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Appendix

ANOCOAT 6004 AND ANOCOAT 6005 INSULATION COATINGS

Supplier

Anocut Engineering Co. 2375 Estes Avenue, Elk Grove Village, Ill. The following technical information is provided for Anocut customers to aid in the use of Anocut equipment. The submission of this information is not under any circumstances to be taken to imply a license under any patent rights pertaining to this subject matter except only in the use in operation of Anocut equipment.

General

Anocoat 6004 and Anocoat 6005 are epoxy type adhesive plastics especially well suited to the coating of copper, beryllium-bronze, and stainless steel electrodes to provide insulation. Anocoat 6004 is in putty form, meant to be applied by knife coating for thick coatings and filling. Anocoat 6005 is a flowable syrup used for thin coatings. Both materials are resistant to most saline, acid, and alkali type electrolytes and have good resistance to peeling, chipping, and mechanical and thermal shock.

Caution

Anocoat 6004 and Anocoat 6005 are toxic. The usual precautions in dealing with epoxy type plastics should be observed. Avoid contact with the skin and avoid breathing of vapors. Anyone working regularly with these materials should be protected by suitable exhaust arrangements. If skin contact occurs, remove with rubbing alcohol followed by washing with soap and water. Remove contaminated clothing and wash before

reuse. Avoid breathing of dust during grinding operations. Wash hands thoroughly before eating or smoking.

Storage

The shelf life of Anocoat 6004 and Anocoat 6005 is limited.

- The material should be stored at 40°F.
- Shelf life—3 to 6 months if stored in a refrigerator at 40°F.
- Shelf life—4 to 6 weeks if not stored in a refrigerator.

Before using, it should be allowed to warm thoroughly to room temperature before opening in order to prevent moisture condensation on the surface.

Application

1. Roughen electrode where coating is desired. See Anocut Engineering Company Technical Bulletin 2-C for more information on this point.
2. Wash electrode in detergent. Rinse thoroughly.
3. Etch electrode, and then wash thoroughly in running hot water. For copper and beryllium-bronze electrodes, use Anocut Engineering Company Anoetch 5001 as prescribed in their Technical Bulletin 2-C. For stainless steel electrodes, use Anoetch 5002 as prescribed in their Technical Bulletin 8-C.
4. Rinse thoroughly and dry at 180°F. Let cool. After etching, it is essential to avoid handling the electrode with the fingers or in any way so that dirt, grease, skin oils, and so on can adhere to the surface which is to be coated. Contamination will destroy the adhesion of the coating to the electrode. Rinse in Toluol just prior to coating and let dry.
5. With Anocoat 6005, dip electrode in the coating and let drain for 15 to 20 min. With Anocoat 6004, apply the coating where desired with a knife.
6. Preheat at 170 to 180°F for minimum of 30 min. This applies to 6005 only. Anocoat 6004 does not require a preheat period.
7. To cure, heat at 335 to 390°F for 60 min (longer at the lower temperatures). For an electrode that has been soldered, the curing temperature must be below the melting point of the solder (335°F is adequate for this). However, the higher curing temperatures (380 to 390°F) can produce a more heat-resistant coating.
8. Clean and polish face. Any coating material left on the cutting lip will cause sparking.

Dilution

The viscosity of Anocoat 6004 and Anocoat 6005 can be reduced in two ways: by heating to about 100°F or by diluting with Toluol. With the second method, take care to avoid entrapment of air in mixing. After mixing, allow time for air bubbles to rise to the surface. Preferably, 18 to 24 hours should be allowed while maintaining the diluted mixture at 90 to 100°F. If Toluol is used, a preheat period must be allowed to permit the Toluol to be driven off. In the case of 6005, this is in addition to the normal preheat period. The greater the dilution, the more time necessary for this purpose. Normally, 30 to 60 min at 150 to 180°F should be sufficient. Heating the coating to decrease viscosity, on the other hand, necessitates no change in the normal curing procedure.

ANOCOAT 6006 INSULATION COATING

Supplier

Anocut Engineering Co., 2375 Estes Avenue, Elk Grove Village, Ill. The following technical information is provided for the assistance of Anocut customers in the use of Anocut equipment. The submission of this information is not under any circumstances to be taken to imply a license under any patent rights pertaining to this subject matter except only in the use in operation of Anocut equipment.

