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# Mass Finishing

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The Metal Finishing Suppliers' Association, Inc. is a trade association of companies and individuals engaged in providing the metal finishing industry with equipment, products and supplies. A primary objective of the Association is to promote the interests and further the welfare of its members and their customers while safeguarding the interests of the ultimate consumer. The Association, along with other groups in the industry, has long realized that the public, the industrial buyer and the designer are not too well informed about metal products finishing nor how to specify high quality coatings on industrial and consumer products.

In 1960 MFSA initiated action to upgrade the durability of metal finishes, in a program known as the “Quality Metal Finishing Project” or QMF. This project has been so successful that it is being continued and enlarged. It consists of programs aimed at: (1) promoting technically sound specifications or standards in cooperation with interested trade and technical societies; (2) providing information to both producers and buyers of metal/other products with various specified surface finishes; and (3) providing printed guides containing information on established standards and specifications, readily accessible for day to day use by the design engineer, the purchasing agent and all those involved in the use of metal product finishes.

The first volume of the series of guides dealt with standards for quality copper/nickel/chromium finishes. Published in 1965, that volume (Vol. 1) has had several printings. It was followed by a second publication, Quality Metal Finishing Guide-Zinc and Cadmium Coatings. Because of the demand for more printings, the MFSA reissued both guides in a series of revisions constantly up-dated. In the decade of the '70s, QMF Guides on Mass Finishing and Tin and Tin Alloy Coatings were written, printed and distributed to further demonstrate our devotion to finish and/or coating quality. In 1983 the QMF Guide on Electroless Nickel Plating was produced. All of the Guides are updated and reprinted as required.

Quality

As an association promoting the interest and welfare of the producers and customers of the metal finishing industry, MFSA realizes that all suffer loss when products, inadequately finished for their intended life, are sold. The consumer may be persuaded to shift to a product with a nonmetallic finish, or a nonmetallic product. MFSA wishes to encourage management to build in the right amount and kind of high quality needed to guarantee the expected or promised service of the unit.

Management needs to know how a high quality metal finish can be achieved, how to select proper specifications for a given service and how to control the release of products to insure that they meet the standards. At the same time management must be confident that this know-how is based upon sound engineering principles and incorporates a reasonable factor of safety.

Since finish quality is related to surface condition, it is logical to review surface preparation and improvement by mass or bulk finishing methods. Mass finishing can economically enhance the utility, attractiveness, and value of the metal, plastic, ceramic or other parts manufactured for industrial or consumer use. While mass finishing processes do not guarantee that the final finish on a product will be a high-quality finish, they do improve surface properties, upgrade product quality, and enhance the image of the finishing industry. Edge, corner, surface finishing, including the removal of burrs, defects, and sharp
edges improves part appearance and handling safety, prepares surfaces for subsequent coating. Other benefits include easier assembly, improved operating performance, increased strength (in part by elimination of surface stress concentrations), longer product life. By imparting compressive stresses to the surfaces, fatigue strength can be improved. Mass finishing processes can develop active metal surfaces—usually with random scratch patterns. On such metal surfaces it is possible to react chemicals, electroplate, adhere paint, anodize, phosphatize, chromate or color efficiently.

**Design for Mass Finishing**

Design of a metal product affects finish quality and can influence deburring and finishing cost. Many of the design factors applicable to parts to be mechanically polished and electroplated need not be considered for the mass finishing operation alone. These systems are flexible so that parts of almost any shape can be processed, weight and size permitting. However, review of part design by those knowledgeable in deburring can cause relocation of webs, hole size changes, etc., where such changes have no effect on part function. Finishing cost reductions can be substantial. Designers can well keep in mind the fact that part surfaces and edges will be deburred, deflashed, radiused and/or refined by media of some type. Therefore, if possible, part dimensions, and contours involving holes, fillets, edges and significant surfaces should be such that media can reach the surfaces to accomplish the desired result efficiently. Parts to be electroplated after mass finishing are, of course, subject to the design considerations, including designation of significant surfaces, outlined in the MFSA QMF Guide to Copper-Nickel-Chromium and Nickel-Chromium Coatings.

**MASS FINISHING**

Mass finishing is the processing of parts or components to be finished in a container, usually with abrasive or nonabrasive media, water and compound. Action or movement of the container is created to cause media to press and/or rub against component surfaces, edges and corners, or components to rub against each other, to remove burrs, radius edges and corners, improve surfaces, alter and/or enhance surface characteristics.

This Guide will review the principles of operation of the various mass finishing systems, discuss the equipment involved, list the different media and finishing compounds used, and describe results that may be accomplished by mass finishing processes. Mass finishing systems involve rotary barrels, vibratory tubs and round bowl machines, centrifugal barrel machines with turret-mounted drums, centrifugal disc machines, and spindle finishing machines. General operating principles are:

1. **Rotary barrel finishing** (tumbling) utilizes the downward sliding movement of the workload after the mass reaches the turnover point during rotation of the barrel.
2. **Vibratory finishing** uses vibratory forces which are transferred from the walls of the machine to the media and thence to the parts in the tub or bowl.
3. **The centrifugal barrel system** uses centrifugal force to increase the pressure of the media on the parts being finished.
4. **The centrifugal disc system** achieves increased pressure of the media on the parts and constant change in speed of the mass.
5. **Spindle finishing** accomplishes surface improvement by fixturing parts on rotating spindles and “plowing” them through a mass of loose abrasive, utilizing both pressure and abrasive action.

