Electrostatic safety during the solvent extraction of copper

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Abstract: On-site studies are reported showing that the solvent extraction of copper can be carried out without risks of electrostatic ignition.

Safety against creation of electrostatic conditions that could ignite flammable gas mixtures relied primarily on the fast electrostatic charge decay capabilities of the solvent and organic liquids being processed. Measurements of the charge decay characteristics of the solvent, the extractant and the loaded and unloaded processing fluids showed that the time for charge relaxation in these fluids was sufficiently fast (0.025 to 0.028 seconds) that the build up of significant electrostatic voltages was prevented throughout pumping and tank separation operations. The use of highly insulating pipework and process tank liners and operation in a low humidity environment did not compromise safety - even though traditional earth bonding of isolated metal parts was not implemented or practical.

Any consideration to change the supply of solvent or extractant needs to be preceded by measurements of the charge decay performance of the processing liquids.

1. Introduction

A major fire occurred at the solvent extraction plant of the Western Mining Corporation 'Olympic Dam' copper mine in Australia in 1999. After the plant was rebuilt a second fire destroyed the plant in October 2001. Considerations indicated that electrostatic discharges were a likely cause. The solvent extraction plant at the Codelco Chile - Radomiro Tomic copper mine, near Calama in north Chile, was nominally identical to that at the ‘Olympic Dam’ plant. It is also a plant located at high altitude, about 3000m above sea level, and the ambient humidity can be down to around 15%RH. The question was reasonably raised as to whether there were comparable risks at the Radomiro Tomic plant. This paper describes the on-site studies carried out to assess these risks.

2. Solvent extraction process

Solvent extraction is used all over the world to transfer copper from a leach solution to an electrolytic solution for electrowinning. This achieves copper cathodes of very high purity. Copper ions are extracted from the leach solution with an organic mixture based on kerosene
(solvent) and an extractant. The organic component flows around a closed loop, first as unloaded organic solution, then mixed with the copper rich solution from the leaching to achieve a loaded organic solution. This is then mixed with the electrolytic solution to transfer the copper ions to the electrowinning process.

3. Observations and measurements

3.1 General aspects of electrostatic conditions

Measurements with a hand held Static Monitor (JCI 140) showed in many locations that the surfaces of the main pipes of high density polyethylene (HDPE) taking process liquids around the plant easily acquired surface voltages around 100V by rubbing and showed very slow charge decay rates. The highest voltage measured was about 180V, but at most other locations voltages were in the 10-50V range.

The fibreglass walkways were easy to charge and showed slow charge decay rates - so providing no opportunity to drain charge from an operator on the walkway.

It was noted that strips of plastic materials were used in coalescer units. These easily became charged on rubbing. Voltages over 5kV were observed. While under liquid this is not a problem, but maybe could become so when this material is removed and handled for cleaning in the open air.

Measurements were made with an intrinsically safe fieldmeter (IDB Model 404) over the foaming surface of loaded organic solvents. The electric fields observed showed readings corresponding to space potentials in the 70-140V range a distance above the surfaces, and lower close to surfaces. The higher voltage at a distance away from the surface indicated that the readings were mainly due to charged mist, not to a charged surface of the liquid or the foam. These voltages were of no ignition risk significance [5,6,7].

3.2 Body voltage measurements

Measurements were made of body voltages in various situations using an Electrostatic Voltmeter (JCI 148).

- Voltages up to about 700V were observed when shoes were scuffed on a fibreglass walkway
- Voltages up to 3.7kV were observed while standing on a fibreglass walkway in antistatic shoes when a company shirt was rubbed on the earthed metal handrail.

Body voltages around 1.7kV were measured on a plant operator.

It is unlikely, but possible, that hazardous level body voltages could occur on operators working on fibreglass walkway surfaces by scuffing his shoes and/or by rubbing clothing against the earthed handrail.

3.3 Measurements on gas atmospheres

Although there is quite a strong smell of ‘solvent’ in several places around the plant, and in particular within the separation tank buildings, the gas analyser (Crowcon Gasman II) showed readings very close to zero at all times and in all locations tested. This was true even close to the liquid surfaces in the open top pools. With kerosene no indication is expected until liquid temperatures exceed 35°C. During the summer, it is thought that temperatures in
the covered building might possibly reach a peak around 45°C. This is still well below the rated flashpoint of the solvent of 70°C. It needs to be noted, however, that surface temperatures of the black HDPE pipework exposed to the sun might well get above ambient. In normal operation the flow of the fluids and circulation through open surface pools is expected to keep temperatures down so no significant levels of flammable gas atmospheres are expected around the plant. It seems that minimum ignition energies for mists and foams may be lowered over normally reported values [4]. However, this is not considered relevant in the present situation because (as noted below) the electrostatic characteristics of the process fluids in this plant will maintain conditions far away from risk threshold values.

3.4 Measurements on materials

Corona charge decay measurements [1,2,3] were made with a Charge Decay Test Unit (JCI 155v5) on a Radomiro company shirt and an overjacket, on a sample of polypropylene liner, on the outside and inside surfaces of a sample section of HDPE pipe, on samples of loaded and unloaded organic solvents and on original solvent, extractant and solvent/extractant mixtures. A corona voltage of –9kV was used with a duration of 20ms.

Measurements on the shirt and jacket and on the sample of polypropylene liner were made with the material supported between the plates of a Charge Measuring Sample Support (JCI 176). Both these samples showed some pre-charge that arose from handling before the start of measurements. This was particularly strong with the shirt (over 225V). With the sections of HDPE pipe the JCI 155v5 was rested directly on the outer and inner surfaces. Charge decay times for the liner and HDPE pipe surfaces were estimated from the rate of decay after several tens of seconds.

