CHAPTER 12

METAL BUILDUP

CHAPTER LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

- *Explain the thermal spray system.*
- *Explain contact electroplating.*

Metal buildup is a rapid and effective method that can be used to apply almost any metal to a base material. It is used to restore worn mechanical equipment, to salvage mismachined or otherwise defective parts, and to protect metals against corrosion. Compared to original component replacement costs, metal buildup is a low-cost, high-quality method of restoration.

As you advance in the MR rating you must know how to prepare a surface for metal buildup and to set up and operate the equipment used in the thermal spray systems and the contact electroplating process. In this chapter, we will briefly discuss the thermal spray systems and contact electroplating. We will not cover the actual spraying or plating processes; you will learn them in classes you need to attend before you can be a qualified sprayer or plater.

Additional information on metalizing is in MIL-STD-1687A(SH), *Thermal Spray Processes for Naval Ship Machinery Applications.*

Additional information on electroplating is in MIL-STD-2197(SH), *Brush Electroplating on Marine Machinery.*

As with any shop equipment, you must observe all posted safety precautions. Review your equipment operators manual for safety precautions and any chapters of *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat,* OPNAV Instruction 5100.19B, that apply to the equipment. Also, read the sections in MIL-STD-1687A(SH) and MIL-STD-2197(SH) that cover safety.

THERMAL SPRAY SYSTEMS

There are four different thermal spray processes: wire-oxygen-fuel spray, wire-consumable electrode spray, plasma-arc spray, and powder-oxygen-fuel spray. All four generally perform the same basic function: they heat the wire or powder to its melting point, atomize the molten material with either high-velocity gas or air, and propel it onto a previously prepared surface. In this chapter we will discuss the wire-oxygen-fuel and powder-oxygen-fuel spray processes, with emphasis on the latter.

The rapid rate at which metal coatings can be sprayed and the portability of the equipment have increased the use of thermal spray processes. Metal coatings are especially useful to (1) rebuild worn shafts and other machine parts not subject to tensile stress, (2) apply hard surfacing that must resist wear and erosion, and (3) protect metal surfaces against heat and corrosion. Navy repair facilities use thermal spray processes to coat metallic and nonmetallic surfaces with practically any metal, metal alloy, ceramic, or cermet that can be made in wire or powder form. (Cermet is a strong alloy of a heat-resistant compound, a metal used especially on turbine blades.)

APPLICATIONS

Thermal spray coatings have been approved by NAVSEA for several applications. Case-by-case approval is not needed for the folllowing applications, but the procedures used for these applications are limited to those approved by NAVSEA:

- Repair of static fit areas to restore original dimensions, finish, and alignment
- Repair of seal (including packing areas) to restore original dimensions and finish
- Repair of fit areas on shafts to restore original dimensions and finish (except for motor generator sets)

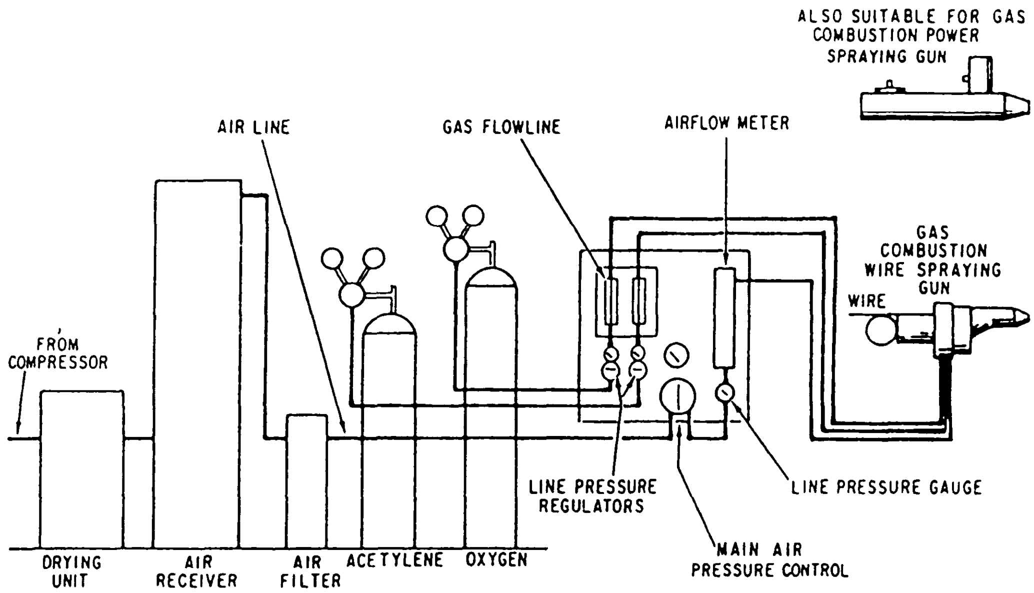

Figure 12-1.—Typical installation for combustion gas spraying.