Less common mass finishing processes include reciprocal finishing, resonant energy finishing, chemically accelerated mass finishing and rotary barrel finishing with vibration.
For reciprocal finishing, parts (usually too large for processing in normal spindle finishing machines) are attached to a holding device and placed into a tub of media, water and compound. The component is moved through the mass of media in a reciprocating motion; finishing is concentrated on just one side of the workpiece. In resonant energy finishing one or more workpieces are clamped in fixtures secured to both ends of a steel beam, and the workpieces are submerged in “fluidized” abrasive. High energy levels are produced by resonating the elastic beam member near its natural frequency. The combination of resonant action of the workpieces and orbital movement of the abrasive grains cleans and finishes the surfaces. The process has some capability for removing internal burrs and cleaning internal surfaces. Chemically accelerated mass finishing is accomplished through the use of compounds which react chemically with the metal workpieces to speed the edge and surface finishing process. Reciprocal finishing, spin or spindle finishing, resonant energy finishing are not strictly mass finishing techniques, since components must be fixtured for processing. However, because they use media and compounds common to the other processes and because fixturing is used on occasion with other processes, they are included.
Mass finishing systems are used for processing castings, forgings, stamped and machined parts made from metal or from plastics, ceramics, wood, molded rubber, fiberglass, or any other material that can be stamped, forged, cast, extruded or machined. The variety of parts that can be finished has few limits. Uniform finishes can be produced on parts in large quantities economically. Bright reflective surfaces can be achieved. Operations that can be performed by mass finishing include fine finishing with low microinch values, removing burrs and rough location points, preparing parts for welding and spot welding, forming radii, cleaning, descaling, deflashing, deburring, corner rounding or chamfering, closing pores in castings, removing flux, relieving highlights in antique finishing, blending machine marks, improving threads, preparing part surfaces for painting and plating, changing stresses in metal parts, blending castings for uniform appearance, improving surfaces for oil retention, removing rust and/or inhibiting corrosion, polishing after plating, drying, providing low-reflection surfaces, prolonging the life of dies, and preparing parts for automatic threading, assembly and extrusion. Stock removal or dimensional change during mass finishing is predictable, and can be controlled within predetermined limits. Even threaded parts made of steel, aluminum or brass can be processed, and at the same time held within dimensional tolerance.

**Relationship of Mass Finishing to Manufacturing**

Mass finishing operations may be interwoven with other steps in the manufacturing process, including material removal, heat treating, descaling, grinding and/or other deburring, surface conditioning, finishing processes. To achieve a smooth flow of parts from one department to another, the mass finishing department may be located as near the previous machining, stamping, heat treating operations, as possible so that little time is lost in parts transfer. After stamping, forging, machining, grinding and other operations, many parts can be mass finished to achieve desired surface improvement and/or prepared for electroplating, painting, other finishing processes, assembly or shipping. A part to be blanked and then formed may be mass finished after blanking to remove burrs prior to forming. If a part is to be heat treated, it is sometimes desirable to accomplish deburring and surface finishing prior to heat treatment. In other cases burrs may be more readily removed after heat treating, and surface finishing may be accomplished along with descaling. Scale removal prior to grinding may increase grinding wheel life 50 percent, and diamond life 25 percent, while increasing production 25-30 percent because wheels need not be dressed so frequently. Mass finishing is not, and can not be expected to be, a means of correcting mistakes made in the fabrication of parts or components. Therefore, adequate quality control of parts routed from fabrication to finishing is essential. Components to be processed to a predetermined level of surface finish quality must be delivered to the finishing machine at a uniform, consistent quality level. Parts must exhibit the specified physical properties, dimensions, also have clean surfaces. If fabrication quality is permitted to vary, the finishing machines will not be able to achieve the surface quality level desired in the specified time, if at all. Poor quality parts require more finishing time, whether the part is a die casting loaded with defects, or a stamping formed on a dull die. The finishing cycle can serve as a check on quality of fabricated parts. If the time required for mass finishing to specifications increases, parts may not be leaving the fabrication process at the correct quality level. By keeping fabricating tools clean and sharp, better parts with smaller burrs, smoother surfaces, less surface soil are produced. Shorter finishing cycles, lower costs, increased machine through-put result.

**PRINCIPLES OF OPERATION**

**Rotary Barrel Finishing**

Rotation of a barrel loaded with parts and media carries the mass continually upward to the turnover point. At this point the force of gravity overcomes the tendency of the mass to
workpieces contact each other, and the upper layers slide, rather than fall, toward the lower area of the barrel. Work is done on parts by this differential sliding action. The area in which the mass slides is called the effective slide area. Although some abrading action occurs as the workload turns over, about 90 percent of the deburring and surface improvement is accomplished during the slide. Maximum abrading action is obtained when the slide is longest. This occurs when the barrel is loaded to 50 to 60 percent of capacity. Higher load levels (to 80 percent) are desirable for some workpieces, such as large or heavy components. Increasing the load level decreases the length of slide, thus reducing probability of workpieces contacting each other, and reducing contact force.

Barrel rotation speeds may range from 50 to 250 sfpm (0.25 to 1.25 smps) depending on type and shape of part being processed and type and/or quality of finish desired. For gentle finishing of delicate parts, a speed of 50 sfpm (0.25 smps) is satisfactory. For maximum abrasive action a speed of 250 sfpm (1.25 smps) can be used. Speeds of 100 to 200 sfpm (0.5 to 1 smps) for cutdown, and 50 to 100 sfpm (0.25 to 0.5 smps) for burnishing are recommended. Slower speeds are suggested for heavy or delicate parts. Excessive rotational speed increases the height of the turnover point until media and parts fall or “cascade” with little or no sliding action. This reduces the efficiency of the process, can cause part damage by part-on-part impingement.

The load ratio of media to parts in rotary barrels varies with the type of part in process. Generally, three parts media to one of parts (by volume) can be used. For most delicate
parts a load ratio of 7 to 1 may be used. For delicate aluminum parts a ratio of 12 to 1 is suggested. Water is added to about 1 inch below the load level for cutting, and to just cover the load of media and parts for burnishing. An appropriate compound is always added.

Most parts can be processed in the mass of media in rotary barrels. However, in some cases fixtures are used to prevent part-on-part impingement, bending or interlocking of complicated or delicate parts. Fixtures also protect heavy parts from impact damage. Some fixtures may be mounted on the doors of the barrel. Fixtures may be used to mask and protect certain part areas. Also, fixtures tend to cause one area of a part to receive more abrading action than another; hence, it may be necessary to reverse barrel rotation for half the cycle to improve finish uniformity.

Submerged barrel finishing (tubbing) is done in a perforated barrel loaded with workpieces and media, rotated in a tank containing a water solution of compound. The process is used for certain types of jewelry finishing and for chemical cleaning of parts. The system permits fines, metal slivers and contaminants to pass through the barrel perforations and settle out in the tank. Sometimes the method is automated so that the barrel is moved from station to station (different tanks and/or solutions), submerged and rotated at each station of the installation.

