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# Corrosion of Beryllium Exposed to Celotex and Water

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## Introduction

Celotex is a commercial rigid cellulose fiberboard product primarily used in the building construction industry. Currently celotex is being used as a packing material in AL-R8 containers. Ion chromatography of celotex packing material at Lawrence Livermore National Laboratory (LLNL) has indicated that this material contains aggressive anions, including chloride, which may accelerate corrosion (1). It is well known that beryllium is susceptible to pitting corrosion when exposed to chloride containing environments. Levy (2) noted pitting in beryllium at the open circuit potential when exposed to 0.1 M NaCl solution. This investigation attempts to evaluate the potential risk of accelerated beryllium corrosion from celotex and water which may occur naturally when celotex dust comes into contact with moisture from the atmosphere.

## Experimental Methods

The celotex packing material analyzed in this investigation was composed of approximately 80 wt% sugar cane fiber, 10% paper, 10% starch, and a wax emulsion. The manufacturing process is a wet slurry process in which no added chlorine is used in the processing. Aluminum sulfate is added to the slurry to precipitate the wax emulsion. The original specifications for storage in the AL-R8 container call for a grade of material which complied with ASTM C208 and C209. In order to obtain a sufficient amount of liquid for electrochemical testing and to insure as much of the water soluble components in celotex were extracted as possible, 111 grams of celotex were ground and then soaked in 700 ml of deionized water for approximately three weeks. A Buchner funnel was used to extract the supernatant liquid from the celotex. Of the original 700 ml of water, 250 ml was extracted and subsequently diluted with 125 ml of deionized water to yield a total of 375 ml of liquid. The pH of this solution was 4.0. Approximately 370 ml of this was used for electrochemistry experiments. This solution was deaerated in high purity argon for three days prior to immersing the sample. The remaining 5 ml of solution was analyzed for chloride and fluoride using ion chromatography (IC). To facilitate the IC analysis, the solution was diluted prior to analysis (1 part solution to 10 parts deionized water).

Potentiodynamic polarization curves were run at a scan rate of 0.1 mV/sec. A 5.3 Hz low pass filter was used to minimize noise. A saturated calomel electrode (SCE) was used for the reference electrode and a platinum mesh for the counter electrode. The S200F beryllium working electrode had a surface area of 1.43 cm<sup>2</sup> and was polished with 400 grit SiC paper prior to testing. Electrochemical measurements were made using commercially available hardware and software. To insure steady state, samples were left at the open circuit potential for one hour prior to running the polarization curves.

## Results and Discussion

Lawrence Livermore National Laboratory conducted an IC analysis of the celotex and found that the chloride concentration was 0.94 g Cl/kg celotex. To determine the precise concentration of Cl<sup>-</sup> and F<sup>-</sup> in our solution, IC analysis was performed at LANL on the 5 ml aliquot removed prior to testing the beryllium. The actual chloride concentration of the solution was determined from the initial and dilution volumes. The chloride concentration, 0.0077M, was calculated to be 1.7 g Cl/kg celotex. The fluoride concentration, 0.0074M, was calculated to be 0.89 g F/kg celotex.

The difference between the Cl<sup>-</sup> and F<sup>-</sup> concentrations determined in the LLNL IC analysis and those determined at LANL likely owes to the differences in the extraction methods. The

celotex at LANL was shredded into 0.5-2 cm size pieces, and allowed to soak in solution for nearly three weeks prior to use. In the LLNL method, the sample sizes were 5-10 grams and no mention of the grinding/shredding of celotex was reported. Further, the samples only soaked in solution for two hours prior to IC analysis. Thus, the smaller particle sizes and longer soak times likely allowed more of the free available chloride to soak into solution.

Microbial analysis of the celotex solution found a high concentration of the bacteria diphtheroids bacillus. This bacteria is a commonly found airborne species. It has not been determined if the bacteria originated in the celotex, but their ability to reproduce was aided by the sugar cane in the celotex. Further, it is not clear whether the presence of this bacteria increases the corrosion rate of beryllium.

The open circuit potential (OCP) as a function of time for S200F beryllium in the deaerated celotex solution is presented in Figure 1. As the OCP rises to -0.88 V SCE, transients in the potential time curve not observed at lower potentials begin to appear. These potential/time transients at longer immersion times are an indication of pitting corrosion. Visual inspection of the beryllium sample revealed localized corrosion sites indicative of pitting corrosion.

A typical potentiodynamic polarization curve showing corrosion behavior of beryllium celotex solution is shown in Figure 2. It is characterized by large changes in current density for small changes in the applied potential, at all potentials above the open circuit potential. In comparison, potentiodynamic polarization curves showing the behavior of beryllium in 0.01 M NaCl, 0.01 M NaF, and a combined 0.01 M NaCl/0.01 M NaF solution are also shown in Figure 3. It can be seen that the electrochemical behavior of beryllium in celotex most closely resembles the 0.01M NaCl solution. Pitting of the beryllium did not occur when exposed to the 0.01M NaF. However, pitting has been observed in more dilute NaF solutions (less than 0.001M). For beryllium in the celotex solution, large changes in the current density were measured for very small changes in the applied potential at all potentials above the OCP.

