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Encapsulation of the glass wire-joint

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Introduction

One of the proposed solutions for the wire-joint problem is to encapsulate the glass wire-joint with a polyester or polyamide tube and epoxy. Previous tests showed that a thin layer of polyester or polyamide tubing or epoxy could protect the glass beads from the effect of CF_4. One main advantage of this solution is that the wire joint still depends on the bonding between the glass and tungsten wire, which is a proven technology and has been used in many areas. This advantage is also a disadvantage because any defect in protecting the glass could be catastrophic. In order for this technique to work, the production process should be simple and has to ensure to cover the glass completely. As shown below, the proposed process should solve the problem.

If this technique is adopted, we recommend maintaining the moisture content in the straw tubes below 500 ppm. This is to reduce the potential amount of HF/CF_4 radicals formed, thus reducing the failure of the glass joints. One of the tests showed that the glass etching is much reduced when the moisture content in the ionization gas is low.

Technique

Since the glass joints have to be completely covered, it is essential that the production technique ensures this. The first step to encapsulation is to slide in a tube over the wire. This process is relatively easy since the diameter of the proposed tube is ~350-400 microns with wall thickness of 15-20 microns. It is 0.9 cm long compared to the finished glass wire-joint which is ~0.6-0.7 cm.

Once the tube is positioned to next to the glass bead, glue is injected into the tube. Because the injection depends on capillary action, the glue has to have the correct viscosity. One of our construction glues (Stycast 1266 epoxy) meets the viscosity condition. The filling of the tube depends on capillary action, and any air bubbles in the tube are very unlikely. The filling process is visible with the naked eye and this should not be a problem. Figure 1 below shows a picture taken with a camera during the filling process. There is a clear boundary between glue and air.

Figure 1. The process of filling the tube with glue.

After the tube is filled with glue, it is slid over the glass wire-joint. As the glass enters the tube, glue covers the glass. This is the first protective layer. Since the viscosity of the glue is low, the glue should cover the glass completely without pushing the glue out from the tube. Figures 2 and 3 show pictures after the glass joint is inside the tube. The excess glue is cleaned and glue is cured overnight.

Figure 2. A picture of an end of the tube. The ball of glue is seen at the left end. The end of the glass wire-joint is seen about 1/3 of the way from the left side. There are a few air bubbles quite easily visible.

Figure 3. This picture shows the middle part of the wire-joint after the encapsulation. In the middle there is the mid-melt which separate the left and right side wire. The air bubbles in the picture are the ones already in the glass wire-joint.

We note that the glass is protected in two ways, once by the glue and the other is by the tube, and it should be safe. However the ends of the tube are only protected with the glue. We need to make sure that the ends of glass are covered with at least ~50 micron thick glue.

The QA for this step is done using a video camera connected to a TV screen. After looking at several samples, we conclude that a proper QA is not difficult at all. The ends of the glass tube inside a tube are quite visible and can easily detect any potential failures. Figure 2 shows a picture of an end of an encapsulated wire-joint. In this picture, one can see one end of the glass wire-joint and glue which fills the tube end. A few small air bubbles are clearly visible.

In the production, the tubes are inserted while the glass wire-joints are made. The encapsulation is done after a spool of the glass wire-joints are made. The wires are pulled out from the spool and cut to the length and lined up in a tray. The wires (about 30-50 per tray) are tensioned to ~20 gram using spring loaded clips. Once they are place on the tray, tubes are filled with glue and slipped over the glass beads. We think that we can complete ~30-50 encapsulations within the glue pot life of 30 minutes.

Fixtures

There are three fixtures. One is the tray where wires are lined up and glass wire-joint are encapsulated, another is the camera for the QA, and the last one is the glue-dispensing fixture. Because most of the encapsulation time is the glue filling time, the design has to be such that the end of the glue dispenser tip and the tube line up very easily. None of these fixtures is particularly hard to construct or costly.

Costs

The production of encapsulated wire joints will require one additional step from the existing glass wire joint manufacture. This includes the injection of glue and the QA of the joint afterwards. We expect to continue with the two current wire joint stations. Both of these stations will operate for ~10 hours per day with the production at each station to be ~120 per day. Each of these stations will require 1 technician per day. In order to do achieve this we will have staggered shifts and rotate these technicians with the module stringing technicians. The new encapsulation station will also operate 8 hours per day and should be able to encapsulate ~30 wire joints per hour. This will equate to 240 wire joints per day. So in addition to the module stringing technicians, we will require a minimum of 4 technicians to manufacture the encapsulated wire joints.

A new encapsulation station will be required to manufacture these joints. This station will include glue injection and video inspection equipment. Also needed will be a station to mix and prepare the two part glue for the operation.

The total labor to remanufacture all wire joints will be 4 full time technicians for 14.5 months. This equates to approximately $205K. The breakdown is 2/3 for making the glass wire joints and 1/3 for the encapsulation.

Conclusion

We believe that the encapsulation is a viable option for the wire-joint. The scheme preserves the excellent bonding between glass and tungsten. The difficulty of this option is to make certain that the glass joint is completely covered with either glue or tube. The proposed production and QA process should ensure this. We also recommend lowering the water level in the straw tubes below 500 ppm (the lower the better) in case there are defective wire-joints. The defective joints are likely to have cracks where CF_4 radicals could get in. We believe that with lower moisture level, the damage to the glass would be minimal.