- Buildup of pump shaft sleeves and wear rings to restore original dimensions
- Repair of bearing shaft journals to restore original dimensions
- Babbitt bearings for auxiliary equipment

Thermal spray is **NOT** approved for the following machinery applications on surface ships:

- Primary and secondary nuclear systems
- Main propulsion turbines
- Ships's service turbine generators
- Reduction gears
- Lineshafts and lineshaft bearings

NOTE: The thermal spray process is **NOT** authorized in the repair of submarine components (MIL-STD-1687A(SH)).

QUALIFICATION OF PERSONNEL

Thermal spray operations are performed only by qualified personnel. Potential operators who pass the performance tests are certified to perform manual spraying, with the coating system and spray process used in the qualification testing. For each process, the operator must prepare test specimens for visual, microscopic, bend, and bond tests using qualified procedures developed for that particular coating and thermal spray process. In addition, the operator is responsible for setting up the spraying equipment (gun-to-work distance, air, fuel gas, and so on) as required by the spraying procedure.

Certified operators retain their certification as long as they do not let 6 months or more time pass between their uses of the thermal spray process. Operators who let their certification lapse may requalify by satisfactorily completing the qualification tests. Complete information about certification is contained in MIL-STD-1687A(SH).

TYPES OF THERMAL SPRAY

The two types of thermal spray discussed in this chapter are wire-oxygen-fuel spray and powder-oxygen-fuel spray.

Wire-Oxygen-Fuel Spray

The wire-oxygen-fuel spray process is suitable for all-purpose use. It offers variable, controlled wire feed rate within the ranges required for all commonly used metalizing wires, and it can be used in both hand-held and machine-mounted applications. Figure 12-1 shows a typical installation.

The type 12E thermal spray gun (fig. 12-2) can spray metalizing wires such as aluminum, zinc, copper, Monel, nickel, and so forth. It can hold wire sizes ranging from 3/16 inch down to 20 gauge, and it can use acetylene, propane, natural gas, manufactured gas, or MPS as fuel. The wire is drawn through the gun and the nozzle by a pair of wire feed drive rollers, powered by

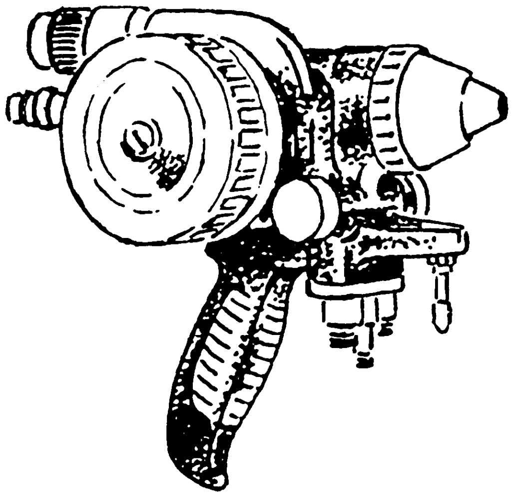

Figure 12-2.—Type 12E spray gun.

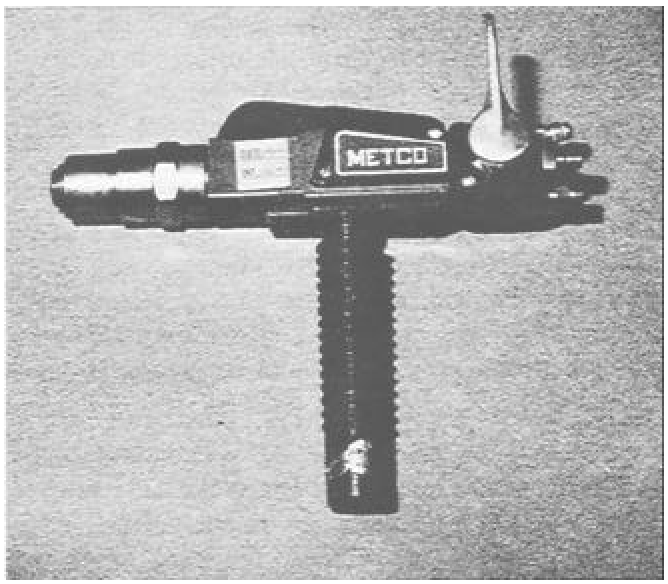

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Figure 12-3.—Type 6P-II powder spray gun.

a self-contained compressed air turbine. At the nozzle, the wire is continually melted in an oxygen-fuel gas flame. Then, a controlled stream of compressed air blasts the molten tip of the wire, producing a fine metal spray. Systems of this type are commonly used to spray aluminum wire coatings for corrosion control on items such as steam valves, stanchions, exhaust manifolds, deck machinery, and equipment foundations.