General

This Anocoat material is very useful for coating intricately shaped electrodes, for coating parts of tooling, and for use as a masking material to protect areas adjacent to areas being machined by ECM. It is necessary to heat the part being coated to above the melting point of the powdered resin. The coating may be applied by spraying or by dipping the part into an aerated bed of the coating material. The coating may be machined to a smooth surface after curing.

Application—Cleaning

The coating adheres only to clean parts. The surface to be coated should be sandblasted or similarly prepared to remove dirt and oxidation. The surface should then be cleansed with a solvent such as trichloroethylene. Brass and copper parts must be cleaned with steel wool and

trichloroethylene after they have been heated since the heating produces an oxide coating on these materials. It is important that this cleaning does not cool the part below 375°F.

Heating

The surface to be coated must be heated to a temperature of 375 to 450°F. A part which dissipates heat rapidly should be heated to the higher temperature. Also, the thickness of the coating parts which are dipped is regulated by the temperature of the part. Higher temperatures produce thicker coatings.

Application

Dipping

An aerated bed of resin is required for dipping applications. Parts to be coated should be dipped, while hot, into the aerated bed for 1 to 3 sec. Heavy coatings should be produced by multiple dippings rather than prolonged exposure.

Spraying

The coating can be applied by spraying with a flocking gun. Air pressure should be at least 40 psi and the air must be dry. Recommended spray guns are

- Binks model 171
- DeVilbis model GB
- Paasche model FF ¾ in.

Curing

Residual heat in the part is usually enough to cure the coating. If not sufficient, the part may be oven cured for 2 min at 375°F or 30 sec at 450°F.

Precautions

Keep away from fire. The fine particles can be ignited by open flames or sparks. Avoid excessive air pressure, use adequate ventilation, and do not inhale dust. If an aerated bed is used, it must be grounded. If sprayed, a spray booth should be used. (It is possible to reclaim the unused resin.) Epoxy materials are toxic. Avoid inhalation. Use rubber gloves to avoid prolonged contact with the skin.

SYNTHETIC RUBBER INSULATION COATING*

This type of insulation may be applied in thicknesses of 0.010 to 0.250 in. It is tough and flexible, and securely bonds to copper that has been specially oxidized and treated with a primer coating. The finished coating may be readily machined using sharp tools, that is, milled, turned, or wet ground.

Materials Required

- Ebonol C Special. Crystalline material, which is made into a water-based solution of strength 1.5 lb/gal, used to oxidize copper. *Supplier*. Enthone Inc., Box 1900, New Haven, Conn.
- C-1445 primer. Liquid prime coat for insulation.
- C-1445 reducer. Liquid used for thinning or removing uncured primer.
- Miccrosol E-1003 Plastisol. Liquid insulation.
- Miccrostrip B. Liquid used for stripping insulation. *Supplier*. Michigan Chrome & Chemical Co., Detroit, Mich.
- Ensign 803 Encostrip Paint Stripper. Liquid used for stripping C-1445 primer. *Supplier*. Ensign Products Co., Cleveland, Ohio.
- Acetone may be used for cleaning up both primer and insulation.

It should be noted that the chemicals above require special handling because of their potential health or fire hazards. The suppliers recommend the necessary precautions.

Insulation Procedure

1. Immerse the tool to be insulated in Turco Vitro-Klene for 20 min. at 180 to 208°F or use a similar degreasing process.
2. Water rinse.
3. Dip for 20 sec, or until no more color changes occur, in 20 to 30% hydrochloric acid to remove surface oxides.
4. Water rinse but do not allow to dry and immediately proceed to next operation.
5. Totally immerse in solution of Ebonol C Special (1.5 lb/gal) at 210 to 215°F. Maneuver to eliminate trapped air in reentrant part of tool. Allow to soak until uniform "velvet" black oxide is formed over surfaces to carry insulation. This takes about 20 min.

* For application to copper only.

6. Thoroughly water rinse tool to flush all Ebonol from fibers of black oxide film and reentrant features of tool. Soaking in an overflowing water tank for 10 min is usually sufficient. *Note.* Do not touch or allow anything to touch areas to be coated.

