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Procurement of Gold-Plated Aluminum Wire for the BaBar Drift Chamber Wire

1 Introduction

This document discusses the specifications and acceptance criteria for the procurement of 300,000 feet of 0.0047-inch-diameter and 150,000 feet of 0.0032-inch-diameter gold-plated aluminum wire for use in construction of a drift chamber for the BaBar experiment at the Stanford Linear Accelerator Center. The Appendix reviews the motivation for the specifications.

2 Specifications

2.1 Aluminum Alloy

The base material of the wire shall be a 5056 aluminum alloy.

2.2 Plating

The wire shall be gold-plated with not less than 20 microinches (0.5 μm) nor more than 36 microinches (0.9 μm) of gold and shall maintain 100% coverage of the wire surface with gold. The gold will be electroplated over two intermediate platings, the first of zincate, and the second of electroless nickel. The thicknesses of the intermediate platings should be less than 10 microinches.

2.3 Diameter

The procurement is for two lots of wire, called Lot A and Lot B. The diameter of the finished wire of Lot A shall be 0.0047 $\pm$ 0.0001 inch (120 $\pm$ 2.5 μm), and that of Lot B shall be 0.0032 $\pm$ 0.0001 inch (80 $\pm$ 2.5 μm).

2.4 Amount

The total length of the wire in Lot A shall be at least 300,000 feet, and that of Lot B shall be at least 150,000 feet.

2.5 Spooling

The wire shall be delivered on 4-inch-diameter spools in continuous, single lengths of no less that 1000 feet and no more than 3000 feet. Each spool shall have a label containing a unique spool number and also indicating the wire diameter, date of manufacture and production lot number. Each spool shall be accompanied by a data sheet summarizing the vendor's characterization of the wire properties.

2.6 Wire Finish

The surface texture of the wire shall not exceed 8 microinches (0.2 μm) by American Standard ASA B46.1-1962).

2.7 Yield Strength

The yield strength, defined by a 0.2% offset on a stress-strain curve, shall be no less than 400 g for Lot A and no less than 160 g for Lot B.

2.8 Stress Relief

The wire shall be stress relieved by heating and/or mechanical working.

2.9 Creep

When the wire is strung between two fixed points with a tension of 180 g for Lot A and 80 g for Lot B, the loss of tension shall be no more than 10% in 10 days.

2.10 Straightness

The wire shall deviate from a straight line by no more than 1/8 inch over a 10 foot length when hung vertically with a 1 g weight. The wire shall be free of kinks and sharp bends.

2.11 Cleanliness

The wire surface shall be free of oils, lubricants, fingerprints and other materials.

2.12 Delivery Schedule

The wire can be delivered in partial lots, but the delivery must be complete by December 31, 1996.

3 Acceptance Criteria

3.1 Initial Acceptance

Each spool of wire will be tested by Princeton University, acting for the BaBar Collaboration, within 30 days of receipt from the vendor. A spool can be rejected for failing to meet any of the specifications listed above. If a spool is rejected it will be returned to the vendor with a detailed description of the problem. The vendor will either replace the entire spool, remove the bad portion or correct the problem by other means mutually agreeable.

3.2 Subsequent Acceptance

During the installation of the wire into the BaBar drift chamber, which will take place at the TRIUMF Laboratory in Vancouver, B.C., Canada, additional samples of wire may be taken for testing. Should a spool exhibit fail to meet any of the specifications in these tests the remaining wire on the spool will be returned to the vendor, who must replace the unused bad wire.

4 Appendix: The BaBar Drift Chamber

4.1 The BaBar Collaboration

The BaBar Collaboration consists of more than 450 physicists from over 50 universities and laboratories worldwide who are engaged in the construction of a large detector of elementary particles. The detector will be operated at the PEP-II electron-positron storage rings at the Stanford Linear Accelerator Center to investigate the violation of CP-invariance in the decays of bottom quarks.

The general question addressed by these studies is what distinguishes our universe from a universe consisting of antimatter.

4.2 A Drift Chamber

One of several detectors being constructed by the BaBar Collaboration is a drift chamber.

A drift chamber is a device to detect charged elementary particles by means of the ionization these cause when they pass through a gas. Arrays of anode and cathode wires at suitable voltages collect the ionization electrons after they 'drift' from the point of ionization to the nearest anode wire. By measurement of the time of the drift, and a knowledge of the drift velocity the location of the ionization, and hence of the elementary particles can be inferred,

That is, a drift chamber is a kind of ruler for measuring the positions of elementary particles.

4.3 The BaBar Drift Chamber

The BaBar drift chamber is in the form of a cylinder approximately 11 feet long and 5 feet in diameter. The endplates are made of aluminum, between which are strung 7104 anode wires at positive high voltage, 14560 grounded cathode wires and 7104 cathode wires at an intermediate voltage. Each wire is 11 feet long. The anode wires are to be 0.0008-inch-diameter gold-plated tungsten and will be strung with 34 g tension. The grounded cathode wires are to be 0.0047-inch-diameter gold-plated aluminum and will be strung at 182 g tension. The intermediate-voltage cathode wires are to be 0.0032-inch-diameter gold-plated aluminum and will be strung at 86 g tension. The total force of the wires on the endplates is about 4 tons.

The desired accuracy of position measurements with the BaBar drift chamber is 0.004 inches (standard deviation).

This procurement refers to the aluminum cathode wires.

4.4 Chamber-Performance Issues

The specifications for the cathode wires are motivated by a number of technical considerations discussed below.