Powder-Oxygen-Fuel Spray

Figure 12-3 shows a type 6P-II powder spray gun. The powder is fed into the gun by a powder feed unit

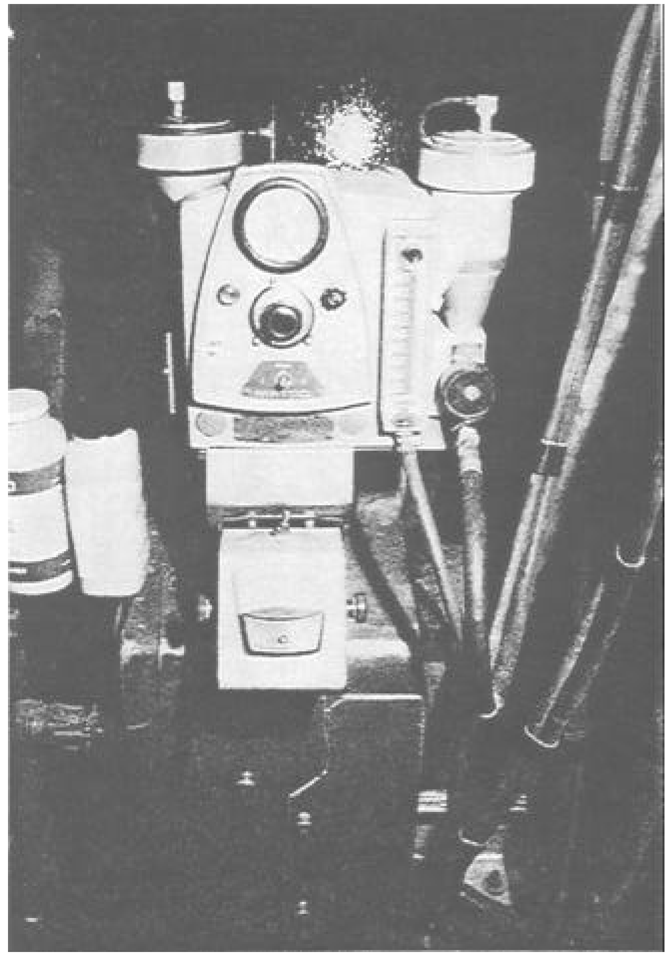

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Figure 12-4.—Power feed unit.

(fig. 12-4). The powder is propelled through the flame where it melts and is deposited on the work in the form of a coating. This gun will spray metal, ceramic, cement, and exothermic powders.

Exothermic coating composites are materials that produce an exothermic (heat evolved) reaction from their chemical creation. For example, when nickel and aluminum composites reach a certain temperature in the spray gun flame, they combine to produce nickel aluminite and heat. The extra heat provided to the molten particles by the exothermic reaction, coupled with the high particle velocity of the thermal spray process, accounts for the self-bonding characteristics of the coating and its exceptional strength.

Exothermic materials are often called one-step coatings. They produce self-bonding, one-step buildup coatings that combine metallurgical bonding with good wear resistance. They also eliminate the need for separate bond and buildup coatings.

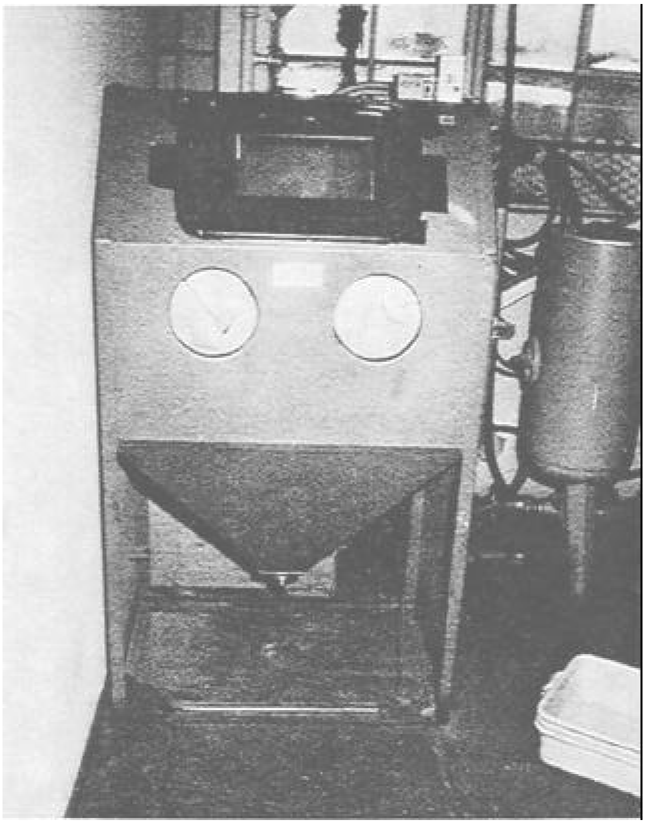

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Figure 12-5.—A typical sandblaster.

PREPARING THE SURFACES

Surface preparation is often the most critical part of the job, yet it often gets the least attention. We cannot overemphasize its importance because an improperly prepared surface will cause the part to fail under operating conditions. For this reason, even the best and most elaborate preparation is still the cheapest part of the job. Quite often, surfaces are not prepared properly because it is inconvenient or the necessary equipment is not available. To help ensure a quality job, be sure you use the required equipment and prepare the surface carefully and thoroughly.

Surface preparation includes three distinct operations: (1) cleaning, (2) undercutting, and (3) surface roughening. We will discuss each of them in the next paragraphs.

