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EFFECTS OF DEBURRING CONTAMINANTS ON ELECTROPLATING ADHESION

Final Report

L. K. Gillespie, Project Leader

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Published February 1978

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Bendix Kansas City Division

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EFFECTS OF DEBURRING CONTAMINANTS ON ELECTROPLATING ADHESION

BDX-613-1757 (Rev.), UNCLASSIFIED Final Report, Published February 1978

Prepared by L. K. Gillespie, D/822

Vibratory deburring and centrifugal barrel finishing can result in inadequate adhesion of electroplated metals. Fine particles of the abrasive metals and compounds used in these processes impregnate the exposed surfaces of the workpieces. If too many of these particles are in the workpiece surfaces, electroplated coatings fail to adhere properly. Ceramic bonded aluminum oxide media causes fewer adhesion problems than fused aluminum oxide media. The implications of impregnated material in other processes were also explored.

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SUMMARY

Component parts of small mechanisms typically require sharp edges to assure reliable operation. A burr-free condition is also needed to prevent jamming of the mechanism caused by burrs breaking loose during operation.

The quickest and least expensive method for removing the burrs and maintaining nearly-sharp edges on many parts is to use either vibratory deburring or centrifugal barrel finishing. These processes, however, can result in inadequate adhesion of electroplated coatings.

The two deburring processes impregnate fine particles from the deburring media and the abrasive compounds into workpiece surfaces. At some point, enough particles are impregnated to prevent a good bond between electroplated metals and the workpiece metal. Aluminum oxide media created more problems than silicon carbide, plastic, or dolomite media. Fused aluminum oxide media resulted in the highest incidence of adhesion failures. Ceramic bonded aluminum oxide produced no failures. The type of media and abrasive used in deburring processes also can affect welding, soldering, brazing, and electrical resistivity. While aluminum oxide creates the most problems, it is typically the most effective deburring and finishing media and the least expensive.

DISCUSSION

SCOPE AND PURPOSE

The successful operation of timers, switches, actuators, and other small precision mechanisms depends upon sharp-edged, burr-free component parts. The objective of this study was to determine how two common processes for producing these high quality edges affect subsequent electroplating. More specifically, the objectives were to determine if surface residues commonly remaining on parts after vibratory deburring and centrifugal barrel finishing affect adhesion of electroplated coatings, and, if so, to find methods to minimize the contamination.

PRIOR WORK

No prior work has been reported by Bendix on this subject, although six reports have been published on vibratory and centrifugal barrel deburring.[1-6]

ACTIVITY

Test 1, Plating Test Panels

Unexplained adhesion failures of electroplated deposits on metal workpieces have occurred sporadically in the past. These failures had been attributed to inadequate cleaning of the workpieces. Recent studies, however, on deburring processes which use loose abrasive particles have provided clues that the deburring process may be responsible for some plating failures. The results of this particular study indicate that some deburring medias and techniques do cause adhesion failures.

Processes such as vibratory deburring, barrel tumbling, centrifugal barrel finishing, and spindle finishing utilize abrasive pebble-like media and very fine abrasive particles to abrade burrs from workpieces. Some of the particles from the media or the abrasive compounds are beaten into the workpiece. Particles can also adhere to surfaces if parts are not adequately cleaned. In both cases, if enough of these particles are present they will cause poor adhesion. While poor adhesion is not visibly obvious on the part, bending the workpiece through 180 degrees or until it fractures will reveal adhesion weak spots.

The assumed reason for inadequate adhesion is that the electroplated deposit cannot adhere tightly to nonconductive materials such as aluminum oxide, silicon carbide, or quartz. The deposit tends to form a bridge over the particles. These bridges represent localized pockets of low adhesion. Severe stress breaks these bridges and exposes the parent metal.

Test Approach

Each group of parts in this study was subjected to either a vibratory finishing or centrifugal barrel finishing operation. The parts were ultrasonically cleaned in one of two detergent solutions and rinsed with water. At least one sample from each group underwent an Auger analysis (AES) to determine the materials present on the surface of the part. A small portion of the part was sputtered away in a 2 minute sputter cycle to remove any thin surface films. The remaining parts in each group were electroplated with a 5- to 8-μm-thick (0.0002 to 0.0003 in.) coating of nickel. These parts then were subjected to 180 degree bend tests or fracture tests. Test specimens included 6.4 by 13 by 0.28 mm (0.25 by 0.5 by 0.011 in.) strips as well as actual piece parts. Workpiece materials included 17-4 PH, 17-7 PH (Armco Steel Corporation), 303 Se, and 304 stainless steel, Kovar (Du Pont Corporation), brass, and beryllium copper.

The plating operation consisted of a trichloroethylene degrease, an alkaline clean, water rinse, hydrochloric acid dip, water rinse, Wood's nickel strike, and then a 1 minute nickel plate. Copper base parts received a cathodic alkaline clean, water rinse, ammonium persulfate dip, water rinse, hydrochloric acid dip, and the nickel plate. Three samples of each deburred condition were electroplated to provide 5.1 to 12.7 μm (0.0002 to 0.0005 in.) of nickel.

The AES charts were then analyzed and compared to the materials used in the vibratory finisher and the centrifugal barrel finisher and to the adhesion results. To provide semiquantitative values for the amount of each element observed, a peak height of each element shown in the AES chart was measured; then, these heights were added and this total was divided into the height of the contaminating element. Thus 10 percent aluminum indicates that the height of the aluminum peak was 0.1 the sum of the peaks of all other elements. Because of the nature of the AES analysis, the 10 percent value does not imply that aluminum covers 10 percent of the surface. This value does, however, provide a comparative quantitative value which is a direct indication of the amount of contaminating elements in the analyzed surface region.

Adhesion results were reported as being either good or bad, depending upon whether or not any voids were detected between the plating and the workpiece. This inspection was performed using 20x magnification.

The finishing media used in this study included fused aluminum oxide nuggets (sizes 8, 14, and 24), ceramic bonded triangles, 4.7 mm (0.187 in.), silicon dioxide impregnated plastic pyramids, 6.35 mm (0.25 in.), and dolomite (calcium magnesium carbonate Number 12 size). An AES analysis of the ceramic bonded triangles indicates they consist of roughly equal amounts of silica and aluminum. The fused aluminum oxide nuggets are almost entirely aluminum oxide.

Kovar and 304 stainless steel were the two principal materials studied. Some 17-4 PH and 17-7 PH stainless steel specimens were studied. Because of the high aluminum content of 17-7 PH stainless steel, it was not possible to detect impregnated aluminum particles in this material. Some samples were plated, however. Production parts of 304 stainless steel, brass, and beryllium copper were also evaluated. A total of 640 samples were utilized.

The vibratory deburred parts were processed in 1-quart Viking deburring machines for 2 hours, then burnished for 0.5 hours in a liquid burnishing agent (Carborundum 23C.). Parts were then ultrasonically cleaned in either Emulclean (Turco) or 25 I detergent (Bendix Corporation). The cleaning was followed with a running hot water rinse.

Parts which were centrifugal barrel finished were treated for 20 minutes at a 147 m/s^2 (15 g) force level. Parts were then burnished for 5 minutes using Carborundum 23C at the same setting. The same cleaning process was used for both centrifugal barrel finished and vibratory deburred parts. Technical descriptions for the materials used in this study are listed in Table A-1. Test results are shown in Table A-2.

One specimen from each group was subjected to the AES analysis. A typical AES trace is shown in Figure 1. The AES settings for that trace were used on all specimens. A reading was taken of the constituents on the surface of the specimen; then, parts were sputtered for 3 minutes at 2 kilovolts and 30 milliamperes. Sputtering at these levels typically removes material to a depth of 200 μm (angstroms) per minute. Thus, the AES reading after the sputtering indicates the constituents present 600 μm (angstroms) below the surface of the specimen.