4.4.1 Wire Material

Some elementary particles pass through the wires as they traverse the chamber. Their interaction with the wire results in deflections of their trajectories, whose measurement is the goal of the drift chamber. These deleterious interactions can be minimized by the use of small wires and by the use of wires made of a low-atomic-number material. Pure beryllium wire might be an ideal choice if affordable; aluminum wire appears to be the lightest practical material.

4.4.2 Wire Diameter

In principle, very fine wires are to be preferred. But beyond issues of manufacturability of such wires, there is an important issue regarding the interaction of fine wires with the positive ions created by the passing elementary particles in the chamber gas. Experience shows that for cathode wires with surface electric fields above 20 kV/cm there is a substantial probability of formation of polymer whiskers out of fragments of the organic chamber gas. Such whiskers lead to continuous discharges in the chamber and effectively halt its operation.

The wire diameters specified above were chosen as small as possible, but such that the surface fields are no more than 20 kV/cm for the anticipated operating voltage.

4.4.3 Gold Plating

The wires are gold-plated for two reasons. First, to insure good electrical contact with the chamber endplates. Second, to avoid possible electrical breakdowns on the surface of the cathode wires due to positive charge buildup on patches of aluminum oxide (the Malter effect).

4.4.4 Surface Finish

Field emission from projections on the cathode wires must be avoided.

4.4.5 Straightness

During installation the wires must be strung by hand through holes only 0.006 inches in diameter. If the wire curls too much it becomes very difficult to 'thread the needle'.

4.4.6 Wire Tension

The wires in the BaBar drift chamber are strung horizontally. The wire tension must be sufficient to keep the 'sag' due to gravity less than 0.004 inches (the desired chamber resolution). The tension must also be large enough to avoid an electrostatic instability due to attractions between anode and cathode wires once they are displaced from their ideal positions.

4.4.7 Creep

Creep is the tendency of a material to deform slowly and permanently under stress. Creep of the aluminum cathode wires results in loss of tension and eventual instability of the wires when under voltage.

4.4.8 Yield Strength

The BaBar drift chamber is designed for a 10-year or more operational life. If any of its 40,000 wires breaks during this time some portion of the detector becomes inoperational until the broken wire can be removed. However, access to the chamber is extremely restricted once it is installed, resulting in delays of weeks to months before a broken wire could be extracted.

Hence there is a tremendous advantage not to break wires.

The yield strength (which is less than the breaking strength) is specified to be more than twice the nominal wire tension to provide a large margin of safety against wire breakage.

4.4.9 Cleanliness

The performance of the drift chamber is greatly affected by surface contamination of the wires. The chamber will be assembled in a class-10,000 cleanroom as a step towards minimizing such contamination. Cleanliness in wire manufacture is also critical.

4.4.10 Schedule

The BaBar drift chamber is currently in early stages of construction. Wire installation should begin in March 1997, and wire procurement, including initial acceptance tests, should be complete well in advance of this date.

The entire BaBar detector is scheduled for completion by late 1998.

5 Remarks on Creep, Elongation and Yield

[This section is not part of the document transmitted to the vendor.]

The order for the wire is being initiated on the basis of the above document. However, we are still discussing some details of wire-production options with California Fine Wire that have not resulted in a formal specification. It appears to me that the above list of specifications is not complete enough to optimize the wire for our application, although it is already slightly longer than the CLEO DR3 specifications.

California Fine Wire appears to have specialized in treatment of the aluminum wire to obtain unusually high yield strengths. This may have been encouraged by high-energy physicists in the hope that it would reduce the risk of wire breakage in drift chambers. However, it is not clear this is the best choice.

A high yield strength seems to be associated with a lesser amount of deformation in the transition from yield to breakage. ['Yield' is defined as a 0.2% departure from a linear stress-strain relation.] That is, once the CFW wire starts to yield little extra stress is required for it to break. Perhaps we would say the CFW wire is brittle rather than ductile.

Stringing the wire should not result in stresses that cause yield or breakage (unless the operator/robot makes a signficant mistake). However, crimping the wire into the crimp pin is a stressful operation. It might be better for the wire to yield more readily and deform under the crimping stress.

The CFW wire seems to exhibit significant creep (with some evidence of large batch-to-batch variation). The present worst case of creep will result in 15-20% departures of wire tension from nominal over the life of the chamber.

The elongation of the wire – amount of stretch before breaking – is presently between 1 and 1.5%, *i.e.*, between 2.8 and 4.2 cm over the length of the BaBar chamber. This is barely adequate to extract a crimp pin from an endplate without breaking the wire.

We know that the BELLE chamber wire has almost zero creep and much greater elongation. Also, its yield strength is much lower than that of the present CFW wire (C. Lu, private communication, confirmed by S. Uno of BELLE).

Naively I might have expected that a ductile wire would have larger creep than a more brittle one, but the comparison between the CFW wire and the BELLE wire suggests that the situation is more complicated.

Mike Greenelsh, president of CFW, advises us that there are several options in the treatment of the wire in which we can trade performance in one property against another. I have asked him to quantify the possible reduction in creep and gain in elongation in exchange, if necessary, for reduction in yield strength. He did not have an immediate answer but felt that they have much of the needed information on hand, and an answer could be given shortly.

We are waiting on this answer to judge whether we should make a small exploration of wire-paramemter space before production starts. If CFW proposes that we consider a significant change in the parameters, we (Princeton as well as any other concerned parties) will obtain and test samples of the alternatively processed wire before committing to production.

This final convergence on the production parameters is not meant to affect the Dec. 31, 1996 delivery date.