Cleaning

You must ensure a good bond between the sprayed coating and the base material to which it is applied. To do that, be sure the areas to be coated and the adjacent areas are free from oil, grease, water, paint, and other foreign matter that may contaminate the coating.

SOLVENT CLEANING.—Before blasting or spraying, use solvent to clean all surfaces that have come in contact with any oil or grease. (Vapor degreasing is preferred, but you may use solvent washing.) When using solvent, be very careful that it is not strong enough to attack the base material; do NOT leave any residue on the surfaces. Trichloroethane and toluene are suitable solvents. Most solvents are flammable and toxic, so you must follow proper precautions when you use them. You also must be very careful to protect any parts that may be attacked by the solvents.

ABRASIVE CLEANING.—You can use a sand blaster such as the one shown in figure 12-5 to remove heavy or insoluble deposits. Be sure to follow your operator's manual. Do not use the same abrasive blasting equipment to roughen surfaces that you use for general cleaning.

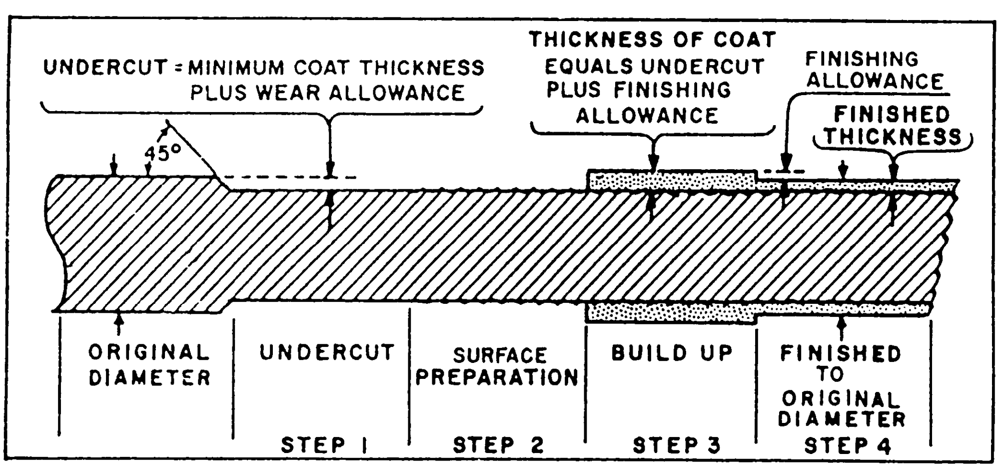

Figure 12-6.—Major steps in restoration of dimensions with thermal spray.

HEAT CLEANING.—Use a solvent to clean porous materials that have been contaminated with grease or oil. Then, heat them for 4 hours to char and drive out foreign materials from the pores. Heat steel alloys at 650°F maximum; heat aluminum alloys at 300°F maximum. Do not heat age-hardening alloys. In thin sections, use lower temperatures to minimize warpage.

Undercutting

In undercutting, you remove enough of the surface of the metal to be built up to ensure a satisfactory thickness of metalized deposit on the finished job. (See fig. 12-6.) Undercutting must be a dry machining operation; any cutting lubricants or coolants used will contaminate the surface of the workpiece. When you build up shafts, be sure the undercut section is concentric to the original axis of the shaft. The length of the undercut should extend beyond both ends of the sleeve or bearing, the limits of the carbon or labyrinth ring, or the packing gland in which the shaft will operate. However, you must be careful not to remove any fillets at points where the shaft section diameter changes. The ends of the undercut should be at 15 to 45 degrees to the base metal.

Several factors determine the depth to which you should undercut a shaft. Some of them are severity of service, the amount of wear expected in service, the depth of metal loss, the remaining thickness of the load-carrying member, and the limits of the coating you will use. In general, the minimum specified depth of the undercut should be at least equal to the recommended minimum thickness of the coating, plus the wear or corrosion tolerance for the application.

Undercutting reduces the effective structural cross section of the part to be metalized. Also, sharp grooves and shoulders without a fillet or radius may produce stress risers. A stress riser is a spot on a part where stresses have been set up that may cause the part to fail.

When you prepare for thermal spraying, carefully examine the workpiece from a design standpoint. Consider all parts that will be subjected to high stresses, shock loads, or critical applications to be sure the structure maintains adequate strength. You cannot depend upon metal spray deposits to restore qualities such as tensile strength or resistance to fatigue stress.

Surface Roughening

After undercutting the shaft, you must roughen the undercut section to provide a bond for the metal spray.

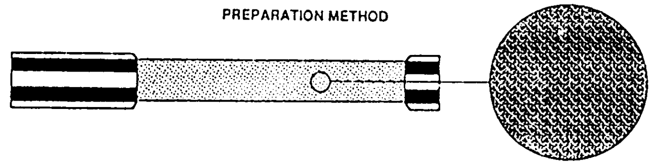

Figure 12-7.—A 2- to 3-mil anchor-tooth profile.