As seen in Figure 1, the AES analysis indicates the presence of carbon, oxygen, iron, nickel, sodium, aluminum, and silicon on the surface of a particular Kovar pin. Table 1 indicates the relative heights of elements found on this pin. Figure 2 illustrates that just below the surface film, aluminum (presumably in the form of aluminum oxide) is present in much greater quantity. In interpreting these charts it is important to note that it is only the relative peak height of contaminants that is significant

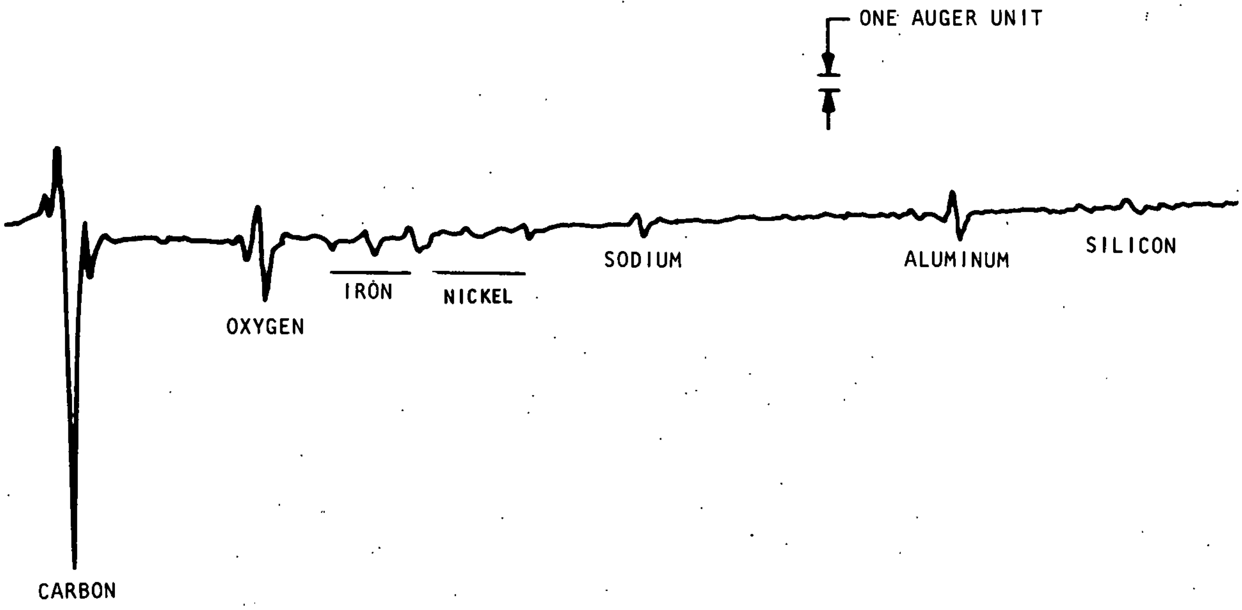

Figure 1. Auger Chart of Kovar Pin Centrifugal Barrel Finished in Aluminum Oxide Before Sputtering

on these charts. This relative height is calculated by summing the primary peak heights of all the elements observed and dividing this into the peak height of the contaminating element. Note that a small secondary peak of iron and nickel occurs in Figure 2. This peak is ignored.

The sodium found in these two figures is either due to salt from handling with bare hands or sodium in the deburring compound soaps.

Figure 3 illustrates an AES plot of a Kovar pin which was not subjected to any form of loose abrasives. Figure 4 shows the results for a pin subjected to silicon carbide media. Dolamite was used in Figure 5.

Observations

The aluminum oxide media does impregnate material into the surface of the part and this cannot be removed by conventional detergent cleaners. Removal of these contaminants can only be accomplished by etching away material until the particles fall off. From 5.1 to 12.7 μm (0.0002 to 0.0005 in.) of material must be removed to provide a surface free of this contaminant.

Table 1. Surface Constituents on Kovar Pin Centrifugal Barrel Finished in Aluminum Oxide

Element	Sputtering		Percent of Total	
	Before	After	Before Sputtering	After Sputtering
Carbon	25	7		
Oxygen	6	20		
Iron	2	30		
Nickel	1	30		
Sodium	2	1		
Aluminum	3	18	7.5	18.8
Silicon	1	0	2.5	0