7. Blow dry.

8. Inspect for deep black velvet appearance of oxide in areas to be coated. If not perfect, repeat steps three through seven.

9. Brush or spray C-1445 primer on surfaces that are to be insulated.

10. Air dry the primer for 15 min.

11. Suspend the tool in oven at 360 to 375°F for 50 to 60 min to cure primer.

12. Allow the tool to air cool to below 150°F.

13. Using masking tape, cover openings, holes, and slots that must be kept free from Miccrosol insulation.

14. Heat to 250 to 260°F for 10 min.

15. While hot, dip the tool slowly into Miccrosol allowing coverage without trapping air. Allow to remain in solution until a sufficient thickness of Miccrosol has jelled onto the surface of the tool.

16. Remove the tool from Miccrosol and allow excess to drain off.

17. Suspend in oven at 220 to 240°F for 25 min for insulation to set firm. If more insulation thickness is required repeat operations 15, 16, and 17.

18. Using a thin blade, trim Miccrosol from surfaces not requiring insulation.

19. Suspend in oven at 350 to 375°F for 50 to 60 min to cure insulation.

20. Air-cool. *Note.* Do not allow any solvents to contaminate the Miccrosol E-1003. Miccrosol is very viscous. When using allow time for it to flow slowly and smoothly without flopping and trapping air bubbles. Use care at all times to avoid creating bubbles in the Miccrosol. Pour or dip the tools slowly.

Recommendations for Further Reading

Electrochemical Machining, by A. E. DeBarr and D. A. Oliver. London: MacDonald and Company (Publishers) Ltd., 1968.

Nine experienced users of the process (the writer was one) from different locations contributed to this book. It deals with the theoretical and some of the practical aspects of ECM.

Non-Traditional Machining Processes, by R. K. Springborn. Dearborn, Michigan: American Society of Tool and Manufacturing Engineers, 1967.

A book with many expert contributors, which provides a concise account of some eleven new manufacturing processes, including ECM.

Electrochemical Machining, by Graduate Students at Harvard Business School. Boston, Massachusetts: The Nimrod Press, Inc., 1966.

Business survey and recommendations on ECM.

Glossary of Terms

The glossary of terms was prepared by the Cincinnati Milacron Company. The ECM terms and their definitions are generally accepted and used in Europe and the United States.

ACCUMULATOR A surge chamber to smooth out the pressure pulsations generated by a high pressure pump.

AMMETER A low-resistance meter connected in series with the circuit, used to measure the machining current (in amperes).

ANODE The work piece in electrochemical machining that is positive in polarity.

ANODIC METAL Metals vary in resistance to corrosion, oxidation, and dissolution in the presence of an electrolyte. A list showing the order of corrosion resistance is called the Galvanic series, and a metal near the bottom of the list will be more anodic in comparison to one at the top of the list and will dissolve, corrode, or oxidize quicker than a metal near the top of the list if the two metals are connected electrically in the presence of an electrolyte.

ARC An electrical flash, bluish in color, which is the result of a short circuit when the cathode physically contacts the work piece while current is flowing. Modern EC machines have anticipator circuitry to eliminate damage to the cathode or the work piece.

ARC ANTICIPATOR An electronic device to monitor the DIDT and the DVDT derivatives to protect the tooling by stopping the machining operation.

ATMOSPHERIC CORROSION Normal deterioration of a metal exposed to the weather. When used in contaminated atmospheres, or at raised temperatures, most metals will show increased breakdown.

AUTOMATIC CYCLE A machine feature that results in the machine automatically completing a machining operation on one work piece.

BACK PRESSURE Pressure above atmospheric which is purposely built up in the machining zone either by a valve or by another set restriction

placed in the discharge side of the electrolyte flow. Back pressure produces the best side wall surface and increases the overcut.

BACKUP A piece of metal, usually the same as or similar to the work piece (anode), or any other device, attached to the back surface of a workpiece and used to overcome breakthrough difficulties.

BERYLLIUM COPPER Copper-base alloys containing varying percentages of beryllium copper and nickel, having high tensile strength, high fatigue limit, and hardness, and a relatively high electrical and thermal conductivity, depending upon heat treatment. This material is primarily used to construct cathodes and holding fixtures.