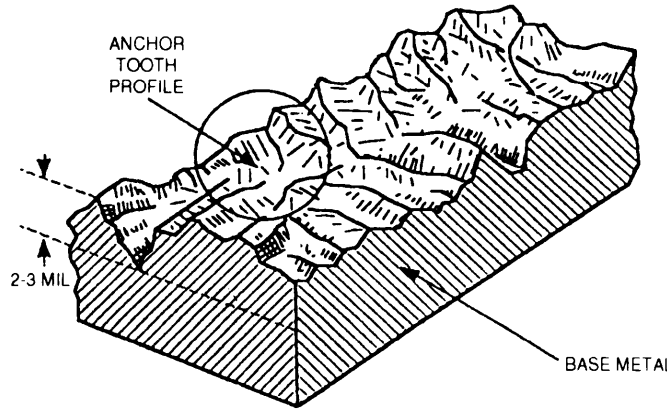

Figure 12-8.—Profile of an anchor-tooth pattern.

Do NOT use a lubricant or coolant during the undercutting and roughening process. Keep the surface clean and dry; you can contaminate it if you touch it with your hands. If the surface becomes contaminated, you must thoroughly clean and degrease it. The cleanliness and roughness greatly affect the strength of the bond between the base metal and the sprayed coating. Two methods of surface roughening are (1) abrasive blasting and (2) macroroughening. Use the latter method to restore dimensions greater than 1/2 inch where you cannot use exothermic materials.

ABRASIVE BLASTING.—Before thermal spraying, use abrasive blasting to condition the surfaces to be coated. Blasting must not be so severe as to distort the part. The required depth of surface roughness is related to the configuration (size and shape) of the part. Where part configuration permits, use a roughness profile of 2 to 3 mils (as shown in figs. 12-7 and 12-8). When this depth may cause distortion because of the part configuration, you can reduce the anchor-tooth pattern to a 1-mil profile.

The blasting particles recommended for surface preparation are angular nonmetallic grit (for example, aluminum oxide) and the recommended mesh size is 16. When a grit is designated for surface preparation, it must remain clean, so do not use it for any other purpose.

Clean, dry air is essential for proper blasting. Traces of oil in the air that cannot be readily detected can seriously affect the bond.

Before reuse, screen the aluminum oxide grit using a 30-mesh screen, and visually inspect it for debris and oil contamination according to MIL-STD-1687A(SH).

Cover and mask all areas of a component that will not be grit blasted to prevent damage or contamination by the abrasive blasting medium and debris. Grit rebounding from the walls of the blast room or blast cabinet may scratch and damage those uncovered areas. Masking may be an expensive part of the operation and you should consider cost when you select the masking method. When you finish blasting, remove any masking material that is unsuitable as masking for the thermal spray process and replace it with suitable material. We will discuss this in later paragraphs.

Rubber or aluminum masking tape is satisfactory for all operations where you can do hand masking economically. Since rubber is not cut by the blasting operation, you can use it almost indefinitely. You can use thin rubber tape for heavy blasting protection.

MACROROUGHENING.—Macroroughening is a lathe operation performed on bearing areas of shafts or similar surfaces. It consists of cutting a narrow, low-pitch, shallow groove or thread in the surface.

APPLYING THE COATING

You will apply the coating by using three distinct procedures: (1) mask the component, (2) spray the coating, and (3) apply a sealant to the coating. We will discuss each in the next paragraphs.

Masking for Spraying

You can use tape, liquid masking compounds, silicon rubber, or metal shielding as thermal-spray masking materials. Tape must be designed for high-temperature use. Masking materials must not cause corrosion or contamination of the sprayed coatings. Generally, you will mask materials to be sprayed with masking tape and masking compound. Use a pressure-sensitive masking tape designed to withstand the usual spray temperatures.

Use masking compound where a liquid masking material is more convenient. It is a water-soluble material that can be brushed onto any surface to prevent the adhesion of sprayed material. Approved masking compound will not run or bleed at the edges.

You also may use masking compound to protect the spray booths and other equipment that is subject to overspray, such as rotating spindles, chucks, lathes, and the like. When you use masking compound for this purpose, be sure you clean the surfaces on a regular schedule and reapply the compound. If you don't, it will eventually dry out and the sprayed material will then stick to the substrate.

In situations where you cannot protect holes, slots, keyways, or other types of recesses with tapes or shields, use inserts of carbon, metal, or rubber. Install them before you begin abrasive blasting and spraying, and leave them in place throughout the thermal spray operation. Remove them after you complete the surface finishing but before you apply the final sealer.

Spraying the Coating

Spray the component using the specifications you will find in the approved procedure for the material being sprayed. These specifications cover gun-to-work distance, rotational or linear speed of the gun to the workpiece, air, fuel, gas, primary and secondary pressures, and power output. Figure 12-9 shows a shaft being thermal sprayed.

Applying the Sealant

Sprayed coatings must be treated with a sealant to prevent corrosive attack or fluid leakage. Select the sealant on the basis of the maximum use temperature of the component and the purpose of sealing the coatings. Apply the sealant after spraying and before finish machining.

SURFACE FINISHING

Use surface finishing to reduce the component to its specified dimensions and to provide a finer surface finish than the sprayed finish. Remove all masking materials before you finish a surface. The acquisition specification or drawing will dictate the finished dimensions.