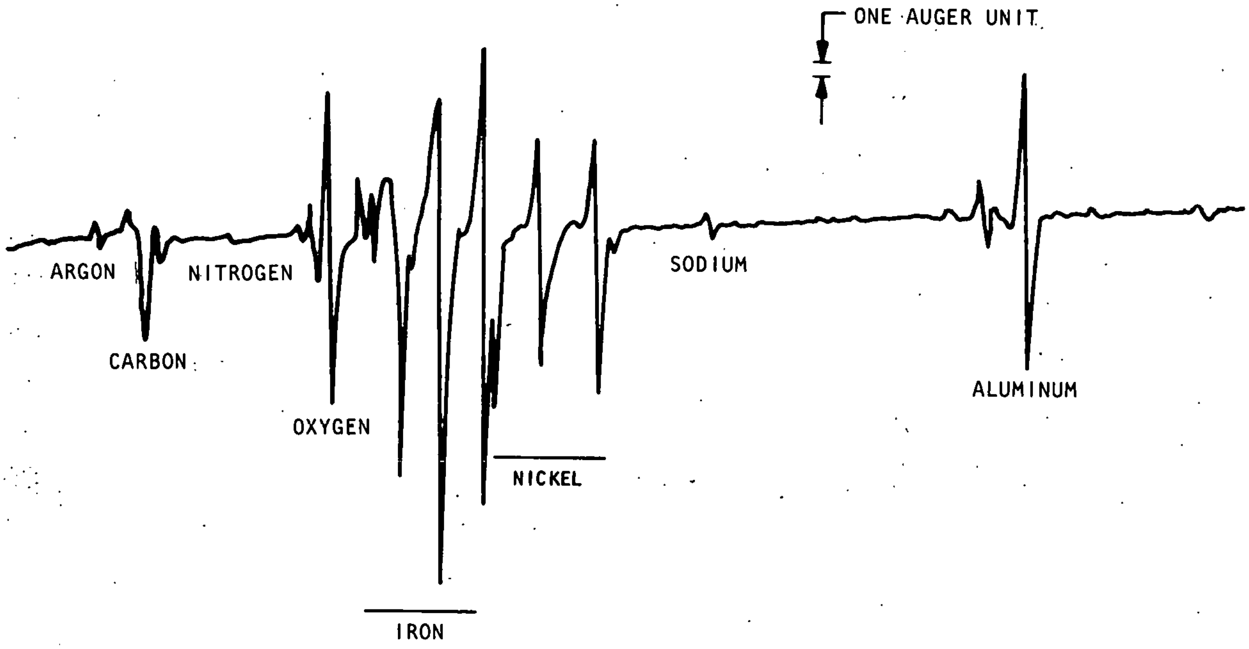

Figure 2. Auger Chart of Kovar Pin After Sputtering 3 Minutes

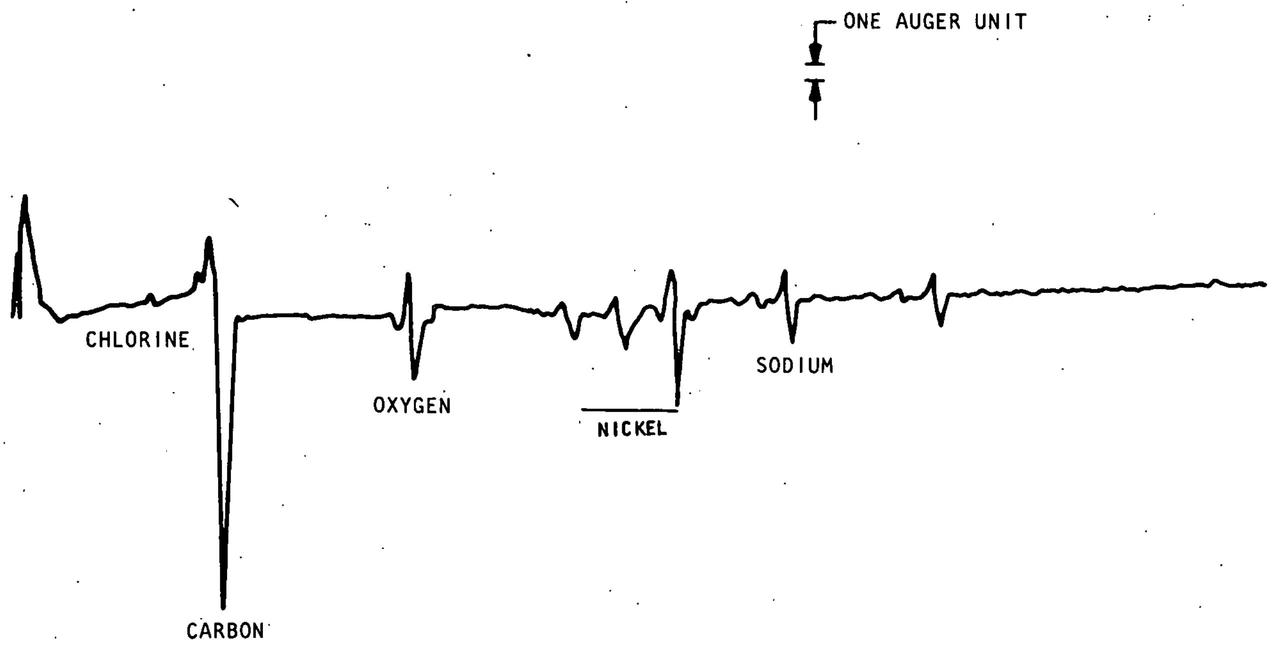

Figure 3. Auger Chart of Kovar Pin Which Was Not Subjected to Abrasives

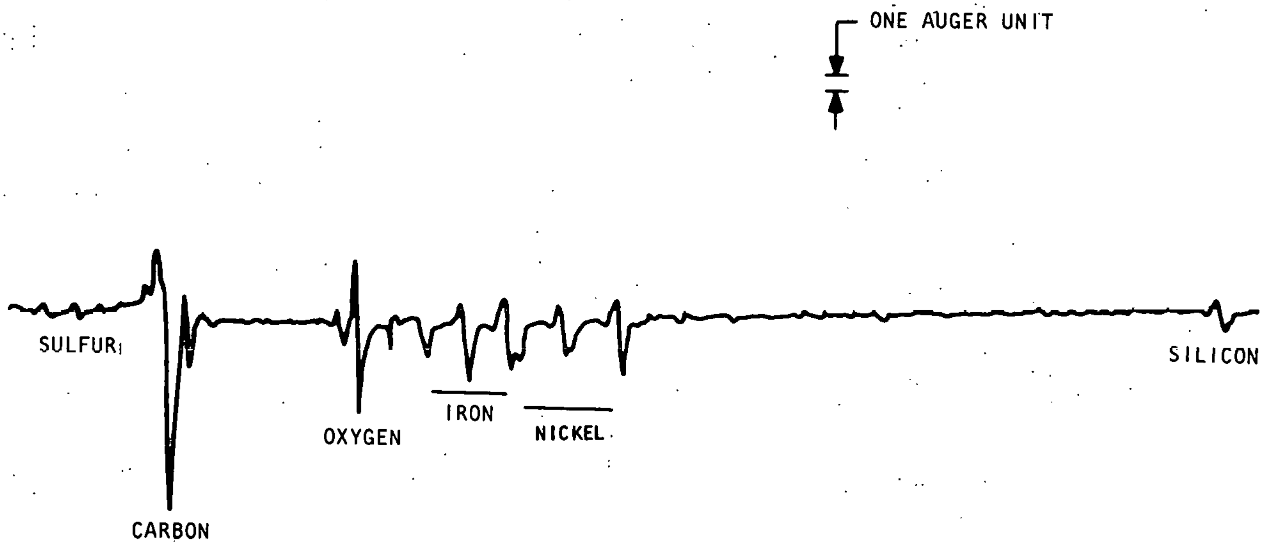

Figure 4. Auger Chart of Kovar Pin Centrifugal Barrel Finished in N8 Silicon Carbide

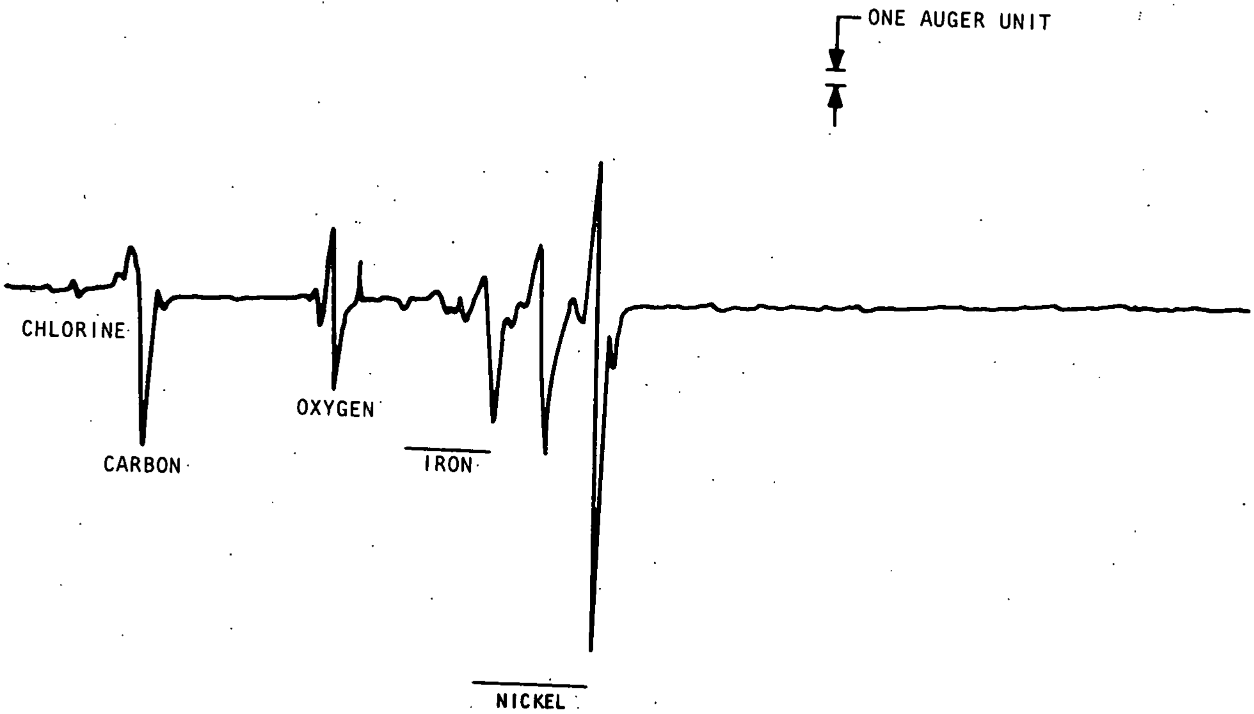

Figure 5. Auger Chart of Kovar Pin Centrifugal Barrel Finished in N14 Dolomite and PC8A

Using the fused aluminum oxide media resulted in more impregnated material than using the ceramic bonded media. Since plating adhesion failures were more frequent at high levels of impregnation, the fused aluminum media resulted in more frequent adhesion failure. When the aluminum peak height constituted more than 10 percent of the peak heights of all elements, adhesion failures were most likely to occur. On hard to activate materials, an aluminum peak height greater than 2.5 percent was a signal that adhesion would be bad.

No measurable contamination occurred when dolomite was used as the finishing media. The AES unit is believed to be capable of identifying any element which exists in a concentration of 2 percent or more at the surface. Extensive studies on Kovar using this media indicated that it was the only media which would assure good plating adhesion, without removing stock from the workpiece.

Plastic media which was impregnated with silicon dioxide particles appeared to cause poor adhesion on the hard-to-activate materials. A mass spectographic analysis of one group of parts centrifugal barrel finished in this media indicated that a thin film of plastic covered the surface. This film is believed to be responsible for the failure of these parts.

In addition to contamination by impregnation occurring, it is also possible for a film to occur on the surface of some parts which had been subjected to loose abrasive finishing. This film, which has been reported by several authors, consists of surfactants, water conditioners, chelating agents, flocculating agents, and abrasive particles. If allowed to dry on the parts, the film forms a barrier which inhibits proper plating and passivation. This film can be prevented by a thorough washing or flushing operation in the finishing cycle. Tarasov[7] notes that the film occurs if the parts are allowed to sit in still media for any length of time.

Some parts were baked at 65°C before they were cleaned. In addition, two different detergents were evaluated for the ultrasonic cleaning operation. Neither of these approaches produced a difference in the plating nor in the amount of impregnated material.

Baking out the water adhering to small media is not a common practice, but it is used when media and parts are small and nearly the same size. It is in those situations that parts must often be manually separated from the media and water. In this mixture, the reflected light from water droplets resembles light from metal parts and thus complicates finding parts. In addition, the surface tension of these droplets makes removal of minute flat parts difficult.

This study also revealed that abrasive particles are present in the lining and surface of vibratory and centrifugal barrel finished tubs. This residual abrasive does come out of the lining and will contaminate the parts. Thus, to prevent abrasive carry-over it is essential to use different tubs for different media. Matsunaga's study[8] also revealed a high degree of abrasive carry-over.

The abrasive particles appear to impregnate stainless steel and Kovar to a depth of 0.008 mm (0.0003 in.). This much material must be removed from each surface before aluminum is no longer visible on an AES analysis.

Side Effects of Processes Using Loose Abrasives

Processes such as vibratory deburring, barrel tumbling, centrifugal barrel finishing, abrasive blasting, and extrude honing all utilize loose abrasive particles to remove burrs. Observers have indicated that the first four of these processes also produced the following side effects:

- Changed workpiece dimensions,
- Radiused edges,
- Improved surface finish,
- Altered residual stresses,
- Reduced elastic limit,
- Changed color,
- Impregnated material, and
- Contaminated surfaces.

While some documentation exists for the first five side effects[7,9-15] little or no work has been reported on the last three. Although a number of electroplating and welding problems have been associated with the last two side effects, not all authors have agreed as to which of these two is the most likely cause of the problems. A search of the literature indicates that no other report has been published that demonstrates a direct relationship between plating or welding problems and the loose abrasive processes.

Test 2, A Study of Possible Impregnation From Several Processes

Additional confirmation of impregnation was obtained in two additional studies. In the first test 12 mm (0.5 in.) cubes of 6061-T6 aluminum and 303 Se stainless steel were subjected to grinding, vibratory deburring, centrifugal barrel finishing, and abrasive blasting. These specimen were subjected to various cleaning processes and submitted with control samples for scanning electron microscope (SEM) observation and energy dispersive X-ray analysis (EDAX). One square millimeter of each specimen was scanned. The medias studied included aluminum oxide, silicon carbide, and glass beads.

Impregnated foreign material could be seen on some samples under magnification. These appeared as chunks of material firmly embedded in the workpiece.

The EDAX system detected amounts of silicon and aluminum ranging from 2 to 5 percent by volume of the elements detected. In some cases the analysis indicated these materials were present but in amounts less than 1 to 2 percent. Aluminum oxide on aluminum samples could not be verified because the surface of aluminum is normally covered with an aluminum oxide film.