BREAKTHROUGH That point in machining a through hole when the cathode machines through the back surface of the work piece.

BRIGHT DIP FINISH The finish obtained by immersing copper or copper alloy tooling, after brazing, in a suitable oxidizing acid solution. This process removes most scale and oxides. Some solutions contain detergents, and a thorough rinsing of the tool is necessary to prevent electrolyte foaming.

BUS BAR A large copper bar used to carry the machining current.

CATHODE The electrode or tool in electrochemical machining, which is negative in polarity.

CATHODE BODY That section of the cathode that supports the tip—the main or middle section.

CATHODIC METAL (see ANODIC METAL). The metal that better resists corrosion, dissolution, or oxidation in preference to another metal, when the metals are connected electrically in the presence of an electrolyte.

CAVITATION The rapid formation and collapse of vapor pockets in a flowing liquid, accompanied with pressure variations. This is a potential source of serious damage to impellers in pumps, valve parts, and so on.

CAVITY MACHINING Three-dimensional machining such as forging dies, molds, and so on. Also known as forming, shaping, or die sinking.

CENTER SLUG (CONE) The projection extending up from the machined surface toward or into the electrolyte passageway, caused by the current distribution in the electrolyte passageway.

CENTRIFUGE A clarifying device using centrifugal force to remove the metal hydroxides (precipitate or sludge) from the electrolyte.

CONDUCTO-LUBE A registered trademark of the Conducto-Lube Company for a conductive silver-base paste, recommended for use in high current connections.

CONTACT AREA The surface area of an electrical conductor that contacts another conductor for the passage of machining current.

COOL-AMP A registered trademark of the Cool-Amp Company for their silver plating powder; used to silver plate the contact area of high current connections.

COPPER TUNGSTEN A sintered copper metal containing 50 to 70% tungsten.

CORROSION PITTING Corrosion with some depth in small individual areas on the surface of a metal. Also known as pitting.

CREVICE CORROSION Associated most often with recesses and crevices such as a lapped joint, the space between two loosely joined plates, or other areas where corrodents may stagnate. It often occurs under the head of a bolt or washer.

CURRENT DENSITY The ratio of the machining current to the machining area, expressed in amperes per square inch (ASI); depends on type of material, but is proportional to the feed rate for a given material and is affected by the type of electrolyte.

DIDT DERIVATIVES The rate of change of current with respect to time.

DVDT DERIVATIVES The rate of change of voltage with respect to time.

DWELL Stopping feed for a predetermined time, with machining current and electrolyte flow remaining on, to produce greater overcut in the vicinity of the cathode lip.

ELECTRICAL CONDUCTIVITY A relative conductivity rating of metals based on the conductivity of technically pure copper which is rated as 100% on the International Annealed Copper Standard scale.

ELECTROCHEMICAL MACHINING (ECM) The controlled removal of metal by electrolytic action, without mechanical aid.

ELECTRODE The cathode or tool made of electrically conductive metal and having the desired contour or shape, size, and so on. It is always connected to the negative terminal of the power supply in electrochemical machining.

ELECTROLYSIS The process of chemical decomposition of metals, encouraged by the passage of current through an electrolyte.

ELECTROLYTE The electrically conductive fluid composed of concentrations of chemicals dissolved in water. Sodium chloride is used to machine a majority of metals, but other salts and various salt combinations have been used for cutting other metals. Dilute acid solutions are also used as electrolytes.

ELECTROLYTE CONCENTRATION The amount of a dissolved substance in solution per unit of volume of the electrolyte. Electrolyte concentration is measured with a hydrometer, and the reading can be converted to the usually expressed pounds per gallon (lb/gal).

ELECTROLYTE CONDUCTIVITY The electrical conductance measured between opposite faces of a 1-cm cube of an electrolyte at the point being measured; opposite of resistivity.

ELECTROLYTE RESISTIVITY The electrical resistance measured between opposite faces of a 1-cm cube of an electrolyte; opposite of conductivity.

ELECTROLYTIC CELL A general term for an area producing electrolysis, consisting essentially of the electrolyte, its container, and the electrodes.

ENTRY RADIUS The radius on the corner between the side wall of the machined cavity and the tool entry surface of the workpiece.