Coatings may be used in the as-sprayed condition whenever permitted. The type, hardness, and thickness of the coating determines the finishing method. You will often finish softer coating materials by machining. You can get a good machine finish in most applications by using high speed and carbide tools. Generally, you will grind harder coating materials to get the best finish.

Take care in any machining or grinding operation to avoid damage to the coating. Improper machining

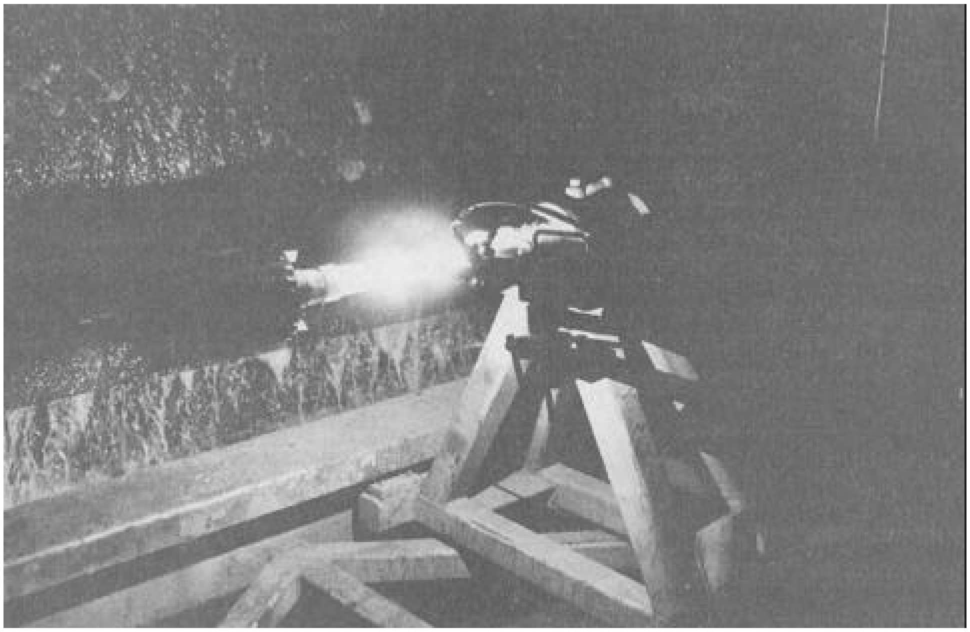

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Figure 12-9.—A shaft being thermal sprayed.

techniques can pull out particles, producing a severely pitted surface or heat checking. It is essential that the sprayed particles be cleanly sheared and not pulled from the surface by the finishing operation.

Generally, wet grinding is better than dry grinding if you use the proper wheel. Use wheels with coarse grain and low bond strength to grind sprayed coatings; this prevents loading the wheel. When you use a coolant, try to get one with a rust inhibitor and keep it clean and free of foreign matter.

Always consult and follow the coating manufacturer's finishing recommendations when you select the finishing technique, including the proper tool, feeds, and speeds.

QUALITY ASSURANCE

In-process inspection of each sprayed component shall assure, as a minimum, verification of the anchor-tooth prepared surface with a profile tape test; no moisture, oil, grit, contaminants, blisters, cracks, chips, pits, or coating separation are present before or during spraying; coating thickness per pass conforms to the procedure, if this is an essential element; and the coating manufacturer's recommended temperature range is maintained.

As a minimum, the end item inspection of sprayed coating will include a visual examination. The finished coating, when examined with a 10X magnification, will be free of defects such as cracks, chips, blisters or loosely adhering particles, oil or other contaminants that bleed out through the coating, pits exposing the undercoat or substrate, and coating separation. The item will be checked for correct dimensions.

CONTACT ELECTROPLATING

Contact (brush-on) electroplating is also called contact plating. It is a method used to deposit metal from concentrated electrolyte solutions without the use of immersion tanks. The solution is held in an absorbent material attached to the anode lead of a dc power pack The cathode lead of the power pack is connected to the workpiece to provide the ground and complete the plating circuit. Electroplating deposits metal when the absorbent material on the anode contacts the work area. Constant motion between the anode and the work is required to produce high-quality, uniform deposits.

Contact electroplating can be used effectively on small to medium size areas to perform the same functions as bath plating. Some examples are corrosion protection, wear resistance, lower electrical contact resistance, and repair of worn or damaged machine parts. This process is not recommended to replace bath plating. However, electroplating is superior to bath plating in some situations, most of which are in the following list:

- The equipment is portable; plating can often be done at the job site.