All vibratory deburred specimens contained impregnated silicon carbide or aluminum oxide regardless of the cleaning method used (Figure 6, conditions A through H). Large quantities of aluminum oxide were evident on the centrifugal barrel finished specimens. The concentration of abrasive was not affected by the cleaning method. Abrasive blasted stainless steel specimens contained either aluminum or silicon depending upon the media used. The aluminum specimens which were blasted with glass beads contained small but measurable amounts of silicon. Specimens which were surface ground but not otherwise subjected to abrasive media contained no impregnated material. Blanked specimens (condition M in Figure 6) of stainless steel which were not subjected to media demonstrated a trace reading of aluminum. This may have been the result of a polishing treatment at the steel mill.

The media used to vibratory finish the samples in this test included size 8 silicon carbide chunks and 4.76 mm (0.187) ceramic bonded aluminum oxide triangles. Carbopolish 2C (Carborundum Company, Electro Minerals Division) was combined with 120 mesh silicon carbide particles to provide an abrasive compound for use with the silicon carbide chunks. Carbofast 1A-1 (Carborundum Company, Electro Minerals Division) was used as an abrasive when the 4.76 mm aluminum oxide triangles were used. All burnished specimens were burnished in Carbocolor 2B (Carborundum Company, Electro Minerals Division). The centrifugal barrel finished samples were processed with Size 12 aluminum oxide nuggets and Carbofast 1A-1. The centrifugal barrel finished specimens were burnished in MFC 113 (Mechanical Finishing Company). Freon PCA was used to clean specimen. Bendix 25I (Bendix Corporation) detergent was also used to clean some parts.

A line pressure of 310 kPa (45 psig) was used with a 6.35 mm (0.25 in.) diameter nozzle for the abrasive blasted specimen.

The ground specimens were produced by grinding 254 μm (0.01 in.) stock from the blanked specimens. The wheels used were 38A46K5VBE (aluminum oxide) and 37C36J8V (silicon carbide).

Test 3, Production Parts

In the third study of impregnation, 0.76 mm (0.03 in.) diameter pins of Kovar were subjected to 12 centrifugal barrel finished media combinations (Table 1). These specimens were also subjected to SEM, EDAX, and AES analyses to determine conditions which minimized impregnation. As in the first study, the SEM was used to pinpoint particles impregnated in the surface. An EDAX analysis of the particles observed from Condition 1 (Table 2) indicated that they were aluminum oxide. AES analysis also indicated that aluminum oxide was present on and beneath the surface of parts centrifugal barrel finished in aluminum oxide.

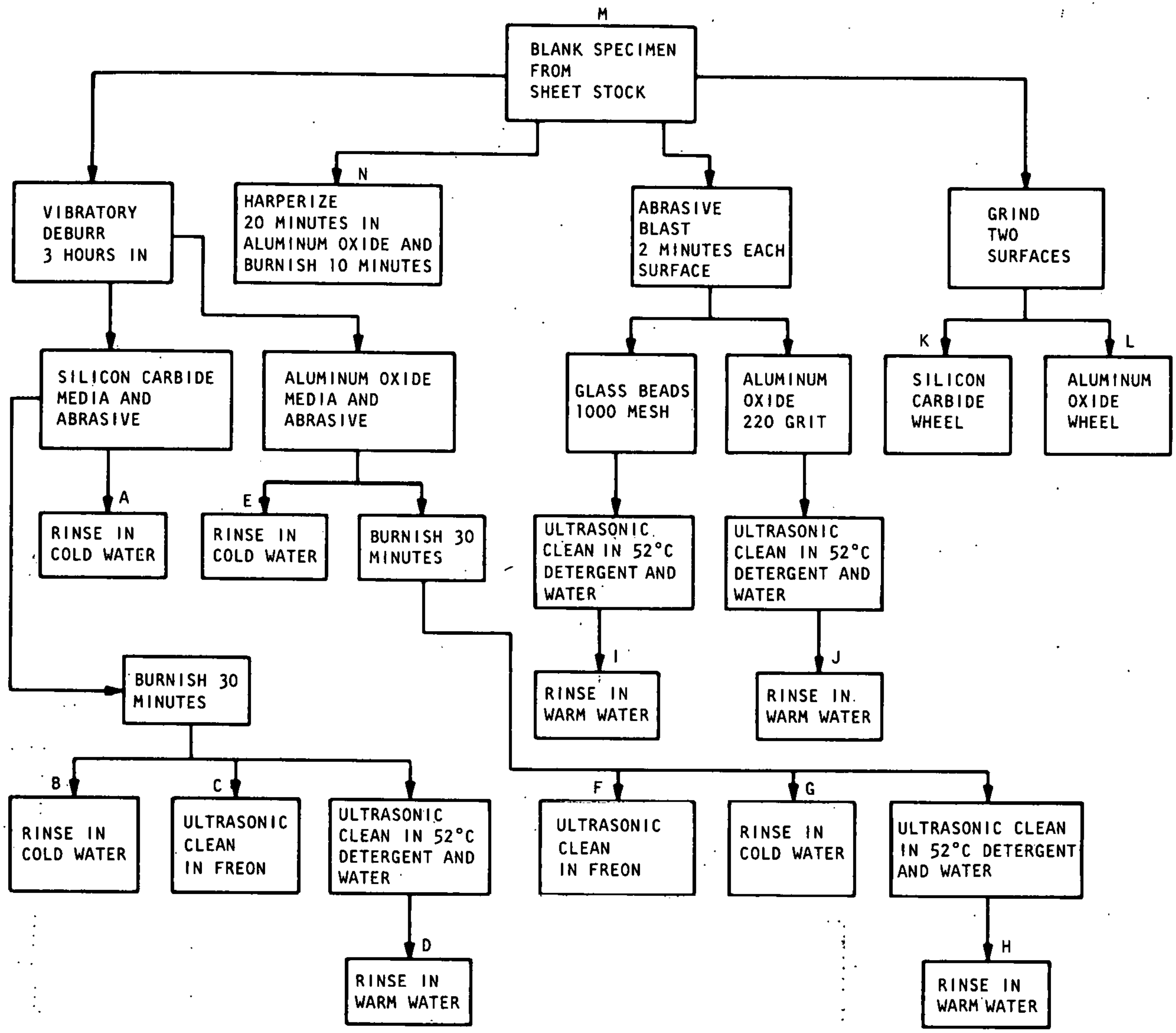

Figure 6. Flowchart of Conditions Studied

A comparative analysis of a part deburred without abrasives is shown. Some silicon was observed on parts subjected to silicon carbide media. No foreign material was found on samples which had been centrifugal barrel finished in dolomite.

Specimens which had first been run in aluminum oxide media then subjected to a followup process (Conditions 2 through 5) still exhibited aluminum oxide peaks on AES analysis after sputtering.

Table 2. Results of Centrifugal Barrel Finishing Deburring

Operation*	Compound			AES Peak Height Results Before Sputtering	
	Abrasive	Burnish	Visual	Aluminum	Silicon
(1) 20 Minutes	1A-1	MFC 113	Black	12	4
(2) Condition (1) Followed by 20 Minutes in $CaMgCO_3$ (N8-N30)	None	None	Dark	100	0
(3) Condition (1) Followed by 20 Minutes in 13 mm (0.5 in.) Plastic* Pyramids	8A**	2B	Gray and dull	0	0
(4) Condition (1) Followed by 20 Minutes in Ground Corn Cob (dry)	None	None	Dark but shiny	0	0
(5) Condition (1) Followed by 20 Minutes in No. 14 Glass Beads	None	None	Very dark but shiny	0	0
(6) 20 Minutes in 6 mm (0.25 in.) Plastic Pyramids	8A	2B	Gray and dull	0	0†
(7) 20 Minutes in N14$CaMgCO_3$	None	2B	Clean and shiny	0	0
(8) 20 Minutes in N24 Plus 4.8 mm (0.19 in.) Triangles (Al203)	1A-1	MFC 113	Dark		
(9) 40 Minutes in N14$CaMgCO_3$	None	2B	Clean and shiny	0	0

Table 2 Continued. Results of Centrifugal Barrel Finishing Deburring

Operation*	Compound		Visual	AES Peak Height Results Before Sputtering	
	Abrasive	Burnish		Aluminum	Silicon
(10) 40 Minutes in N8SiC	8A	2B	Dark	0	12
(11) 40 Minutes in N8SiC	None	Almco 20***	Dark	1	18
(12) 40 Minutes in N14CaMgCO_3	8A	2B	Clean and very shiny	0	0

All tests were performed at 15 g setting. All burnish operations were for 5 minutes. Specimens from Tests 1 through 6 were subsequently rinsed in agitated water and ultrasonic cleaned in Freon. Specimens 6 through 12 were rinsed in agitated water and ultrasonic cleaned in 25I Detergent (Bendix Corporation).

*Values in this table are peak height before sputtering as a percent of the carbon peak height.

**Carbofast 8A, Carborundum Company, Electro Minerals Division.

***ALMCO Industrial Deburring and Finishing Equipment.

†Meseran and mass spectrometer analysis indicated that a polyamide residue was left on the part from this operation.