EQUILIBRIUM GAP A condition where the metal removal rate is equal to the feed rate. The machining current and the electrolyte flow have leveled out and are steady.

EXIT RADIUS The radius on the corner between the side wall of the machined cavity or hole and the tool exit surface of the workpiece.

FARADAY'S LAWS OF ELECTROLYSIS A theoretical basis for computing the amount of material set free, or deposited, by the ECM process. The amount removed is directly proportional to the current that passes through the electrolyte from the anode to the cathode in a given time. In practice, a number of factors tend to reduce the actual rate of metal removal per ampere.

FEED IN Moving the tool towards or into the work piece.

FEED OUT Retracting the tool from a cavity already machined in the work piece, with machining current and electrolyte flow remaining on to produce additional overcut or to obtain better surface finish.

FEED RATE The selected rate at which the cathode advances into or retracts from the work piece, usually expressed in thousandths of an inch per minute.

FEED RATE METER The instrument that indicates the rate at which the platen advances or retracts, usually expressed in thousandths of an inch per minute.

FILTER (IN-LINE) A high pressure filter that prevents foreign particles from reaching the machining gap. It is placed as close as possible to the machining gap.

FIXED WORKTABLE A work table fastened to the machine frame; one that cannot be moved to position the work piece.

FLOW LINES Narrow grooves or fine lines on the electrochemically machined surface of a workpiece caused by turbulent, inadequate, or nonuniform electrolyte flow through the machining gap, at conditions promoting unstable anodic oxide films on the workpiece surface.

FLOW RATE The volume of electrolyte passing through the machine gap, expressed in gallons per minute (gal/min).

FLUIDIZED BED A device built like an open tank, of almost any size, using air currents or vibration, or both, to keep dry powders in suspension or agitation. A heated object held in the agitated powder for a period of time will attract some particles and will become coated with the powder. Cured under heat, the powder becomes a usable insulation.

GALVANIC CORROSION The result of two dissimilar metals in contact with each other in an electrolyte, one tending to corrode faster than the other.

GAP, MACHINING The distance between the front face of the tool and the surface being machined.

HEAT EXCHANGER A unit used to cool a liquid by a refrigerant gas, evaporation, or water cooling.

HYDRODYNAMICS The science that deals with the motion of fluids and the forces acting on solid bodies immersed in fluids.

HYDROMETER A sealed glass cylinder with a weighted bulb and graduated stem, used to determine the specific gravity of a liquid by reading the figures on the portion of the graduated stem that emerges from the liquid being tested. Specific gravity, or degrees of Baume, Salimeter, and so on, can be converted to concentration in pounds per gallon if the temperature is also considered.

HYDROSTATIC FORCE The force applied by a liquid under pressure.

HYGROSENSOR An electronic device that detects the presence of moisture or water, as from overflow or leakage.

INCLUSION A particle of foreign matter, such as oxide, sulphide, or silicate, in the work piece material. Inclusions are most frequent in castings and forgings and are particularly troublesome for electrochemical machining.

INSULATION An electrically nonconductive material, either organic (epoxy) or inorganic (porcelain enamel), applied to the tool and fixture to restrict the flow of machining current to the desired areas.

INTERGRANULAR ATTACK A type of electrochemical corrosion that progresses along the grain boundaries of an alloy, usually because the grain boundary regions contain anodic material as compared to the central regions of the grain.

LAMINAR FLOW A smooth flow pattern of a fluid, as contrasted to turbulent flow.

LIP CLEARANCE The small area of the machining face of a cathode that extends beyond the body or shank of the cathode. This lip supplies protection for the insulation. Also known as tool land.

MACHINING CURRENT The electrical current which is used to remove metal from desired location on the part. It is the total current flowing between tool and work piece.

MACHINING ENCLOSURE The barrier that surrounds the machining operation to contain the electrolyte spray; usually made of stainless steel and/or plastic.

MACHINING VOLTAGE The voltage applied across the machining gap.

MACHINING ZONE The space between the active face of the tool and the machined surface of the work during machining.

METAL REMOVAL RATE The volume of metal removed in a unit of time, usually expressed in cubic inches per minute. This will vary from one metal to another, depending on its chemical analysis, as well as the chemistry and temperature of the electrolyte.