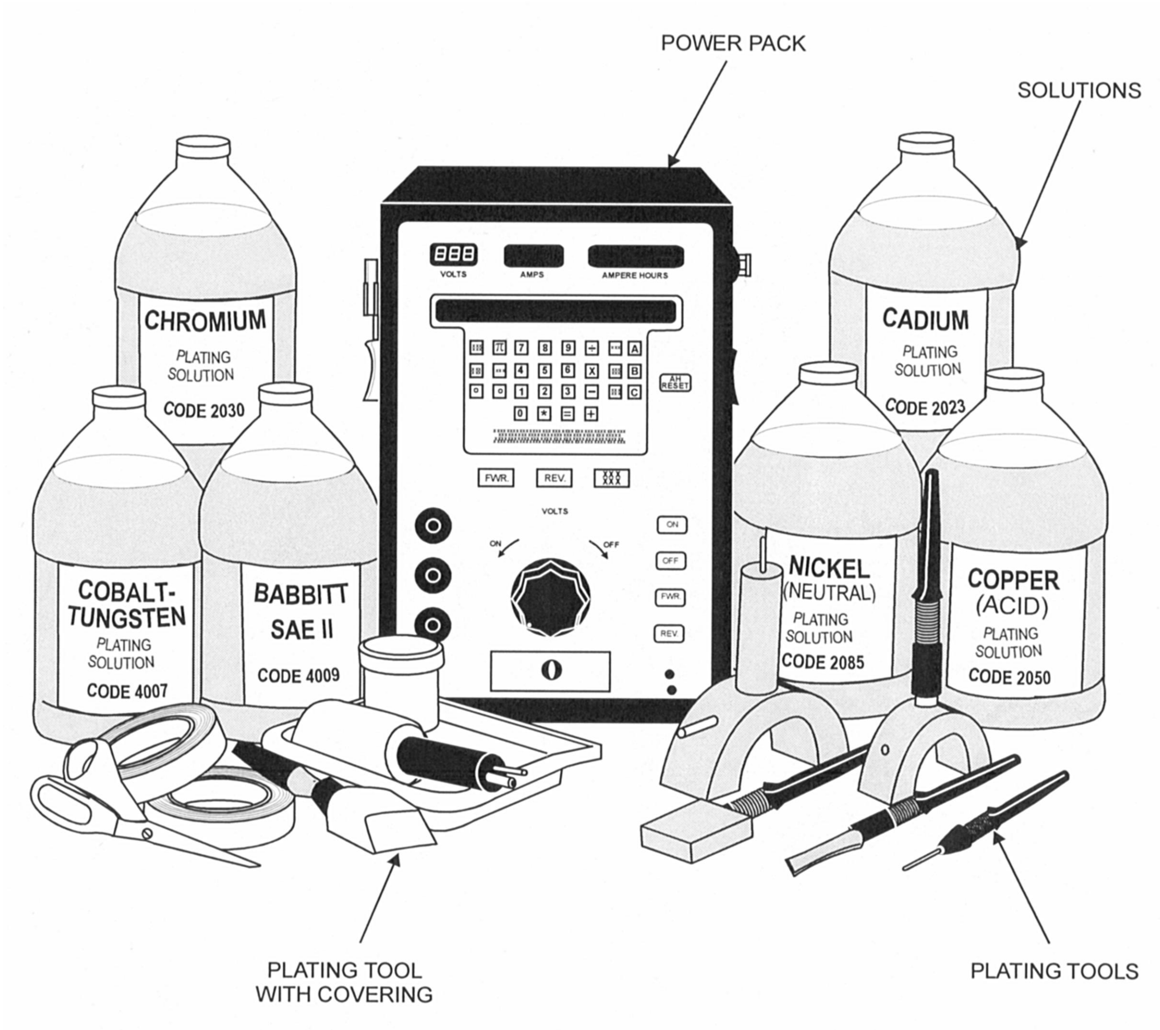

Figure 12-10.—Electroplating equipment.

- It can reduce the amount of masking and disassembly required.
- It permits plating of small areas of large assembled components or parts too large for available plating tanks.
- By plating to the required thickness, it can often eliminate finish machining or grinding of the plated surface.
- Damaged or defective areas of existing plating can be touched up instead of complete stripping and replating of the entire part.

ELECTROPLATING EQUIPMENT

We will discuss contact electroplating equipment in the following paragraphs. These are the power pack, plating tools, solutions, and plating tool coverings, and they are shown in figure 12-10. We will cover them briefly because your plating machine operators manual covers them in depth.

Power Pack

Contact plating power packs are available in the following dc output ranges: 0 to 15 amperes at 0 to 20 volts and 0 to 150 amperes at 0 to 40 volts. They operate on 115- or 230-volt, 60-Hz, single- or three-phase ac input.

The intermediate sizes, 25 to 100 ampere maximum output, are the most common. They are portable, weighing less than 150 lbs, yet can provide the required power for most shipboard and shop work A unit in the 60- to 100-ampere range is recommended as basic contact plating shop equipment. It will remain useful even if changes in the workload require smaller or larger units to supplement it.

Plating Tools

Contact plating tools consist of a stylus handle with a conductive core, which is insulated for operator safety, and an insoluble anode normally of high-quality graphite. Since considerable heat is generated during plating operations, there must be a means of cooling the plating tool. The handles of plating tools have cooling fins to dissipate heat, but you may need to cool larger tools with plating solution or water. Graphite anodes are brittle and are not practical where a very small diameter anode is required. For plating holes less than 1/2 inch in diameter, or narrow slots and keyways, anodes made of 90 percent platinum and 10 percent iridium material are recommended.