In a subsequent analysis of parts, it was noted that parts deburred in preformed silicon carbide exhibited no silicon peaks (Condition 10, Table A-3). The fact that the preformed shape left no material on the parts but the blocky chunks of silicon carbide did, indicates that generalizations about materials may be meaningless. This is further supported by a study of parts subjected to barrel tumbling. No aluminum oxide was found on these parts although everything centrifugal barrel finished in aluminum oxide exhibited aluminum oxide peaks on the AES analysis (Table A-3).

Although no study was performed on the size of particles impregnated into the workpiece, in Matsunaga's study[8] of microcrystalline aluminum oxide, impregnated particles were 1 μm or smaller. In Williams' study[16] of embedment of silicon carbide lapping particles, it was found that the weight of impregnated material varied from 0.4 to 44.5 $\mu g/cm^2$ of surface. Williams' test utilized 500 grit abrasive which is 11 to 28 μm in size.

If the impregnated particles of the present study were 12 μm in diameter and if 44.5 $\mu g/cm^2$ of these particles were impregnated, then there are 291 particles per μg or 12,943 particles/cm^2. An inspection of Matsunaga's photographs indicates there were 2 to 6 x 10^8 embedded particles for 645 mm^2 ($in.^2$) of surface area.

Implications of Impregnation

Abrasive particles impregnated into the workpiece can cause the following problems:

- Reduced tool life in machining,
- Poor solder and braze bonds,
- Poor electroplating bonds,
- Substandard welds, and
- Changes in electrical resistivity.

Machining

Hard spots in any material shorten cutter and punch life. It would be expected, therefore, that impregnated material would similarly shorten tool life. On high precision parts produced in lots of 50 to 200 pieces tool wear is not the predominant reason for changing tools. Thus a reduction in tool life is not a major consideration in this type of production. In most cases the abrasive deburring processes are performed after all machining operations have been completed, thus any impregnated material would have no influence on tool life.

Soldering and Brazing

Solder will not bond well to surfaces which have aluminum oxide on them, nor will brazing alloys wet well on surfaces impregnated with aluminum oxide.[17]

Welding

Aluminum oxide is an inert material with a high melting point and does not melt during welding. When the surrounding metal cools, however, the inclusions (aluminum oxide particles) are either forced out of the joint, resulting in weld voids, or cooling of the molten metal produces large stress concentrations around the particles. Either case results in an inferior weld.

Silicon carbide media and abrasives do not cause these problems, since silicon and silicates are normal slag products which rise to the surface of the weld. Parts which are subsequently gold plated should not be processed in silicon carbide, however, since the gold may react with the silicates to form gold silicide or other crack-producing products. Excesses of Al_2O_3 or SiO_2 in electron beam welds can cause beam disruption.

Electrical Resistivity

Low voltage, low current electrical contacts are sensitive to minute changes in electrical resistivity. Glass beads, fine aluminum oxide or silicon carbide particles will change this resistivity. In one study in which a S.S. White abrasive blasting unit was used to clean the surfaces of contacts, only dolomite was successful in removing oxides without increasing contact loop resistance (CLR).

The presence of foreign material in the surface of some metals will create local electrolytic cells which can accelerate corrosion. Because the materials normally used in deburring operations are basically insulators, this facet of impregnation would not be expected to cause any abnormal corrosion. Faster corrosion could be significant if metal particles of any kind are used in the deburring process.

Cleaning

In the previous paragraphs, it had been assumed that material observed using EDAX or Auger analysis was impregnated material. The more likely case is that some of the observed elements were impregnated and some were part of a surface film.

A contaminating film of soap and abrasive can remain on parts after deburring. In some cases, this film can be wiped off with tissue paper, or rinsed off using soap and water. In other cases the film cannot be removed by either of these methods.

In one case, previously reported,[3] it was noted that ceramic bonded aluminum oxide media left a black film on 416 stainless steel parts. This film could be wiped off with tissue paper, but it could not be prevented by changing abrasive compounds. However, by using plastic media, the film did not appear.

During Bendix testing it was noted that the abrasive and burnishing compounds also can be a source of contamination. In these tests, 22 combinations of compounds were evaluated on 303 Se and 17-4 PH stainless steel, 6061-T6 aluminum, and beryllium copper. Plastic cones were used as media to eliminate the influence of aluminum oxide. (While plastic media is commonly used to polish surfaces which are subsequently plated, a mass spectrograph of parts centrifugal barrel finished in a polyester plastic indicated that a plastic residue remained on the surface of the parts.) It was noted that the following conditions occurred:

- Burnishing compounds eliminated stains and dark colors on most specimens.
- Abrasive and burnishing soap films remained in many of the hard to reach pockets when only warm running water was used to clean the parts.

In subsequent testing, it has also been observed that particles of dry abrasive or burnishing compounds will sometimes clog small holes.

Extrude Hone Deburring

The loose abrasive deburring processes tend to produce contaminated or impregnated surfaces; however, no such trend has been observed resulting from the extrude hone process. A study of cleaning extrude hone X-base media from parts indicated that ultrasonic cleaning in 52°C (126°F) detergent and water removed all but 1 mg of material from two 77-mm long (3 in.) intersecting holes. This represented a six parts per million (ppm) concentration. A subsequent cleaning in Tri-Ethane (Pittsburgh Plate Glass Company, Chemical Division) removed all traces of this material.

Implications of Inadequate Cleaning

As in the case of impregnated material, surface films resulting from abrasive processes will also result in reduced tool life, poor solder and braze bonds, poor electroplating bonds, substandard welds, and changes in electrical resistivity.

In addition, it is conceivable that they could also cause changes in the coefficient of friction, minute loose particles in assembly, and scoring of mating surfaces.

It has been known for some time that fine abrasive particles can settle out on the surface of parts and form an extremely adherent coating. This coating can be so well bonded that only chemical etching or mechanical polishing will remove it. Tarasov, for example, notes such a case.

"This is illustrated by some tumbled copper parts to which abrasive particles roughly 0.001 inch in size were so firmly attached that they could not all be removed even by scrubbing with a stiff brush in a soap solution."[7]

On some materials, the film from aluminum oxide is white and visibly gritty. On other materials such as Kovar, the film is black and visible only as a color change. Nickel plated Kovar parts which have this black film of aluminum oxide prior to plating have been known to result in poor plating adhesion.

This film can be prevented by using appropriate abrasive compounds and media and thoroughly cleaning parts before the film can dry on them. These precautions will eliminate most of the problems in the above list which are the result of a surface film.

If parts have a polyester film on their surface (from the plastic media), standard cleaning processes will not remove this film. Methylene chloride should remove this film, but the use of this chemical requires special precautions since it is hazardous to health. One would assume that this film would not noticeably affect welds. Since this plastic is used extensively throughout industry to provide preplate finishes, it is compatible with several commercial plating processes. This plastic film would obviously cause resistance problems in low voltage contacts.

Parts that are centrifugal barrel finished with a combination of an abrasive compound and case hardened pins always have a black film on them. In many cases, even a 5 minute burnish operation will not remove this film from the workpiece. If an abrasive media is also used with the pins, it too will be coated with this black film. At this time, the source of, and composition of, the film is still unknown although several possibilities have been suggested. The only apparent solution is to brush polish the parts to remove the film or utilize a long burnishing cycle which doubles the total barrel finishing time.

A study of extrude hone X-base media effects on contact loop resistance (CLR) indicated that this media caused no subsequent circuit degradation as a result of media entrapment and subsequent outgassing. As a result, parts which have been extrude hone deburred with this carrier and cleaned should not affect the electrical resistance of any electromechanical assembly.

Matching Media to Product Needs

Based on the comments previously made, solutions to the problems discussed might seem obvious--silicon carbide or dolomite. In practice, however, these materials present other problems. Dolomite will remove burrs with thicknesses of 25.4 μm (0.0010 in.) while aluminum oxide media will remove burrs up to 76.2 μm (0.003 in.) in the same or shorter cycle time. Silicon carbide under similar conditions will remove burrs in the order of 50.8 μm (0.002 in.). Dolomite wears quickly. For the same cutting action, aluminum oxide will outlast dolomite by a factor of 1000. Silicon carbide chunks fracture easily and the resulting small particles quickly lodge in small holes and slots.

The fact that plastic media is used extensively for plated and non-plated parts indicates that for many parts this media is acceptable in many situations. The same can be said for many other materials.

Because of these limitations, it is not possible to select one media which will solve all problems. Each part must be evaluated on the basis of its material, its geometry, its function, whether or not it is subsequently welded or plated, and requirements of the total assembly.

Figure 7 illustrates the typical sequence of events which must be considered in selecting media. Each of the items listed represents a general consideration. There are several additional considerations. For example, under part geometry, one must consider the overall shape, the overall size, and the effect of holes, slots, and undercuts.