MICRON One millionth of a meter or 0.00003937 in. Twenty-five microns are about 0.001 in. and 50 μ are about 0.002 in.

MIL A length of measurement equal to 0.001 in.

MIST COLLECTOR A unit that separates electrolyte mist from hydrogen and air ducted from the machining enclosure.

MOUNTING PLATE A metal plate fastened to the machine platen that supports the tool (cathode) body.

MOVABLE WORK TABLE Not fixed; can be positioned in the longitudinal, cross, and vertical axes, and is sometimes rotational.

OPEN HEIGHT Distance between the work table and the platen, with the quill fully retracted.

OVERCUT The distance between a side of the cathode lip and the side wall of a machined hole or cavity. This distance is measured at right angles to the feed axis and is usually expressed in thousandths of an inch per side.

PASSIVE PROTECTIVE FILM A thin, transparent oxide film, formed naturally in air or by immersion in an acid solution, which enables some metals to resist corrosion.

PENETRATION RATE The variable rate at which the cathode advances into or retracts from the work piece, usually expressed in thousandths of an inch per minute.

PLANING The finishing of a surface, or the sizing of a bar or a rod, with tool travel parallel to the surface being machined. This method usually produces low microinch surface finishes.

RAPID TRAVERSE RATE The fixed rapid rate at which the platen retracts from or approaches the work piece, as compared to the adjustable feed rate, for the machining part of the cycle.

SACRIFICIAL ANODE A length of expendable metal, usually rod or wire, used to protect a permanent part from stray machining effects. Copper becomes anodic to stainless steel when attached to a positive polarity work table or fixture.

SEPARATING FORCE The force resulting from the high pressure electrolyte tending to separate the electrode and the work piece.

SHORT Short circuit resulting from the cathode physically contacting the work piece with current flowing, causing arcing, sparking, and possible tool damage.

SIDE GAP (OVERCUT) The distance between a side of the cathode lip and the side wall of a machined hole or cavity. This distance is measured at right angles to the feed axis and is usually expressed in thousandths of an inch per side.

SLUDGE Mudlike metal hydroxides, oxides, and so on removed from the electrolyte by a centrifuge or filters.

SMUT A coating (black when machining steel) that appears on the cathode during electrochemical machining.

SPARK The result of a minute short circuit from small metal particles in the machining gap—yellow or orange in color.

SPECIFIC GRAVITY (OF THE ELECTROLYTE) The weight ratio of a given volume of the electrolyte to that of an equal volume of pure water.

STRAY CURRENT Any electrical current which removes metal from areas of the work piece, fixture, or machine, other than where desired.

STRAY MACHINING Very low current density electrochemical machining which takes place in areas other than at the machining gap.

THERMAL CONDUCTIVITY The relative ability of a material to absorb or to transfer heat.

THROWING POWER (OF THE ELECTROLYTE) The "wild" cutting or "stray" machining of an electrolyte adjacent to the actual machining area. Throwing power is increased by higher operating voltages and by increased conductivity of the electrolyte.

TREPANNING Machining the perimeter of a desired shape, from a piece of greater area.

TRI-SODIUM PHOSPHATE Inexpensive cleaner that can be used to clean out the electrolyte system, or in general clean up around electrochemical machines.

TURBULENT FLOW Electrolyte flow that is extremely agitated. It is a "mixed up" flow and the resulting eddies cause an increase in resistance to flow.

UNIFORM FLOW Electrolyte flow through the machining gap which is smooth and uniform in the entire machining area. Good machine design must be augmented by good tooling design to accomplish this end. (It is usually also turbulent flow.)

VALENCE The degree of combining power of a chemical element. The higher the valence at which the metal goes into solution, the lower the metal removal rate.

VISCOSITY The internal resistance of a substance to becoming a fluid, caused by molecular attraction.

VOLTMETER A measuring instrument consisting of a galvanometer plus a series resistor to establish the range and connected across a piece of electrical equipment to measure the voltage (electrical pressure) applied.

VOLUME, PERIPHERAL The combined outside linear dimensions of the machining face multiplied by the machining gap dimension.

WORK TABLE A flat metal surface, usually made of copper or stainless steel, that supports and holds the work piece or fixture while the part is machined.

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