The equipment manufacturers offer removable anodes in a wide range of standard sizes and in three basic shapes: cylindrical or convex to plate inside diameters, concave for outside diameter's, and flat or spatula shaped. You also may purchase graphite material to manufacture special tools.

Solutions

The solutions used in contact plating include preparatory solutions used to clean and activate the surface to be plated, plating solutions used to deposit pure or alloy metals, and stripping solutions used to remove defective plating. These solutions are manufactured and sold by the process equipment manufacturers. You can use solutions of any trade name if the deposits meet the applicable plating specification and if they are certified by procedure tests. However, do NOT use plating and preparatory solutions of different manufacturers for the same plating job.

For plating operations, pour solution into a shallow glass or plastic dishes or beakers for dipping, or use them in a pump that dispenses solution through the tool.

Plating Tool Coverings

The most common tool covering is cotton batting of surgical grade U.S.P. long fiber, sterile cotton. It is fastened to the anode to hold and distribute the solution uniformly. You can use cotton batting alone for jobs that involve a few short preparing and plating operations, or to ensure maximum tool to workpiece contact for plating in corners or on irregularly shaped areas. When you need longer tool cover life, place cotton, Dacron, or cotton-Dacron tubegauze sleeving over the cotton batting. You also may use Dacron batting, Pellon, and treated Scotchbrite to cover plating tools.

APPLICATIONS

The contact plating process is a rapidly expanding field. When used to deposit a corrosion-resistant coating, electroplating has shown enough success to permit almost unrestricted use. The vast field of possible applications in the repair of worn or damaged parts of high-speed rotating and reciprocating machinery is limited only by the knowledge and skills of the operator in areas where plating is allowed. Electroplating applications are classified as follows:

Class 1: Plating used for decorative or corrosion prevention functions only

Class 2: Plating on parts to restore dimensions on surfaces that remain in static contact with gaskets, O-rings, or other metal surfaces

Class 3: Plating on parts that make rubbing or intermittent contact with other plated or unplated parts, including electrical contacts except those in class 3A

Class 3A: Plating on rubbing contact surfaces of turbines, reduction gears, electric power generating units, main propulsion shaft seals, steam valves, and other sliding contact areas when specified

Class 4: Plating on parts under the cognizance of the Nuclear Propulsion Directorate

Refer to MIL-STD-2197(SH) for plating applications for each of these classes.

OPERATOR QUALIFICATION

Operators will be qualified by the quality assurance function of the plating activity before being permitted to perform contact electroplating.

Before examination for qualification, each prospective operator will successfully complete a manufacturer-sponsored training course or one provided by the plating activity. The course shall be approved by the quality assurance function of the plating activity and will as a minimum prepare the prospective operator to demonstrate a knowledge of the following:

- The technical aspects of brush electroplating
- Job safety for hazardous chemicals and electrical work
- The calculation of plating amperage, plating time, quantity of solution required, surface area, and ampere-hours
- The meaning of the terms *current density, activation, anode, cathode, adhesion, burned deposits, modules, porosity stripping, etch, waterbreak, matte finish, volts,* and *amperes.*
- Setup and operation of a power supply
- Preparation of metal surface for brush electroplating
- Selection, preparation of, and postuse care of the plating tools (anodes) and covers
- The attributes used to control plating thickness time and quality
- Prevention of contamination of plating solutions
- Proper masking technique
- Proper plating technique
- Proper surface finishing technique
- Evaluation of the deposit's adhesion, thickness, and visual appearance
- Preparation of job records

An operator will have passed a written examination covering these subjects. The examination will be administered either by the training activity or the plating activity, and approved by the quality assurance function of the plating activity.

The operator will demonstrate to the quality assurance function of the plating activity that he or she is capable of performing brush electroplating by plating test specimens following MIL-STD-2197(SH) specifications.

Requalification is required when the operator has not performed any production work for which he or she is qualified for a period of 12 months or more, or when the quality assurance function of the plating activity has reason to question the ability of the operator to produce quality plating.

PLATING PROCEDURES

Brush electroplating will be performed to an approved written procedure. The procedure will contain as a minimum the following:

- A unique identifying number
- Date of approval
- Authorizing signature
- Applicable plating thickness
- Plating treatment's, such as stress relief or peening, if required
- Required operators qualification
- Preliminary cleaning
- Electrocleaning and etching
- Rinsing
- Activating
- Plating solutions, preplate (if needed), current density, and anode to cathode speed
- Drying
- Postplate treatments, such as blasting or grinding, if required
- Records
- Inspection requirements and acceptance criteria

In addition to MIL-STD-2197(SH) and MIL-STD-865, commercial manuals provided by brush electroplating solution and equipment contractors form the basis for information pertaining to brush electroplating.

QUALITY ASSURANCE

The quality assurance function of the plating activity shall enforce the requirements of M-STD-2197(SH). The tests will include visual inspection, adhesion test, thickness of deposit, and dye penetrant inspection for classes 3 and 3A applications only.