Tables A-4 through A-8 list typical constituents of the loose abrasive processes and some of their properties which are significant in deburring and finishing operations and in situations involving impregnation. Additional data on these materials has been published in mineralogy texts.[18,19]

Aluminum oxide media is the cheapest, most durable, most widely used, and exists in several forms. Preform shapes such as triangles and cylinders consist of aluminum oxide powder mixed with a ceramic binder. This binder can be either vitrified or non-vitrified. Sintered aluminum oxide nuggets (chips) are widely used. The color of these nuggets, which varies widely (gray, brown, and blue), is one indicator of the agressiveness of the nuggets. Fused aluminum oxide nuggets, which have a very fine crystal structure are used when long media life is desirable. The surface of this material is a glassy black. Several degrees of friability are also available in aluminum oxide media.[8,20] The same comments apply to silicon carbide media.

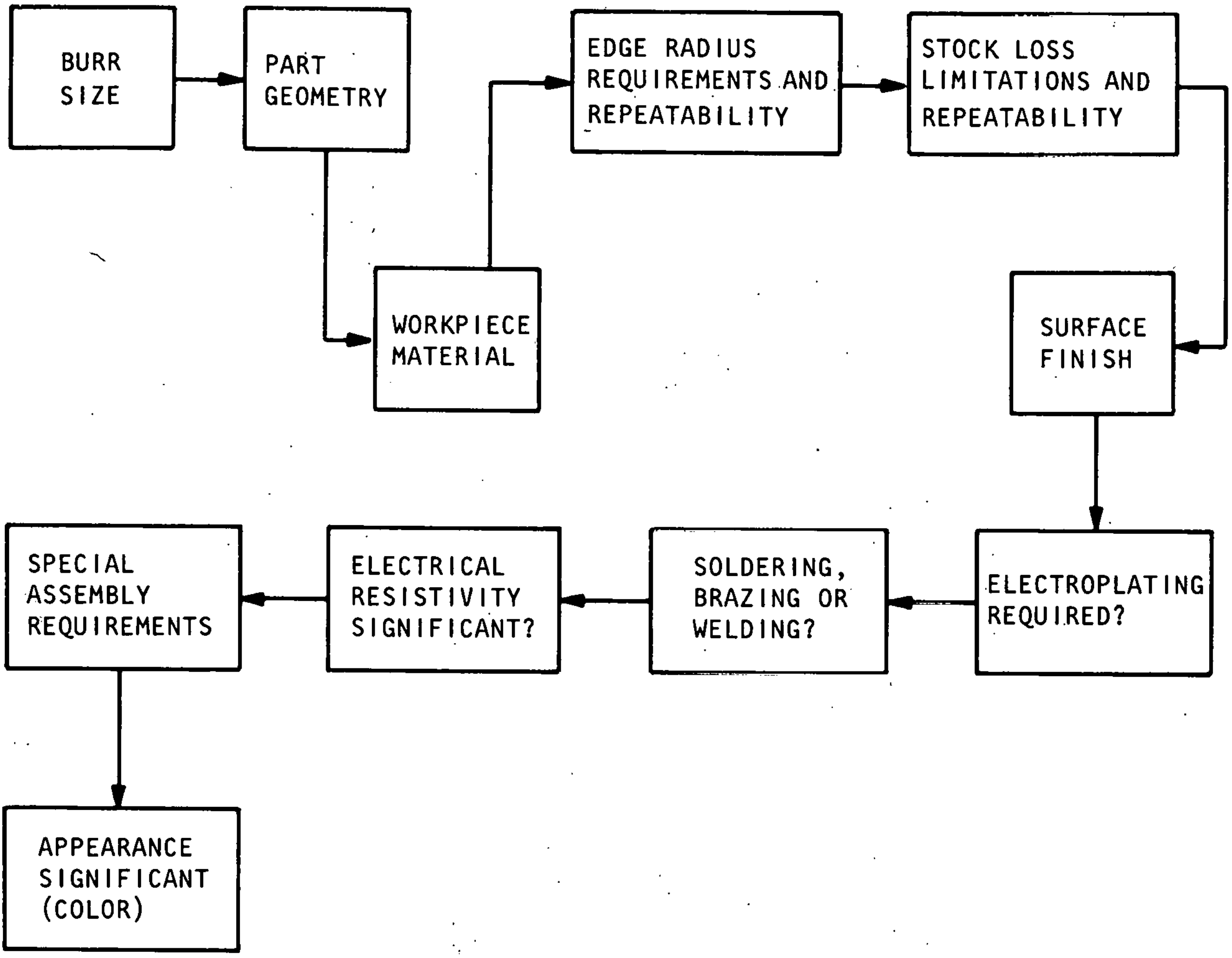

Figure 7. Considerations Used in Selecting Abrasive Media

Individuals in many companies have assumed that all aluminum oxide medias are the same except for shape and color. As a result, little thought was given when new media were ordered to replenish existing stock. If a less expensive source could be found the media was mixed with old media. It has become very difficult to isolate the source of the sporadic problems often blamed on the loose abrasive finishing process. In some cases, media suppliers changed their source of material or made some change to their process. As a result, noticeable plating problems might not occur or be observed for several months after tumbling, barrel finishing, or vibratory finishing.

Based on the limited quantitative knowledge available at this time, the following guidelines should be utilized whenever possible:

- Use aluminum oxide media whenever possible, since it is the most economical and is available in a wide variety of sizes and shapes.
- Use silicon carbide for welded or plated parts. Use preform shapes if possible, since they do not break down into small chunks which will clog small holes.
- Use dolomite for ultrahigh quality levels of plating, or for parts required to operate at very low currents and voltages.

When the previous guidelines cannot be followed, the following general approaches should be used:

- Keep the tumbling operating time to a minimum.
- For welded parts, use plastic media or dolomite.
- Use silicon dioxide (quartz) media and abrasive.
- Use steel media.
- Tumble parts without using media.

Removing Impregnated Material and Surface Residues

There are two methods which can be used to remove surface and subsurface contaminants. By resubmitting the workpiece to a vibratory or barrel type process, it is possible to remove films and impregnated material. While surface residues are physically rubbed off, impregnated material is only removed by grinding enough material off the workpiece to get below the impregnated material. This appears to require 7.62 μm (0.0003 in.) stock removal on each side of nonporous materials such as stainless steel. This technique is only successful if an abrasive material can be found which does not also impregnate the workpiece during the stock removal process.

The second method is to chemically or electrochemically etch off enough surface metal to reach noncontaminated metal. Experience with Kovar pins indicated that 7.87 μm (0.00031 in.) on each side was the least amount which could be removed in a controlled situation. The solution used to clean this material consisted of a mixture of 750 cm^3 acetic acid, 250 cm^3 nitric acid, 15 cm^3 hydrochloric acid, and 5 cm^3 hydrofluoric acid. A 10 second etch with ultrasonic agitation was sufficient to remove the film and adjacent metal.

Soap films can be removed in many cases by dipping the part in 52°C (125°F) detergent and water then rinsing it immediately in hot water. On copper alloy parts, dipping in brass cleaner then muriatic acid provides some improvement. Chemical bright dips also can be used if stock loss is not critical.

Cleaning and Compounds

The abrasive compounds and cleaning techniques currently used or specified at Bendix appear adequate for most parts. Some improvement is needed on parts which have been deburred in steel pins or silicon carbide. Both of these turn some workpiece materials black. The existing process of ultrasonic cleaning parts in 52°C (125°F) detergent then rinsing in warm water will not remove films left by the steel pins. Parts must not be dried before the cleaning is performed because this bonds the film to the part. Freon does not remove the films from the abrasive processes.

General observations made include the following plating processes:

- Abrasive particles are actually impregnated into the workpiece.
- Hard to activate materials such as 303 Se, 17-7 PH, and 17-4 PH stainless steels are affected more by impregnation than other materials.
- Fused aluminum oxide media results in higher levals of impregnated aluminum and increases the probability of plating adhesion failures.
- When an Auger analysis indicates that the aluminum peak constitutes more than 10 percent of the peak heights of all elements, the likelihood of adhesion failure is very high. On hard to activate materials, an aluminum peak height greater than 1 percent greatly increases the likelihood of adhesion failures.
- Little significant difference was observed between the results produced by the two cleaning solutions.
- Lowering barrel finishing G-forces did not improve results on the hard to activate 17-4 PH stainless steel.
- Hardness differences did not affect the results in 17-4 PH stainless steel.
- All brass parts (which are easy to activate) exhibited good adhesion.
- Beryllium-copper surface luster after activation is a good indicator of potential plating adhesion.

- By removing 2.54 to 12.7 μm (0.0001 to 0.0005 in.) of stock in the activation process, all traces of the aluminum will disappear.
- No noticeable difference was observed between parts vibratory finished and those which were barrel finished.
- The silicon dioxide impregnated plastic media appeared to cause poor adhesion on the hard to activate materials.
- Dolomite media does not cause adhesion problems.
- Silicon carbide media can cause adhesion problems.

ACCOMPLISHMENTS

This study proved that tumbling media does impregnate the workpiece. Either a surface film or impregnated material covers the surface of most parts subjected to such processes. The resultant effects of these observations have been discussed in terms of subsequent plating, welding, machining, electrical properties, and operating life. Abrasive blasting produces the same effects as tumbling. Neither grinding wheels nor extrude hone media produce any of these side effects.