For measurements on liquids the samples were placed in a stainless steel dish, about 100x70mm and 50mm deep and the JCI 155v5 was rested on the upper edge of the dish. The liquid surface was about 5mm below the underside of the instrument baseplate. The copper content of the ‘loaded’ process liquid was typically 10-12g l\(^{-1}\) and the ‘unloaded’ (from the discharge of a stripping stage) was 5-6 g l\(^{-1}\). The ‘solvent’ was Escaid-100 (pure kerosene). The usual ‘extractant’ was Acorga 5774. Some measurements were also made on another extractant available, M5640. A fresh mixture of source processing fluid, 20% solvent and 80% extractant (Agorga 5774), was made and tested. The results are summarised below and charge decay graphs for the various liquids are shown in Figures 1-6.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Decay time ((V_{pk} - V_{pk/e})) (s)</th>
<th>Initial peak voltage ((V))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company shirt</td>
<td>570</td>
<td>-1530</td>
</tr>
<tr>
<td>Company overjacket</td>
<td>8-17</td>
<td>-1684</td>
</tr>
<tr>
<td>Polypropylene liner</td>
<td>about 2000</td>
<td>-1655</td>
</tr>
<tr>
<td>Outside HDPE pipe</td>
<td>about 300</td>
<td>-1920</td>
</tr>
<tr>
<td>Inside HDPE pipe</td>
<td>about 4000</td>
<td>-1300</td>
</tr>
<tr>
<td>Loaded process liquid</td>
<td>1</td>
<td>0.028</td>
</tr>
<tr>
<td>Unloaded process liquid</td>
<td>2</td>
<td>0.025</td>
</tr>
<tr>
<td>Fresh solvent (kerosene)</td>
<td>5</td>
<td>0.480</td>
</tr>
<tr>
<td>Fresh extractant Acorga 5774</td>
<td>4</td>
<td>0.243</td>
</tr>
<tr>
<td>Fresh extractant M5640</td>
<td>3</td>
<td>0.328</td>
</tr>
<tr>
<td>Fresh mixture (20/80%)</td>
<td>6</td>
<td>0.402</td>
</tr>
</tbody>
</table>
The main points from the above charge decay studies are that:
- the shirt and over-jacket showed easy pre-charging and long charge decay times
- charge decay times on the HDPE pipe and on the polypropylene liner were very long
- charge decay times on all the process liquids were short. They were particularly short for the samples of processing liquids taken from production (0.025-0.028s), but even the source extractant and solvent liquids showed very reasonable charge decay times (less than ½ s).
- the charge decay curves for all the solvent and extractant liquids were very reproducible. The extractant liquids both showed a nearly constant rate of decay. This indicates that just these liquids were behaving Ohmically.

It was not feasible to measure ‘capacitance loading’ values in the usual way [1,2,3] because it was not easy to support the samples in a way that allowed measurement of the quantities of corona charge transferred. If it is assumed that comparable quantities of charge were transferred for the same corona voltage then the initial peak surface voltages indicate, inversely, the capacitance experienced by charge on the test surface. For the processing liquids this suggests that the capacitance of the ‘loaded’ liquid is much higher than for the ‘unloaded’. Both of these are higher than for the solvent, extractant or solvent/extractant mixture liquids. This indicates the influence of the residual copper loading in the ‘unloaded’ liquid on the capacitance loading.

4. Assessment of ignition risks

The short charge decay times measured for the loaded and unloaded process liquids (0.025-0.028s) will be very effective in limiting the occurrence of any significant electrostatic voltages on pipework and associated items and in separation tanks around the plant. Fresh solvent, extractant and the operational mixture of these show fairly short charge decay times – below ½ second. The shorter decay times of the samples of loaded and unloaded liquid show that decay times are reduced by processing actions.

If the textbook relationship between decay time and volume resistivity, \( \tau = \varepsilon \varepsilon_0 \rho \), applies then equivalent conductivities can be calculated from the present decay time measurements. Decay times of 0.025-0.028s would be equivalent to conductivities around 650pS m\(^{-1}\) - and decay times around ½ s would be equivalent to a conductivity around 35pS m\(^{-1}\).

Published research on electrostatic hazards associated with fuel flow in metal and plastic pipes indicates that liquid conductivities need to be above 200 pS m\(^{-1}\) [8] to 1000 pS m\(^{-1}\) [6] to avoid ignition risks. This information supports the present conclusion that plant operation is safe with present processing liquids.

5. Conclusions

Corona charge decay measurements on loaded and unloaded organic solvent solutions showed that both were able to dissipate static electric charge very quickly - with decay times of 0.025 to 0.028s. This gave good confidence that static charge will not create any significant potentials anywhere in the solvent extraction section of the plant during normal plant operation.

Electrostatic safety depends critically upon maintaining short charge decay times in the processing liquids. Any consideration of alternative solvents or extractants must therefore include appropriate measurement of charge decay times to confirm suitability.
Consideration was given to the risks that might arise at failure of normal operations – for instance a leak at a flange seal. It was recommended that a flammable gas analyser be used to check the local gas atmosphere and that when operators required to work where there is, or is likely to be, a flammable atmosphere they should wear clothing chosen to avoid retention of static charge and creation of significant body voltages. Suitable clothing should show corona charge decay times below 0.5s under the local working humidity conditions (around 20%RH). These operators should be provided with a suitable earth bonding cord that is connected to earth before they enter the risk area.

The outcome of the present study shows the importance of the electrostatic characteristics of the extractant and solvent fluids to the design, material selection and costs for solvent extraction plant.

References:
