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**SUBJECT:** USE OF SILVER IN ETCHED-WIRING CARDS

**To:** J. W. Forrester

**From:** A. L. Loeb, B. B. Paine

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**Abstract:** Silver migration occurs easily through and across the surface of a variety of materials in the presence of moisture and unipolar potential. The behavior of silver is peculiar in that it may migrate more easily than any other metal. It is recommended that no silver be used in contact with laminated plastic materials, where potential is present, in equipment which is intended to operate dependably for long periods of time.

### Introduction

A brief study has been made of the conditions which contribute to the migration of silver in laminated plastic materials. This has included discussions with Professor Louis Harris of the MIT Chemistry Department, and with interested staff members at Squier Signal Laboratories and at Bell Telephone Laboratories, in cooperation with Mr. John Little of IBM.

### Findings

1. Silver can migrate through any porous or fibrous material, and across various surfaces, in the presence of moisture and with unipolar potential applied. This occurs because:
  - A. The silver atom and its ion  $\text{Ag}^+$  are about equally stable, so that the atom is easily oxidized and the ion easily reduced in an appropriate environment, such as reducing organic radicals, surface catalysts, or even the presence of light.
  - B. Silver hydroxide is quite soluble, and is a strong base.
  - C. Silver forms various highly soluble complex ions. The silver-ammonia complex is a good example. Complex anions containing silver are also commonly formed. Therefore, silver may migrate in either direction.
  - D. Oxidation products of cellulose (present in the paper or cloth reinforcing materials) can reduce the silver in solution to its metallic form. Cellulose is quite hygroscopic.

Findings (continued)

2. The silver ion can migrate with about 1000 times the facility of gold. It is the most active metal in this sense of all those tested by Bell Laboratories.

Migration has been seen to occur readily across the surface of clean ceramic bodies of various kinds, and also across the surfaces of other materials. Samples of paper-base phenolic seen at Bell Laboratories exhibited blackening throughout the body of the material, caused by colloidal silver deposits.

3. Certain plastic materials, such as cellulose acetate butyrate (Tenite II), do not appear to support migration, but this is apparently due to their homogeneity and lack of porosity. Also, the silver ion is large and cannot travel through plastics but only along interfaces or surfaces of fibers.
4. Migration cannot proceed at any noticeable rate in the absence of moisture. There may be a humidity threshold for some materials below which migration cannot occur. This possibility has not been fully studied.
5. The migration phenomenon is not yet fully understood. There are many unknown factors involved.

Conclusions

The presence of silver in laminated plastic materials may prejudice the long-term reliability of equipment. It is recommended that silver in contact with plastics be avoided in critical equipment. A report presenting recommendations for AN/FSQ-7 will be prepared jointly with IBM.

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