For plated precision parts, which are difficult to activate, aluminum oxide finishing media should be avoided. Dolomite should be used as a media on these parts. On parts which are easy to activate, ceramic bonded aluminum oxide, silicon carbide, or the plastic media can be used with only occasional adhesion problems. The fused aluminum oxide can be used when plating adhesion does not have to pass the 180 degree bend test, or when 0.007 mm (0.0003 in.) stock can be etched from each surface.

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APPENDIX. DATA TABLES

Table A-1. Description of Medias and Compounds Used in This Study

Triangles 4.8 mm (0.19 in.)	Ceramic bonded aluminum oxide, 4.8 by 4.8 by 3.2 mm (0.19 by 0.19 by 0.125 in.), Fortune Industries AX90 composition.
N14 Media	Fused aluminum oxide chip (random shape), ANSI No. 14 size, Metal Finishing Company No. 281(R)-14
N8 Media	Fused aluminum oxide chip (random shape), ANSI No. 8 size, Carborundum Company
N12 Dolomite	Calcium magnesium carbonate chip (random shape) approximately ANSI No. 12, Aremco Products Corporation
Plastic Pyramids 6.1 mm (0.25 in.)	6.1 by 6.1 mm (0.25 by 0.25 in.) pyramid, Almco supercut type X plastic (with impregnated silicon dioxide)
1A-1	Abrasive compound, Almco No. 3
23C	Liquid burnishing compound, Almco 2350

Table A-2. Test Conditions and Results

Test Code	Finishing Process	Workpiece Material	Auger Analysis*** (Sputtered Results Only) Al	Si	Ca	Mg	Adhesion Results
1	None (control sample)	304 SST	--				Good
		Kovar	1.06				Good
		17-7 PH	9.48				Bad
2	None (control sample)	304 SST					*
							*
3	Vibratory deburr 2 hours 3/16 triangles & 1A-1 Emul. clean	304 SST	--				Good
		Kovar	--				Good
		17-7 PH	1.90				Good
4	Same as #3, except cleaned in 25I detergent	304 SST	--				Good
		Kovar	--				Good
		17-7 PH	2.93				Good
5	Harperize 20 min. at 15g's 3/16 triangles and 1A-1** Emul. clean	304 SST	--				Good
		Kovar	--				Good
		17-7 PH	--				Bad
6	Same as #5, except cleaned in 25I detergent	304 SST	--				Good
		Kovar	--				Good
		17-7 PH	0.95				Bad
7	Harperize 20 min. at 15g's N14 media & 1A-1 Emul. clean	304 SST	8.63				Bad
		Kovar	7.16				Good
		17-7 PH	8.66				Bad
8	Same as #7 except cleaned in 25I detergent	304 SST	11.43				Bad
		Kovar	4.51				Good
		17-7 PH	10.88				Bad

Table A-2 Continued. Test Conditions and Results

Test Code	Finishing Process	Workpiece Material	Auger Analysis*** (Sputtered Results Only)				Adhesion Results
			Al	Si	Ca	Mg	
9	Same as #7 except parts were baked at 250°F prior to cleaning	304 SST	9.28				Bad
		Kovar	10.00				Good
		17-7 PH	9.88				Bad
10	Harperize 20 min. at 15g's 1/4" plastic pyramids &1A -1 Emul. Clean	304 SST	0.63	0.63			Bad (edges only)
		Kovar		0.96			Good
		17-7 PH	0.91	0.45			Bad
12	Harperize 20 min. at 15g's N8 SiC media, no abrasive + Emul. clean	304 SST	12.81				Bad
		Kovar	11.78				Bad
		17-7 PH	13.39				Bad
13	Same as #12 except cleaned + in 25I	304 SST	12.82				Bad
		Kovar	10.96				Bad
		17-7 PH	16.59				Bad
14	Harperize 20 min. at 15g's N8 media and 1A-1 Emul. clean	304 SST	2.99				Bad
		Kovar	8.19				Bad
15	Vibratory deburr 2 hours N8 media and 1A-1 Emul. cleaner	304 SST	6.96				Bad
		Kovar	8.06				Bad
7 Repeat		304 SST	4.15				Good
		Kovar	3.17				Good
10 Repeat		304 SST	8.35				Good
		Kovar	1.77	0.58			Poor
12 Repeat		304 SST	1.11	3.33			Good
		Kovar	1.49	2.77			Good

Table A-2 Continued. Test Conditions and Results

Test Code	Finishing Process	Workpiece Material	Auger Analysis*** (Sputtered Results Only)				Adhesion Results
			Al	Si	Ca	Mg	
A1	Harperize 20 min. at 15g's N8 & 1A-1 Emul. clean	304 SST	7.45				Bad
A2	Harperize 20 min. at 15g's 3/15 triangles, no abrasive Bake dry before cleaning Emul. clean	304 SST	2.58	2.75		1.20	Bad
A3	Same as A2 except no bake	304 SST	2.55	2.72		1.19	Bad
B1	Harperize 20 min. at 15g's N14 & 1A-1 Emul. clean	BeCu Recheck	0 5.17	0		0	Bad Good
B2	Same as B1 except media is N12 dolomite, no abrasive, No burnishing	BeCu Recheck	0 0	0 0		0 0	Bad Good
B3	Same as B1 except media is 3/15 triangles, no abrasive	BeCu Recheck	1.18 1.20	1.88 1.00		.24 --	Good Good
C1	Same as #3	BeCu	0.33				Good
C2	Same as #15	BeCu	4.83				Bad
D1	Same as A2	Alloy 6 Brass	3.29	2.87		0.82	Good
D2	Same as B1	Alloy 6 Brass	6.56				Good
D3	Same as #15	Alloy 6 Brass	0	0		0	Good

Table A-2 Continued. Test Conditions and Results

Test Code	Finishing Process	Workpiece Material	Auger Analysis*** (Sputtered Results Only)				Adhesion Results
			Al	Si	Ca	Mg	
H1	Vibratory 2 hrs. in N8 SiC, no abrasives	302 SST	7.38	4.43			Bad
H2	Vibratory 2 hrs. in 1/4" plastic pyramids & 1A-1	302 SST	--	--	--	--	Good
J1	Control sample (as rec'd sheet stock)	302 SST	--	--	--	--	Bad
		Kovar	.54	--	--	--	Good
K1	Harperize 20 min. in dolomite, 15g's, no abrasives	304 SST	--	--	6.68	1.60	Bad
		Kovar	--	--	14.24	4.43	Good
K2	Harperize 20 min. in N8 SiC, no abrasives, 15g's	304 SST	7.4	8.73			Bad
		Kovar	6.55	6.89			Bad

*These samples were not plated.

**The failure of any contaminating material to appear indicates this group of parts was not subjected to the finishing media. A repeat of these conditions revealed that aluminum and silicon are present after this finishing cycle.

+The existence of a large aluminum peak and no silicon peak indicates that aluminum oxide was used to process this part instead of silicon carbide.

Dashes (--) indicate this material was not observed.

***Values shown indicate the relative quantitative level of material present. This value was obtained by measuring the height of the "spike" found for the particular element indicated on the Auger chart then dividing by the sum of the heights of all other elements shown on the chart. Carbon and oxygen are two noncontaminating elements found on most surfaces that necessitate this relative comparison technique.

Table A-2 Continued. Test Conditions and Results

Test Code	Finishing Process	Workpiece Material	Auger Analysis*** (Sputtered Results Only) Al	Si	Ca	Mg	Adhesion Results
D4	Same as B2	Alloy 6 Brass	0	0		0	Good
D5	Same as #12	Alloy 6 Brass	4.60	1.61		0	Good
E1	Repeat of #12	Kovar					Good
		304 SST	6.38	2.84			Bad
E2	Repeat of #5	Kovar					Good
		304 SST	1.88	1.08			Bad
E3	Same as #7 except media is N24 and 1A-1	Kovar					Good
		304 SST	5.56	0.65			Bad
E4	Same as B2	Kovar					Good
		304 SST	0	0	2.55	2.55	Good
F1	Same as B1 except 5g's force was used	Kovar	2.61				Good
		304 SST	3.54				Bad
F2	Same as B1 except 10g's force was used	Kovar	4.73				Good
		304 SST	5.56				Bad
G1	Harperize 10 min. at 15g's N3 & 1A-1	17-4 PH Ann.	4.04				Bad
		17-4 PH H900	4.48				Bad
G2	Same as G1 except run for 20 minutes	17-4 PH Ann.	5.49				Bad
		17-4 PH H900	4.92				Bad
G3	Same as G1 except run for 40 minutes	17-4 PH Ann.	4.22				Bad
		17-4 PH H900	3.83				Bad

Table A-3. Materials Commonly Used in Deburring Processes

Operation	Media	Abrasive Compound	Burnish Compound	Auger Results			Material	Part
				AL	Si	C		
1 Harperize 20 minutes	N24AL203	1A-1	MFC 113	3 18[a]	1 0[a]	25 7[a]	Kovar	Pin
2. Tumbled 4 hours	$\frac{1}{4}$ AL_2O_3 triangles[b]		Almco 15	0[a]	0[a]	14[a]	Alloy 52	Pin
3 Tumbled 4 hours	$\frac{1}{4}$ AL_2O_3 triangles[b]	$NA(SO_4)_2$		0	0	15	Alloy 52	Pin
4. Harperized 20 minutes	Steel + Dolamite	None		0	0	12	Kovar	Pin
5. Harperized 20 minutes	$N14AL_2O_3$	$NA(SO_4)_2$		5	0	12	Kovar	Pin
6 Harperized 20 minutes	N8SiC	None		1	4	11	Kovar	Flat Plate
7 Harperized 20 minutes	N8SiC	None		1[a]	5[a]	4[a]	Kovar	Flat Plate
8 Harperized 40 minutes	N8SiC	None		0[c]	0[c]	11[c]	Kovar	Flat Plate
9 Harperized 40 minutes	N8SiC	None		0[a,d]	0[a,d]	6[a,d]	Kovar	Flat Plate
10 Harperized 40 minutes followed by 20 minutes in $\frac{1}{4}$" SiC triangles	N8SiC $\frac{1}{4}$" SiC triangles	None		0[e]	0[e]	10[e]	Kovar	Flat Plate
11 Harperized 20 min. in N8SiC followed by 20 min. in Dolamite	N8SiC N16 Dolamite	8A	2B	0 0[a]	2 2[a]	8 2[a]	Kovar	Pin

[a] After sputtering 3 minutes (Ep = 5 kV, V mod = 3 eV, Rc = off, Ip = 30 A, V mult = 2.2 kV, SENS = 0.2

[b] Norton fastcut

[c] Sodium and magnesium peaks to 5 units

[d] Magnesium peak jumps to 5 units

[e] A sodium peak of 5 units is visible but no magnesium is visible

Table A-4. Materials Commonly Used in Loose Abrasive Processes

Abrasive Compounds			
Abrasive Particles	Soap	Burnishing Compounds	Abrasive Media
AL_2O_3	Surfactants	Brighteners	Table A-5
SiO_2	Water Conditioners	Water Conditioners	
SiC	Coloring Agents		
Pumice	Chelating Agents		
	Flocculanting Agents		

Table A-5. Materials Commonly Used in Abrasive Blasting

	Carrier	
Abrasive	Air	Water
Glass Bead	X	
Silica Sand	X	X
Steel Shot	X	
Calcium Magnesium Carbonate	X	
AL_2O_3	X	X
SiC	X	X
Plastic*	X	
Nut Shells	X	
Novacite (SIO_2)	X	X

*Polycarbonate and other materials.

Table A-6. Media Commonly Used in Loose Abrasive Deburring

			Abrasive Cutting[2]			Barrel Polishing[2]			Burnishing[2]		
Abrasive Type	Abrasive Size[1]	Operation Type	Ferrous	Non-Ferrous	Plastics	Ferrous	Non-Ferrous	Plastics	Ferrous	Non-Ferrous	Plastics
Aluminum Oxide Shapes	10 mesh to 2"	Wet	A	A	N	A	A	N	N	N	N
Aluminum Oxide Powders[3]	16 mesh and smaller	Wet or dry	A	A	B	A	A	B	N	N	N
Aluminum Oxide (Ceramic Bonded)	1/16 to 2"	Wet	A	A	B	A	A	N	N	N	N
Bonded Abrasive	1/16 to 2"	Wet	A	A	N	A	A	N	N	N	N
Granite Chips[4]	1/16 to $1\frac{1}{2}$"	Wet	A	A	N	B	B	N	N	N	N
Flint Stone[4]	1/16 to 2"	Wet	A	A	C	B	B	N	N	N	N
Quartzite[4]	Various	Wet	A	A	N	B	B	N	N	N	N
Marble[4]	Various	Wet	A	A	N	B	B	N	N	N	N
Limestone Chips[4]	1/16 to $1\frac{1}{2}$"	Wet	A	A	C	A	A	N	N	N	N
Sand (Builders)	8 mesh & finer	Wet or dry	A	A	C	A	A	C	N	N	N
Rolled Zinc Slugs	Various	Wet	BW	BW	N	AW	AW	N	A	A	N
Soft Steel Balls & Shapes	1/8 to 1/2"	Wet	BW	BW	N	AW	AW	N	N	N	N
Wood Balls & Shapes	Various	Wet or dry	BW[5]	BW[5]	AW	BW[5]	BW[5]	AW	A[5]	A[5]	A[5]
Veg. Ivory Chips	Various	Wet/dry	BW[6]	BW[6]	N	BW[6]	BW[6]	N	A	A	N
Nut Shells	Various	Wet/dry	N	N	AW	BW	BW	A	A	A	A
Hard Steel Balls & Shapes	1/64 to $\frac{1}{4}$"	Wet or dry	N	N	N	N	N	N	A	A	N
Glass Burnishing Balls		Wet	N	N	N	N	N	N	-	A	-
Macerated Corn Cobs	Mixed, Dust free	Dry	N	N	N	N	N	N	A	A	A

Table A-6 Continued. Media Commonly Used in Loose Abrasive Deburring

Abrasive Type	Abrasive Size[1]	Operation Type	Abrasive Cutting[2]			Barrel Polishing[2]			Burnishing[2]		
			Ferrous	Non-Ferrous	Plastics	Ferrous	Non-Ferrous	Plastics	Ferrous	Non-Ferrous	Plastics
Leather Scraps	Various	Wet/dry	N	N	N	N	N	N	A	A	A
Felt Scraps	Various	Dry	N	N	N	N	N	N	A	A	A
Iron Powder		Wet	A	A	-	A	A	-	N	N	N
Plastics					-	-	A				
Plastics + SiO_2[7]	¼ to 2"	Wet	A	A	-	A			A	A	
Plastics + AL_2O_3	¼ to 2"	Wet	A	A	-	A					
Plastics + SiC	¼ to 2"	Wet	A	A	-	A					
Plastic Coated Steel		Dry	-	-	-	-	-	-		C	

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[1] Other sizes available for special applications.

[2] A widely used; B, often used, a good second choice; C, occasionally used; AW & BW, used with added fine abrasive; N, never used.

[3] Usually mixed with other media but occasionally used alone.

[4] Available in quarried state or processed to remove sharp corners. Quarried form only good for roughest operation.

[5] With or without other media.

[6] See wood balls.

[7] Many plastic medias have an abrasive mixed with them.

Table A-7. Typical Properties of Blasting and Tumbling Media.*

MATERIAL	HARDNESS (Mohs Scale)	GRAIN SHAPE	SPECIFIC GRAVITY	COLOR	FREE SILICA CONTENT	FREE IRON CONTENT	REUSE
Corn Cobs	2	Cubical	1.3	Tan	None	None	Good
Walnut Shells	3	Cubical	1.3	Lt. Brown	None	None	Good
Novaculite	4	Angular	2.5	White	90%	None	Poor
Glass Beads	4.5	Spherical	3.0	Crystal	None	None	Good
Sand	5	Rounded	1.75	Tan	90-100%	<1%	Fair
Mineral Shot (Poly-Grit)	6-7	Angular	3.16	Black	None	<1%	Good
Steel Shot/Grit	6-7	Spherical Angular	4.80	Steel Grey	None	99%	Excellent
Flint Shot	6-7	Spherical	1.75	White	90-100%	<1%	Good
Garnet	7	Spherical	4	Pink	<2%	<2%	Good
Quartz	7	Spherical	2.65	White	100%	<2%	Fair
Zircon	7.5	Cubical	4.56	Tan	<5%	<1%	Good
Emery	8	Angular	4.00	Reddish Brown	<1%	<3%	Good
Aluminum Oxide	9	Cubical	3.80	Brown	<1%	<1%	Very Good
Silicon Carbide	9	Cubical	3.13	Black Green	<1%	<1%	Good
PLASTIC		—	0.8		NONE	NONE	GOOD

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* After data published by MDC Industries, Philadelphia, Pennsylvania

Table A-8. Materials Commonly Used in Abrasive Flow Deburring Processes

Abrasive Compound*	Carrier	Additional Additives
SiC	Silicone Rubber	Mineral Oil
AL_2O_3	Kneaded Rubber	Water
BC_2	Proprietary Material	Thickening Agents
Diamond		Thinning Agents

*Extrude Hone and Dynetics Corporation

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J. L. Couchman/F. J. Boyle/B. W. Landes, D/821, 2A36	29
L. K. Gillespie, D/822, 2A36	30-39
G. E. Klement, D/822, 2A36	40
W. P. McKay, D/822, 2A36	41
D. P. Roberts/C. E. Spitzkeit, D/823, 1A27	42
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Vibratory deburring and centrifugal barrel finishing can result in inadequate adhesion of electroplated metals. Fine particles of the abrasive metals and compounds used in these processes impregnate the exposed surfaces of the workpieces. If too many of these particles are in the workpiece surfaces, electroplated coatings fail to adhere properly. Ceramic bonded aluminum

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MECHANICAL: Deburring Effects on Electroplating

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