td>3A</td>
<td>OPENS UTILITY VALVE.</td>
<td>NO SIGNIFICANT IMPACT.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CURRENT R-F-C</td>
<td>STEP</td>
<td>CAUSE/SCENARIO</td>
<td>ACTIONS</td>
<td>REVISE D</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1 II A</td>
<td>4A10</td>
<td>INCORRECT SAMPLE DISPOSITION CAUSING HCN RELEASE</td>
<td>CHANGE PROCEDURE TO OXIDIZE SAMPLE PRIOR TO DISPOSAL OF WASTE; WASTE WILL BE CHARGED TO NEXT BATCH.</td>
<td>3 A 4</td>
<td></td>
</tr>
<tr>
<td>1 II A</td>
<td>4A6</td>
<td>INCORRECT SAMPLE DISPOSITION CAUSING HCN RELEASE.</td>
<td>CHANGE PROCEDURE TO OXIDIZE SAMPLE PRIOR TO DISPOSAL OF WASTE; WASTE WILL BE CHARGED TO NEXT BATCH.</td>
<td>3 A 4</td>
<td></td>
</tr>
<tr>
<td>1 II A</td>
<td>9I</td>
<td>WRONGLY DETERMINE PROCESS STEP NEUTRALIZING WITH ACID IN SCRUBBER. BLOWER OFF.</td>
<td>1. MODIFY OPERATING PROCEDURE TO HAVE VERIFICATION; 2. TRANSFER SCRUBBER LIQUOR TO REACTOR; AND 3. ALWAYS KEEP BLOWER ON.</td>
<td>3 IV A</td>
<td></td>
</tr>
<tr>
<td>2 I C</td>
<td>3D</td>
<td>SAMPLE VALVE LEFT OPEN DURING WASTE TRANSFER TO REACTOR.</td>
<td>NEED TO CHANGE TO SELF-CLOSING SAMPLE VALVE.</td>
<td>4 IV C</td>
<td></td>
</tr>
<tr>
<td>2 I C</td>
<td>6L</td>
<td>DRUM COULD BE DROPPED ON OPERATOR WHILE REMOVING IT FROM UNDERNEATH DROP CHUTE.</td>
<td>INSTALL RAMP TO FACILITATE DRUM REMOVAL.</td>
<td>3 II C</td>
<td></td>
</tr>
<tr>
<td>2 I C</td>
<td>8H</td>
<td>DRUM COULD BE DROPPED ON OPERATOR WHILE REMOVING IT FROM UNDERNEATH DROP CHUTE.</td>
<td>INSTALL RAMP TO FACILITATE DRUM REMOVAL.</td>
<td>3 II C</td>
<td></td>
</tr>
<tr>
<td>2 III A</td>
<td>3D</td>
<td>ACID IN R-1 FLOWS TO FEED DRUM.</td>
<td>REDESIGN FEED INTRODUCTION TO PREVENT BACKFLOW: 1. REPIPE; 2. 3-WAY VALVE TO PUMP P-P2; or 3. INDEPENDENT PUMP TO TOP OF P-R1.</td>
<td>3 VA</td>
<td></td>
</tr>
<tr>
<td>2 III A</td>
<td>4C3</td>
<td>OPERATOR FAILS TO REALIZE PRESENCE OF CYANIDE AND PROCEEDS TO ADD ACID FOR pH REDUCTION AS CALLED FOR IN CHROME PROCEDURE. SCRUBBER IS OVERTAXED AND HCN IS RELEASED TO ENVIRONMENT. BLOWER REMAINS ON. INTERLOCK FAILS. NO OPERATOR INTERDICTION.</td>
<td>INTERLOCK SECOND HCN ALARM TO ACID ADDITION.</td>
<td>3 IV A</td>
<td></td>
</tr>
<tr>
<td>2 III A</td>
<td>4D3</td>
<td>ACID IS TRANSFERRED TO SODIUM HYDROSULFIDE SOLUTION THROUGH 3 IMPROPERLY POSITIONED VALVES CREATING H2S IN ROOM.</td>
<td>1. REVISE OPERATING INSTRUCTIONS TO PRECLUDE PRESENCE OF SODIUM HYDROSULFIDE IN OPERATION; AND 2. ADD 3 WAY AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04.</td>
<td>4 I A</td>
<td></td>
</tr>
<tr>
<td>2 III A</td>
<td>4F14</td>
<td>ACID IS TRANSFERRED TO SODIUM HYDROSULFIDE BY IMPROPERLY POSITIONED VALVES.</td>
<td>ADD 3 WAY AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04.</td>
<td>4 I A</td>
<td></td>
</tr>
<tr>
<td>CURRENT R-F-C</td>
<td>STEP</td>
<td>CAUSE/SCENARIO</td>
<td>ACTIONS</td>
<td>REVISE D</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2 III A</td>
<td>4F2</td>
<td>OPERATOR FAILS TO REALIZE PRESENCE OF CYANIDE AND PROCCEEDS TO ADD ACID FOR pH REDUCTION AS CALLED FOR IN METALS/CHROME PROCEDURE. SCRUBBER IS OVERTAXED AND HCN IS RELEASED TO ENVIRONMENT. BLOWER REMAINS ON. INTERLOCK FAILS. NO OPERATOR INTERDICTION.</td>
<td>INTERLOCK SECOND HCN ALARM TO ACID ADDITION.</td>
<td>3 IV A</td>
<td></td>
</tr>
<tr>
<td>3 I D</td>
<td>2C</td>
<td>START SCRUBBER PUMP P-P3 SAMPLE VALVE LEFT OPEN.</td>
<td>INSTALL SPRING RETURN SAMPLE VALVE.</td>
<td>4 IV D</td>
<td></td>
</tr>
<tr>
<td>3 I D</td>
<td>3E</td>
<td>SEVERAL PATHWAYS FOR LOW LEVEL SKIN CONTACT.</td>
<td>VERIFY OPERATOR TRAINING IN OCCUPATION HYGIENE.</td>
<td>2 II D</td>
<td></td>
</tr>
<tr>
<td>3 I D</td>
<td>4A11</td>
<td>SODIUM THIOSULFATE INTRODUCED TO SOLIDS FEED HOPPER AND REACTS WITH SOLID CALCIUM HYPOCHLORITE RESIDUAL FROM PREVIOUS DRY FEED OPERATION.</td>
<td>CHARGE THIOSULFATE AS LIQUID FROM P-T1. CLEAN DRY FEED HOPPER.</td>
<td>4 V D</td>
<td></td>
</tr>
<tr>
<td>3 I D</td>
<td>4A5</td>
<td>PH DROPS BELOW 10 DURING CALCIUM HYPOCHLORITE ADDITION.</td>
<td>ADD pH ALARM TO PROGRAM LOGIC.</td>
<td>4 I D</td>
<td></td>
</tr>
<tr>
<td>3 I D</td>
<td>4B8</td>
<td>SODIUM THIOSULFATE INTRODUCED TO SOLIDS FEED HOPPER REACTS WITH SOLID CALCIUM HYPOCHLORITE RESIDUAL FROM PREVIOUS DRY FEED OPERATION.</td>
<td>CHARGE THIOSULFATE AS LIQUID FROM P-T1. CLEAN DRY FEED HOPPER.</td>
<td>4 V D</td>
<td></td>
</tr>
<tr>
<td>3 III B</td>
<td>4E3 or 4E4</td>
<td>ACID OR BASE IS BEING TRANSFERRED AND MIX WITH BASE OR ACID CAUSING ERUPTION OF REAGENTS; OPERATOR EXPOSURE DUE TO 3 IMPROPERLY POSITIONED VALVES.</td>
<td>ADD 3-WAY VALVE AT INTERSECTION OF 1/2 CF-TT-07 AND 1/2 CF-15T-04.</td>
<td>4 V B</td>
<td></td>
</tr>
<tr>
<td>3 III B</td>
<td>9H</td>
<td>35% PEROXIDE REACTS WITH REDUCTANT CREATING HEAT &amp; HYDROGEN RESULTING IN EXPLOSION.</td>
<td>REPLACE 35% PEROXIDE WITH 20% TO MAKE SYSTEM INTRINSICALLY SAFE.</td>
<td>3 III B</td>
<td></td>
</tr>
<tr>
<td>3 IV A</td>
<td>3D</td>
<td>WASTE INTRODUCED TO ACID REAGENT DRUM FROM: 1. WASTE DRUM. 2. REACTOR.</td>
<td>REVISE OPERATING PROCEDURES TO PREVENT CONNECTION OF ACID DRUM TO SYSTEM WHILE CYANIDE SOLUTION IS PRESENT.</td>
<td>3 V A</td>
<td></td>
</tr>
<tr>
<td>3 IV B</td>
<td>4F7</td>
<td>PLUG LEFT OFF Y-STRAINER, VALVE LEFT OPEN. OPERATOR COVERED WITH CONCENTRATED NaOH.</td>
<td>REVISE OPERATING INSTRUCTIONS TO ASSURE Y-STRAINER IS CAPPED.</td>
<td>4 V B</td>
<td></td>
</tr>
<tr>
<td>3 VA</td>
<td>3B</td>
<td>HCN IS PRESENT IN DRUM HEAD SPACE.</td>
<td>1. VERIFY PROPER OPERATION. AND 2. MODIFY PROCEDURE TO INCLUDE VENT CAPTURE AT DRUM OPENING.</td>
<td>3 VA</td>
<td></td>
</tr>
<tr>
<td>4 IV C</td>
<td>4F10 &amp; 4F12</td>
<td>VALVES V-28 &amp; FV-28 ARE INCORRECTLY OPEN AND MATERIAL IS PUMPED FROM TUFF-TANK THRU HOPPER (P-F1A) ONTO FLOOR.</td>
<td>EMPHASIZE VERIFICATION OF VALVE CLOSURE IN OPERATING INSTRUCTIONS.</td>
<td>4 V C</td>
<td></td>
</tr>
<tr>
<td>4 IV C</td>
<td>4F8</td>
<td>POLISHING FILTER LID LEFT OFF.</td>
<td>EMPHASIZE VERIFICATION OF VALVE CLOSURE IN OPERATING INSTRUCTIONS.</td>
<td>4 V C</td>
<td></td>
</tr>
<tr>
<td>4 VC</td>
<td>3C</td>
<td>DRUM LIQUID FULL. LIQUID OVERFLOWS TO DRUM TOP.</td>
<td>ASSURE HEAD SPACE DURING SAMPLING.</td>
<td>4 V C</td>
<td></td>
</tr>
</tbody>
</table>