The theoretical pitting potential for beryllium in a solution containing 0.0077 M chloride is -0.864 V SCE. This value was calculated using the linear fit for the plot in Figure 4. This value compares well with the observed pitting potentials of approximately -0.850 V and -0.870 V SCE and the theoretical line shown in Figure 4. However, the theoretical pitting potential calculated from the LLNL Cl<sup>-</sup> concentration analysis does not compare well with the measured pitting potential. The values from LLNL are approximately 50-75 mV more negative than the observed pitting potentials for beryllium in Cl<sup>-</sup>. More negative values are consistent with an underestimation of chloride concentration.

## Conclusions

These results indicate that storage conditions which may expose beryllium to a combination of celotex and moisture will result in pitting corrosion of the beryllium. Currently we are investigating the exact atmospheric conditions (i.e. temperature, humidity, celotex dust levels) which will result in pitting corrosion of beryllium. This is being accomplished with an atmospheric corrosion chamber which can simulate storage conditions.

## References

1. "Extraction Analysis of Celotex Packing Material", James D. LeMay, Lawrence Livermore National Laboratory, April 14, 1995.
2. D. J. Levy, The Electrolytic Polarization of Beryllium, Lockheed Missiles and Space Technical Report No. 6-90-61-75, (1961).

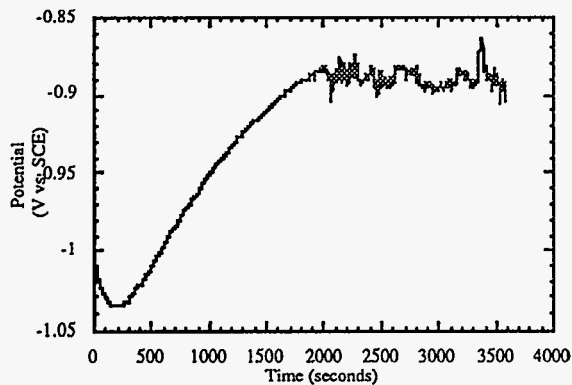


Figure 1. Open circuit potential as a function of time for S200F beryllium in celotex solution.

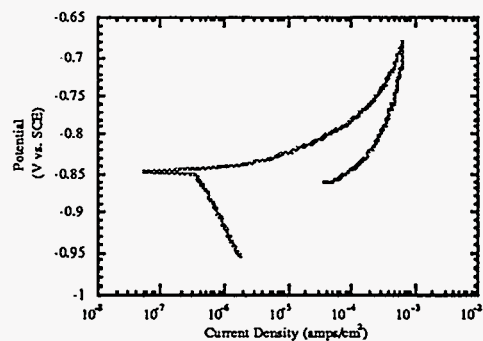


Figure 2. Potentiodynamic polarization curve for S200F Be in celotex solution.

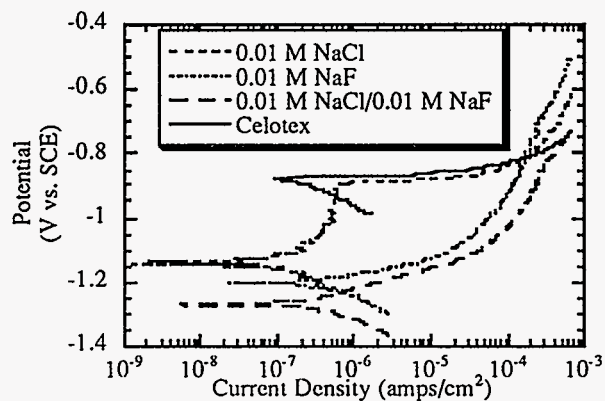


Figure 3. Potentiodynamic polarization curves for S200F beryllium. All solutions were deaerated and kept at ambient temperature.

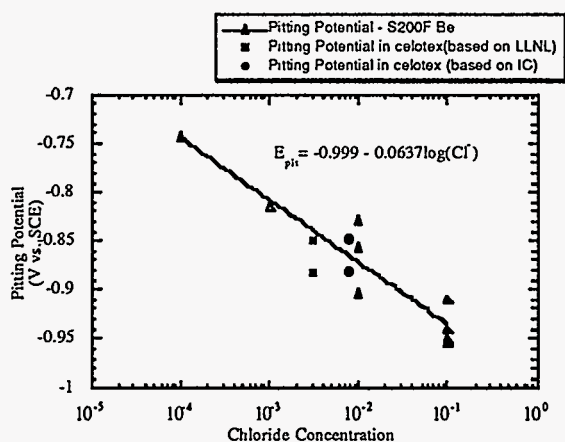


Figure 4. Pitting Potential for S200F beryllium as a function of chloride concentration. Measurements made in deaerated NaCl at ambient temperature. Graph also presents pitting potential observed in celotex solution based on both LLNL and LANL calculations of chloride concentration.