Variations in rotary barrel equipment include the open-end tilting type, bottlenecked tilting-type, horizontal-octagonal (conventional), horizontal-polygonal, -multiple-drum, -compartmented (common), -end-loading, -submerged. The open-end tilting barrel and the bottlenecked tilting barrel are used for finishing and drying parts, for ball burnishing and self tumbling. Parts run in this barrel can be inspected during the cycle, water and compound can be added. Barrel can be tilted to discharge the load. The horizontal barrel (in all its design variations) can process batch after batch of parts uniformly if the media, water, cycle time, and compounds are controlled within specified limits. The rotary barrel is an outstanding tool for generation of radii on stampings, but is less effective in finishing part cavities or recesses. Flat parts requiring a heavy radius on all edges can be processed more efficiently in rotary barrels; barrels have the ability to do a considerable amount of work on part edges because of the differential slide which occurs during rotation.
Vibratory Finishing

A vibratory finishing machine is an open-topped tub, round or oval bowl mounted on springs, usually lined with polyurethane, containing the workload of media and parts. Energy in the form of vibratory forces is transferred from the machine’s drive system to the mass of media and then to surfaces of the parts throughout the entire load. Vibratory motion is induced by an eccentric weight system mounted on a drive mechanism. Adjusting the degree of eccentricity (amplitude) and/or the drive speed (frequency) causes the unit to shake in a controlled manner and create a rolling motion in the media/parts mass.

Vibratory finishing differs from rotary barrel finishing in that the entire mass in a vibrator is in motion at the same time. In a rotary barrel only the upper 15 to 25 percent—the slide zone—is in action at any one time. Parts are constantly subjected to a compressive scrubbing action which not only cleans, deburrs, rounds sharp corners, and smooths surface imperfections, but also changes residual stresses in the parts—usually from tensile to slightly compressive. The vibratory machine can handle larger parts, remove moderate burrs more rapidly, is more readily automated, is easier to operate, cleaner, and achieves more abrasive action in recessed areas of components. Process cycles are much shorter than those in a rotary barrel.
The greater the speed and/or amplitude of the vibratory process, the faster metal is removed from parts, and the rougher the surface finish produced for a given type of media and compound. Increasing these variables also increases the media wear rate. All factors, including part size, shape, material, specified finishing operation, and media must be considered before selecting the frequency (speed) and amplitude to make this process most efficient. The manufacturing engineering department (following or modifying equipment manufacturers' recommendations) may specify the operating conditions on a Process Sheet to be used by the machine operator. Frequency may range from 900 to 3,000 cycles/min. Amplitude can range from 1/16 to 3/8 in. (2 to 10 mm). Most equipment operates from 1,100 to 2,100 cycles/min. and 1/8 to 3/4 in. (3 to 6 mm) amplitude. Smaller machines at lower amplitudes can use the higher frequencies.

The tub vibrator is an open container with a cross section which is usually U-shaped, and with flat parallel ends. Parts and media are loaded into the open top, discharged through doors or by other means. Automatic features of modern tub-type machines can include automatic tilting devices to speed media and parts unloading, doors for discharging the mass onto a screen deck, media return conveyors and hoppers for semi-automatic production, dividers to separate large parts, and drain and flow-through solution systems. Fully automatic, unattended systems have automatic parts loading and unloading, automatic replenishment of media, compound and water or compound solution. While vibrating mesh separating screens are standard, tie rod screens, inverse separation, magnetic separation, tie rod screens with steps to turn over parts, tie rod and screen combinations, auxiliary screens with independent amplitude control, other devices are available to solve separation problems. Media classification systems are often included.

Tub vibrators are made in capacities from less than 1 to over 200 cu. ft. (about 1 to over 6,000 l). Equipment has been built to process parts as long as 40 ft. (12 m), and for finishing parts with a cross section of as much as 6 ft. by 6 ft. (2 m by 2 m). Long tub vibrators can achieve continuous processing with parts fed in at one end, discharged at the opposite end (which may be lower than the loading point). Parts are then separated from media, media are returned by a simple belt conveyor or through a storage unit. Such systems are suitable for process cycles of up to 30 min. A series of tub vibrators (modules) may be joined together with polyurethane couplings for processing components as long as 100 ft. (30.5 m)—structural members, aircraft wing spars and struts, engine blocks, long castings and forgings. Each module may have its own drive motor and side door for media unloading.
The round bowl vibrator has an open-top circular chamber, with half-circle cross section, mounted horizontally. Chambers may also be built in an oval shape. Some chambers are constructed with a rise or elevation to facilitate part separation. The machines are driven by a vibratory motor mounted directly under the center of the bowl with a vertical shaft. Vibratory action is imparted to the spring-mounted bowl by eccentric weights mounted on the vertical shaft. When eccentric weights at either end of the shaft are properly set, a spiral motion is imparted to the mass of media and parts. The rotating eccentric weights also induce a tridimensional vibration in the abrasive media to produce an efficient scrubbing action on the parts. Changing the relationship of the weights alters the spiral path, the speed at which the mass moves around the bowl, and the amplitude of vibration. Round vibrators usually operate at speeds from 1,100 to 1,800 cycles/min. (rpm). Cycle times can be controlled at prescribed values.

Round bowl vibrators are available in sizes from less than 1 (bench models) to about 100 cu. ft. (about 2 to 2,800 l). Short, medium and long “radius ratios” are available. (Radius ratio is determined by dividing the radius of the bowl by the radius of the processing chamber or channel). Conventional round vibrators have radius ratios of 3 to 4. A “long radius” vibrator has a radius ratio of 8 to 9.5. Long radius machines are suggested for use with steel media. The high bulk density of the steel media requires a vibrator of rugged design. Polyurethane linings have superior wear characteristics, and made feasible certain vibratory and other higher energy processes.

Most round vibrators have simple integral separating systems. Either external or internal separation is available with screens or more complex inverse decks with automatic media classification. Separating screens can be mounted directly on the chamber. At the end of a cycle, parts and media are deflected with a gate up onto a screen. The media drop back into the bowl, and the parts are carried out across the screen deck. Features can include magnetic separation, secondary screen decks for separating parts with critical finish requirements, automatic weight shifters for control of continuous processing time, and flow-through solution systems. Accurate and fully automatic compound solution metering systems are standard.

The round bowl vibrator is capable of more gentle action than tub equipment because parts hold their relationship with one another better as they proceed around the bowl, with less...
chance of part-on-part impingement. Action in bowls may be slower than in tub units. Indexing “floating” compartments for round vibrators make possible individual processing of large dense parts, large parts made of softer metals, and parts with critical preplate or prepaint surfaces. Compartments can be programmed to halt for preselected time dwell intervals. Loading, processing and unloading can be automated. In some cases it may be necessary to mount parts on fixtures, then place the fixture in the vibratory chamber. Parts so mounted are more easily separated from the media mass, and are protected from contact. Round vibrators are compact in size and operate at lower noise levels than tub vibrators. Noise controls can be installed to further reduce noise levels.

The volumetric loads that can be handled in a given vibratory machine vary with the model, size and the manufacturer. Procedures have been developed to make possible the calculation of finishing equipment working capacity for predetermined conditions, and the number of parts of given size and type which can be processed per cycle.* Parts are normally

processed with media. The media-to-parts ratio controls the amount of part-on-part contact that can be expected during the finishing cycle (Table I). Round vibrators can normally operate at lower media-to-part ratios because there is no “end effect” as in tub equipment. Tub vibrators, during long cycles, tend to cause parts concentrations to be heavier at each end of the machine than in the middle.

**TABLE I**

**MEDIA-TO-PART RATIOS FOR BARREL AND VIBRATORY FINISHING**

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<tr>
<th>Media-to-Part Ratio by Volume</th>
<th>Normal Commercial Application</th>
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<tr>
<td>0:1</td>
<td>No media. Part on part. Used for beating off burrs. No cutting. For burnishing in some cases.</td>
</tr>
<tr>
<td>1:1</td>
<td>Equal volumes of media and parts. Forgings, sand castings. Results in very rough surfaces.</td>
</tr>
<tr>
<td>3:1</td>
<td>About minimum for nonferrous metals. Considerable part-on-part contact. Fair to good for ferrous metals.</td>
</tr>
<tr>
<td>4:1</td>
<td>Probably &quot;average&quot; conditions for nonferrous parts. Fair to good surfaces. Good for ferrous metals.</td>
</tr>
<tr>
<td>5:1</td>
<td>Good for nonferrous metals. Minimal part-on-part contact.</td>
</tr>
<tr>
<td>6:1</td>
<td>Very good for nonferrous parts. Usually specified for preplate work on zinc with plastic media.</td>
</tr>
<tr>
<td>8:1</td>
<td>For higher quality preplate finishes.</td>
</tr>
<tr>
<td>10:1 to 15:1 or more</td>
<td>For better finishes. Used for irregularly shaped parts or parts subject to tangling or bending. To achieve no part-on-part contact, load one part per machine or compartment. Fixtures used in some cases.</td>
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Correct selection and use of compound-water solutions is essential for good, consistent mass finishing results. Compounds may be liquid or powder and may be added to finishing equipment on a batch basis, or by means of a recirculation or flow-through system. Maximum operating efficiency of vibratory machines depends in part on proper use of media, compounds, and water. Efficiency is reduced when the machine is flooded with too much water (compound solutions), or when media becomes coated with a viscous slurry of

![Fig. 11 — Drains and fines screens available for use in one line of vibratory finishing machines. (Photo courtesy Roto-Finish, Kalamazoo, Michigan).](image-url)
abrasive, or if excessive foam develops. Media must be kept clean to move freely to perform desired functions. Machines must be equipped with proper drains to remove soiled solution, metallic fines, flash, undersized media particles (to prevent lodging), etc. Drain hoses connected to sumps confine the soiled effluent for subsequent disposal as required. Proper control of the amount of compound solution in the machine is equally important.

To add the compound solution (chemical compound dissolved in water) in a controlled manner, most vibratory finishing systems employ a “recirculation” system or “flow-through” system. Compound solution may also be added manually in a batch premix procedure. Recirculation involves the pumping of the compound solution from a storage tank into the vibrator to flush away soils, fines, etc., after which the solution drains back into the tank. Some solids settle in the tank and are not recirculated. In the flow-through system, a relatively dilute “fresh” compound solution is metered into the vibrator at a flow rate of 1 to 2.25 gal./cu. ft. of mass per hr. (0.13 to 0.3 l/l/hr.). The solution flows through
Fig. 15—Sketch showing action in centrifugal barrel machine, with turret rotating at 250 rpm and each drum rotating at 60 rpm in the opposite direction. Combined action creates pressure between media and parts many times the force of gravity. (Photo courtesy Harper Surface Finishing Systems, Meriden, Connecticut).

The mass and is discharged to the holding sump. Solution is always at the optimum, predetermined concentration and the media and parts are kept clean during the cycle. Fines and sludge are washed out continuously. The flow-through system can produce the cleanest parts most uniformly, and is the preferred technique for vibrators. Proper control of the flow rate of compound solution in vibrators has a major effect on media wear and metal removal rates. The process becomes more efficient at the higher flow rates, achieving increased metal removal. Controlled solution addition is made automatically using a compound metering pump and rotameter. System is efficient and economical.

### Centrifugal Barrel Finishing

The centrifugal barrel process is one of the high-energy finishing processes, in which the energy created within the mass in a container is greater than that obtained with standard vibratory or other methods. High-energy processes include also the centrifugal disc, spindle finishing, and vibratory tub and bowl machines with higher frequencies and amplitudes.

Centrifugal barrel finishing is carried out in equipment comprised of a number of drums mounted on the periphery of a turret (drums may be of circular, hexagonal, or heptagonal
cross section). Equipment size ranges from less than \( \frac{1}{4} \) cu. ft. (7 l) to 100 cu. ft. (2,832 l) capacity. Machines are available with the turret and drums rotating in a horizontal plane or in a vertical plane. The turret rotates at high rpm in one direction while the drums rotate at a slower speed in the opposite direction. The drums are loaded in a manner similar to that for rotary barrel with parts, media, water and compound. Turret rotation creates a high centrifugal force, up to 50 or more times the force of gravity. This compacts the load within the drums into a tight mass. Rotation of the drums causes the media to slide against the workload, maintaining a smooth rubbing action with no workpiece impingement, to remove burrs, form radii, refine surfaces, and impart high compressive stress to part surface layers (for improved resistance to fatigue failure). Machines are quiet in operation and require no noise-abatement measures.

The abrading action, under high centrifugal force, results in short process cycles. Most cycles rarely exceed 15 min. for deburring and finishing. Because of the counter rotation of drums to turrets, a completely smooth sliding action of media against components is generated, with little possibility of one part falling or impinging against another. This smooth action achieves consistent and reproducible results. Very close tolerances are maintained even with fragile parts, and very smooth surface finishes are achieved. Tolerances of 0.0001 in. (0.0025 mm) are common.

Relative action on edges and surfaces of parts can be controlled by choice of media size and centrifugal force. Generally, smaller media can be used with a 1:1 media-to-parts volume ratio, resulting in greater uniformity of radii and edges, and greater action in holes and recesses. Media particle size is specified to meet requirements of uniformity and to ease separation without increasing time of the process cycle. Harder types of media are preferred. Using hard, low abrasion media, deburring can be accomplished during a run at high speed. Then, surfaces can be refined simply by changing to a slower speed for the balance of the cycle. Normally, drums are loaded to 60 to 70 percent of capacity, with the water solution of compound just above the load level. Centrifugal barrel finishing can be run as a dry process also. Fixtures can be used to insure specified finishes on critical surfaces.

Economic considerations frequently dictate the choice between centrifugal barrel equipment and other mass finishing processes. If satisfactory results are achieved with a process cycle of less than 1-2 hours, a vibratory process is more economical. If the process cycle is much longer, if there is a wide variety of components to be handled, or if there are special finishing requirements or parts of very high precision, centrifugal barrel machines are usually better.

Centrifugal Disc Finishing

The centrifugal disc machine is an open top cylinder or bowl with stationary side walls. Bottom of the cylinder is formed by a disc which is driven to rotate at high speed (100 rpm). Media, compound and parts are contained in the cylinder. As the disc rotates with peripheral speeds up to 2,000 ft./min. (10.2 m/s), the mass of media and parts is accelerated outward and upward against the stationary side walls of the container. Media and parts rise to the top, then “turnover” and flow in toward the center and back down to the rotating disc at the bottom.

Parts can be finished faster in centrifugal disc machines than in vibratory equipment, because of the centrifugal forces of as much as ten times gravity pressing abrasive media against parts in the workload. Less floor space is required for finishing; there is less work in progress. Parts can be readily inspected during the process cycle. Variable speed can occasionally combine deburring with a final, more gentle surface refinement operation. The
faster process speeds increase rate of media wear, increase demands on the compound solution and its flow rate. Disc machines cannot handle very large parts, nor can very small parts or media be handled because there must be a gap, generally less than 0.010 in. (0.25 mm) between the disc and the cylinder walls.

Centrifugal disc equipment is available with capacities ranging from about 1 to 20 cu. ft. (28 to 566 l.). Equipment has full automation and programming capabilities, including operation by CAD/CAM, CNC or microprocessor. Abrasion resistant materials are recommended for the cylinders and discs to provide a reasonable life. The load may be emptied through a door in the side of the container through which parts and media can be fed, or by tilting the entire bowl through 180 deg. to dump the load. Parts and media separation, classification, washing systems, and the return of media to the container for the next operation are similar to the techniques used with tub vibratory machines.

**Spindle Finishing**

Spindle finishing is carried out by mounting parts on spindles and immersing them in a mass of relatively fine media contained in an open-top tub or bowl. Through movement—usually rotation—of the tub, spindle, or both, media flows against and over part edges and surfaces to accomplish deburring and surface refinement. The process features fast, precise deburring or finishing with good control, reliability, and uniformity. Parts are handled individually; there is no part-on-part impingement during processing or unloading. The tub which holds the media can be kept in a stationary position, rotated about its center axis, or vibrated. Tub vibration may be used to keep media loose when large workpieces are being rotated or oscillated. Tub diameters may range from 36 to 60 in. (0.9 to 1.52 m). Tub rotational speeds for heavy deburring and short cycles can range up to 1,800 sfpm (9.14 smps). Speeds of 200 to 900 sfpm (1 to 4.6 smps) are used for surfaces requiring less radical correction or refinement.

The spindle— shaft to which the fixture and part are attached—can be held stationary, rotated (in reverse of tub rotational direction), or oscillated about its own axis. Spindle rotational speeds of 10 to 100 rpm keep all workpiece surfaces exposed to the media for

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**Fig. 18**—Sketch shows action in centrifugal disc machine. Clearance between spinner and seal ring is typically 0.005 in (0.127 mm). (*Photo courtesy Harper Surface Finishing Systems, Meriden, Connecticut*).

**Fig. 19** (right)—Centrifugal disc finishing machine with flow-through compound solution system. Entire processing chamber tilts down to unload. (*Photo courtesy Roto-Finish, Kalamazoo, Michigan*).
uniform, gentler finishing. Spindle speeds up to 3,000 rpm can be used to shorten process
cycles when the tub is also rotating. For maximum action—where velocity of media is
greatest—spindles should place parts as close as possible to both the outer periphery and
the bottom of the rotating tub. The head holds the spindle above the tub. From one to 16
spindles can be held by one head, and more than one head can be installed on the machine.
The head can be stationary, rotated about a center axis, or oscillated up and down. Head
rotation keeps parts in fresh media in a stationary tub. A head with a number of spindles
may index the spindles into and out of the tub for unloading/loading while the tub rotates
continuously. Robot loading and unloading of spindles is available.

Fixtures which hold parts to spindles may operate in a vertical position or tilt up to 90 deg.
from the vertical. The fixture must position the workpiece so that specified surfaces are
processed. Fixtures must be designed for easy and quick replacement on spindles.
Operating parameters of the tub, head, spindle and fixture are listed in Table II. Combinations
of these variables can be selected to obtain the type of motion best suited to
perform specified operations at minimum cost.

<table>
<thead>
<tr>
<th>Tub</th>
<th>Head</th>
<th>Spindle</th>
<th>Fixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary</td>
<td>Stationary</td>
<td>Stationary</td>
<td>Vertical</td>
</tr>
<tr>
<td>Rotating</td>
<td>Rotating</td>
<td>Rotating</td>
<td>Tilting</td>
</tr>
<tr>
<td>Vibrating</td>
<td>Oscillating</td>
<td>Oscillating</td>
<td></td>
</tr>
</tbody>
</table>

Although many types and sizes of media may be used, small aluminum oxide nuggets are
selected for many operations. A water solution of compound is metered into (or through)
the tub. Fine finishing of some components can be done in a dry operation using media
mixtures of fine abrasives and ground corncobs or crushed walnut shells. Selection of
media type and particle size is determined by the part and the surface finish requirements.

Spindle machine process cycles may run from just a few seconds up to several minutes. To
increase metal cutting or shorten cycles: (1) increase tub, spindle, or head speeds, or a
combination of all three; (2) locate part closer to machine wall; (3) select more abrasive
Selection of equipment to carry out a specific finishing process involves technical, production, and economic considerations. The parts to be processed, finish or finishes desired, equipment characteristics, and other variables must be considered. A careful examination of each part, its finish specifications, and a flow chart of its previous operations (if available) will help to determine how the part can be processed most efficiently and at minimum cost. Generally, if mass finishing procedures are installed to supplant existing hand or mechanical finishing methods, manufacturing cost savings will result. Likewise, when mass finishing processes are installed along with fabricating equipment in a new facility, the operation will usually be found to be economical.

Working capacity of a finishing machine is the actual volume of media and parts which the machine can accommodate for the specified process and cycle. Machines are rated as to capacity, and this Guide will identify machines according to rated capacity. It is prudent for the finisher to compare a machine’s rated capacity with its working capacity.

Energy levels required for operation of finishing equipment increase in the order: rotary barrel; round vibrator; tub vibrator; centrifugal disc; centrifugal barrel; spindle machine. Degree of processing activity or action obtained from each type of machine increases, generally, in the same order.
The following are among the factors to be considered in order that mass finishing equipment be found applicable, and that the correct finishing system for the manufacturing plant in question be selected:

1. Production requirements: parts per hour or per 24-hour day. (Determination of degree of automation that is justified).
2. Finish quality requirements; operations to be performed by mass finishing.
3. Number of different parts to be processed; part size range; possible need for fixtures.
4. Metal or metals involved.
5. Determination of parts per load and cycle time(s).
6. Equipment cost, including installation.
7. Equipment life; maintenance cost.
8. Operating cost of the system, including labor and material handling cost.
9. Floor space required.

To estimate the finishing cost per part for a complete cycle, it is necessary to estimate the equipment depreciation, maintenance cost and operating cost. Operating cost includes cost of energy consumed, compound used, media consumed, cost of labor including handling, cost of fixturing, if required. Total cost, divided by the number of parts processed in one batch or unit of time considered, determines the estimated cost per part. This figure may be used for comparison with existing finishing methods, or with estimated finishing cost determined for another process also being evaluated. Manufacturers of mass finishing equipment of all types stand ready to consult and advise potential users, and also process sample parts through various procedures as an aid to establishing or confirming finish quality standards, and estimating equipment, installation, and operating costs. After a mass finishing process has been justified and is introduced, a continuing review of processes and procedures with supplier representatives can sometimes lead to further cost savings as refinements in processes, new techniques and new developments become available for commercial practice.

A mass finishing computer calculations program* is available to aid the finisher in determining such factors as working capacity of mass finishing equipment, estimated time cycles, calculations regarding the relationship between part size and shape and production requirements, estimate of supplies required, plus many miscellaneous calculations. A useful calculation is that of determining the number of workpieces in question that can be safely run in the particular machine, taking into consideration the shape and dimensions of the parts.

**Equipment Considerations**

Table III outlines some of the factors to be considered in selecting one or more of the principal types of mass finishing equipment.

Generally, mass finishing machines are lined to eliminate wear of the equipment and reduce noise of operation. Equipment units are lined, as appropriate, with a polyurethane elastomer. This type of lining provides temperature resistance up to about 160 deg. F. (56 deg. C) and a long service life. Polyurethane linings are resistant to the action of almost any compound now in use, but are subject to attack by some solvents such as trichloroethylene. Metal barrels are normally lined with polyurethane, but may be lined with hardwood (maple) for use in dry operations.

*Society of Manufacturing Engineers, Marketing Services, One SME Drive, P. O. Box 930, Dearborn, Michigan 48121, or John B. Kittredge, Consultant, 3801 Winding Way, Kalamazoo, Michigan 49007-1036.
TABLE III
CHARACTERISTICS OF MASS FINISHING EQUIPMENT/PROCESSES
(Equipment/Process listed in order of decreasing time cycles)

<table>
<thead>
<tr>
<th>Equipment/Process</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibratory Bowl</td>
<td>Open for in-process inspection. Can use full batch and continuous operation. Requires no auxiliary equipment to automate. Internal separation possible. Low cost for general purpose work. Simple selection and operation; little operator skill required. External, interior areas finished.</td>
<td>Process cycle can be longer than that of vibratory tub. Some part size limitation.</td>
</tr>
<tr>
<td>Vibratory Tub</td>
<td>Short process cycle. External material handling and separation required. No part size limitation. Open for in-process inspection. Can employ batch or in-line automation. Finishes external and internal areas with similar action.</td>
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</tbody>
</table>

MEDIA—TYPES AND APPLICATIONS

Finishing media may be defined as the material used to perform work on the surface of parts being processed. Media include abrasive and nonabrasive types, both in natural and synthetic forms. Media has evolved from crushed and graded rock to synthetic rock,
preformed ceramic-bonded abrasives, preformed resin-bonded abrasives, steel and other materials. Dimensionally uniform with predictable wear, engineering quality media “cutting tools” are available in a great variety of useful shapes, sizes and surface finish or cutting capabilities.

The primary functions of media are as follows:

1. **Cleaning.** Both abrasive and nonabrasive media have the ability to scrub surfaces and physically assist the compounds in their cleaning function. The scrubbing action provided by media acts synergistically with compounds to make possible removal of organic soils as well as scale and other inorganic residue.

2. **Deburring, surface improvement.** Abrasive media can remove burrs and smooth surfaces. Cutting grades of media, therefore, may be considered abrasive devices or abrasive grain carriers, releasing the required amount and size of abrasive per unit time. Large media pieces increase the impact force of the abrasive on the metal part, thereby increasing the speed of the abrasive action.

3. **Developing surface luster.** Nonabrasive media, or media with a low degree of abrasiveness, are designed to develop luster on surfaces of metal or other parts. Such media deburr by peening, decreasing sharpness without removing the burr itself. Use of the proper media can control degree of surface luster, from bright to dull with a completely random scratch pattern, or any intermediate condition.

4. **Parts separation.** An important function of media is to separate and cushion parts during deburring, surface improvement, cutting, burnishing. Table I offers suggestions for appropriate media-to-parts volume ratios under various production conditions.

5. **Drying.** Parts from wet mass finishing processes may be dried in ground corn cob or other media, sometimes in heated rotary barrels or vibratory machines.

**Natural Media**

Natural abrasive media include random shape granite, limestone, Turkish emery, American emery, river rock, novaculite, flint, corundum (a natural aluminum oxide). Media may be classified in several size ranges from 3/32 to 3/16 in. (2.4 to 4.8 mm) to 1/8 to 2 in. (38 to 51 mm). Natural media are softer and wear down more rapidly; their crystalline structure limits their cutting rate. Many natural abrasives tend to fracture and create lodging problems. Novaculite and flint media are soft-type cutting media; have a short but useful life. As novaculite wears down, it maintains a sharp and flaky particle shape which can be valuable for removing burrs from fine holes and grooves. Limestone is one of the softest abrasives. Granite, with a different crystalline structure than limestone, is more friable and cuts a little faster. Granite and limestone may still have some application in rotary barrels. Corundum finds application where slightly improved surfaces are desired and less abrasion is acceptable.

Agricultural materials such as saw dust, ground corn cob fines, and crushed walnut shells are used for some mass finishing drying operations, and/or to impart luster to plated surfaces. When mixed with fine abrasives, these media are capable of smoothing surfaces, polishing intricately detailed components, and imparting high luster to parts for the jewelry industry. Mixtures of walnut shells, corn cobs with fine abrasives are used to finish molds, dies, bearing races and rollers in centrifugal barrel machines. Surfaces are smoothed to below 1 microinch (0.025 micrometer) AA, while exact tolerances are maintained without generating significant radii on sharp edges.

Preformed hardwood media can be used in a “dry process” in a hardwood-lined barrel, vibrator or centrifugal machine to transform as-molded parts formed of any number of plastic, metallic, or other materials into a high quality product with radius ed edges and...
surfaces simulating a color buffed finish. Depending on the roughness of the original plastic
surface and the final finish desired, various mass finishing steps may be specified.
Generally, four steps are required, including a cut-down, refine, polish, and final waxing.
Appropriate abrasives or other materials are added along with the preformed hardwood
media to accomplish the desired result in each process step. Wooden media may also be
used to apply organic coatings or oil to parts in rotary barrels. Once the wood media is
coated, the minimum additional organic material needed to coat the parts in the load can be
added. Thus, at the end of the cycle—even with a polyurethane coating—parts are “set” and
“dry” to facilitate handling.

Synthetic Abrasive Media
Fused and sintered aluminum oxide media (nuggets) are manufactured in a grade for
cutting and a grade for brightening. The media have greater abrading capabilities than
natural stone. Uniform quality in specified size ranges can be obtained. The dense,
nonporous, rounded, random-shaped pieces have a crystal texture at the surface that
combines cutting ability with burnishing quality. Media take on a sheen after initial use, or
“break-in,” and then undergo little change except for a low, uniform wear. Hard forms of
media can produce smooth finishes, below 2 micron. (0.05 microm) AA, and high color.
The bulk density of a fused aluminum oxide chip (125 to 135 lb./cu. ft.-2.0 to 2.2 kg/l) is
enough to impart a forceful rubbing or deburring action, but not enough to cause the
metallic parts to float on top of the mass. True deburring, surface finishing, and radiusing
can be done; time cycles are shorter. Fused silicon carbide media, in sizes about 1/4 in. (6.35
mm) in diameter or below, are useful for finishing parts which are to be brazed or welded.
Aluminum oxide media are not recommended because they may leave residual particles in
the surface to impair weld quality.

Preformed Ceramic Media
Media are manufactured from clays and other ceramic materials, mixed with various
quantities of an abrasive (generally aluminum oxide), formed into shapes, then fired
(vitrified). Media properties are determined by the proportion of abrasive to bonding
material, type of bonding material, type of abrasive, abrasive grain size, and degree of
firing. The abrasive grains are held together by “glass bridges” which tend to give chip
clearance and a reasonable media life. Abrasive content and abrasive particle size variations
provide cutting ability from extra fast cut to slow-to-cut (pure porcelain with no abrasive
content). Abrasive content can vary from none to 50 percent. Abrasive grain size can vary
from 60 to 600 grit. Media with higher abrasive content, or media that have been fired “soft”
have higher cutting rates and higher wear rates. Conversely, media with lower abrasive
content, or media that have been fired “hard” show lower cutting rates and lower wear
rates. Media can be selected with the degree of abrasion and surface finishing capability to
suit virtually every application. Quality is uniformly consistent and dimensional changes
during use are uniform and predictable.
Media are formed into a wide range of sizes of triangles, cylinders, stars, arrowheads, balls, cones, diamonds, tetrahedra, and others, plus straight-cut shapes, angle cuts at several different angles. The variety of shapes and sizes makes it possible to select media to provide access to critical surfaces and edges, provide long media life without creating lodging problems, and permit easy separation of parts from media. Cylinders, cones, and spheres are generally selected to deburr and finish parts with a variety of holes. Triangular shapes are selected for deburring slots. Angle cut triangles and cylinders in sizes from $\frac{3}{16}$ to $1\frac{3}{8}$ in. (5 to 50 mm) are popular. Average bulk density of ceramic media is 90 to 110 lb./cu. ft. (1.5 to 1.8 kg/l).

Ceramic media shapes with no abrasive are used for fine finishing and burnishing. Media with about 50 percent of 60 grit aluminum oxide are used to perform rapid deburring, edge radius generation and stock removal. Media containing from 20 to 25 percent aluminum oxide of 100 grit or finer grain size are used in vibratory systems for burr removal and surface improvement because of longer life. Ceramic media find application in deburring steel and cast iron for a final finish or prior to painting. Because of their high cutting speed, vitreous bonded media normally produce a matte finish. However, through use of proper compounds and techniques, a low micro-inch finish can be achieved.

**Preformed Plastic Media**

**Low Density (Conventional) Plastic Media** (resin bonded) contain fine silica flour and/or aluminum oxide, polyester resin, and a catalyst. Media are molded into specified shapes—then pretumbled to remove flash. Media shapes such as triangles and cylinders, formed at angles to create sharper points, are useful for finishing recesses and holes. Sizes to suit all applications are produced. In addition to silica, crushed quartz, fused aluminum oxide, or silicon carbide may be used as abrasives in plastic media. Media may contain from 50 to 70 percent by weight of abrasive which may be of 120 grit size or finer. Media bulk density is 50 to 65 lb. cu. ft. (0.8 to 1.04 kg/l). Because of low density, cushioning effect, resilience, mild abrasive action, plastic media are used for deburring soft alloys such as zinc base die castings, aluminum, copper, and brass. Plastic media also find use for precision finishing of delicate and complicated parts, and for preplate finishing to low microinch values with minimum impingement damage. Smooth, generally not lustrous finishes can be achieved. Preplate or final finishing of plastic parts can be carried out with appropriate plastic media. Nylon media—particularly nylon conical shapes—are also used for polishing plastic workpieces. Nylon media also find use in cryogenic finishing or deflashing of molded rubber parts. Any tendency of plastic media to produce excessive sludging or foam, and/or leave undesirable residues on part surfaces can be controlled by selecting the proper compound system.

**Urea Formaldehyde Plastic Media** contain abrasive, a urea formaldehyde resin and an acidic catalyst. Media are molded into various shapes as specified. Media cut faster, wear longer, produce finer finishes, and create no foaming problems. Effluent from the process can be treated for disposal easily. Media leave processed part surfaces clean and free from
Fig. 24—Shapes of preformed ceramic media in more common use. Left to right: Cylindrical, Wedge, 22 deg. Angle Cut Tri-Star, 22 deg. Angle Cut Triangle, 45 deg. Angle Cut Cylinder, 22 deg. Angle Cut Cylinder. All shapes are available in several sizes and dimensions. [Illustration courtesy Vibra Finish Co., San Fernando, California.]

residue. Careful control of compounds is essential to prevent possible corrosion of steel parts in processing. Nonferrous parts, of course, are not subject to this problem.

**High Density Polyester Media** are molded from a blended polyester resin containing a higher density abrasive into cones, truncated cones, triangles, pyramids, tetrahedra, stars, arrowheads, wedges. Size range is from ¼ to 4 in. (6.35 to 101.6 mm). Generally, the larger the media, the faster the finish and the coarser the surface. The smaller the media, the longer the cycle and the finer the finish. Media are formulated for fine cut with bulk density of 95 lb./cu. ft. (1.52 kg/l), standard cut with bulk density of 100 lb./cu. ft. (1.6 kg/l), and fast cut with bulk density of 107 lb./cu. ft. (1.71 kg/l).

The high density plastic media exhibit excellent cutting performance due to weight, sharp crystal facets of the silicate filler and large number of grain particles per cu. ft. There is little fragmentation or chipping. Surfaces are left free from residue. Low rms surface finishes are produced in short cycle times with little impingement. Fine cut media are used for finishing all metals, especially soft metals and plastic components. Standard cut media produce low rms finishes on all metals, including stainless steel forgings, with shorter cycles. Fast cut media make possible minimum cycle times in finishing all metal surfaces. There is little if any, foaming.

**Preformed Metallic Media**

Case hardened steel, through-hardened steel, stainless steel, zinc, cold rolled steel are among materials used in the manufacture of metallic media. Metallic media are characterized by long life and infrequent replacement (unless allowed to rust). Only a steel structure properly carburized and heat treated will make possible the mirror-bright, flaw-free surface on high grade burnishing media. Steel media are of uniform size and shape, do not fracture in use, will not lodge in recesses if correct sizes and shapes are chosen. Bulk density of steel media is greatest of all mass finishing media, about 300 lb./cu. ft. (4.8 kg/l). By reason of the high media density, parts are cushioned and supported in the mass. Pressure exerted by metallic media on metal parts being processed causes the surface of the metal to flow and smooth out scratches, porosity and imperfections. Burrs are removed rapidly, metal edges peened quickly, parts and solutions are kept clean, part surfaces brightened.

Steel media are generally supplied in the following shapes and sizes:
- **Spherical Ball**—bearing quality—1/16 to ¾ in. (1.6 to 15.9 mm) in diameter.
- Ball with Flats at opposite sides—generally same sizes as above.
- **Ballcones**—half ball, half cone, with belt—¼ to 5/16 in. (3.2 to 7.9 mm).
- **Cones**—two cones with belt—¼ in. through ½ in. (3.2 through 12.7 mm).
- **Diagonals**—angle cut cylinder—1/16 to ¾ in. (1.6 to 9.5 mm) in diameter.
- **Ovalballs**—football shape—¼ to 5/16 in. (3.2 to 7.9 mm).
Pins—long, slender, pointed ends—1/8 by 3/32 in. (3.2 by 9.5 mm), 1/16 by 1/16 in. (1.6 by 12.7 mm), 1/16 by 9/32 in. (1.6 by 7.1 mm).

Pebs—rain drop shape—1/32 to 3/16 in. (0.8 to 4.8 mm).

Preformed, uniformly sized and hardened steel or stainless steel media are used for fast deburring (by peening) of metal parts, deflashing or finishing of certain plastics, deflashing and cleaning ceramic forms, removal of both organic and inorganic soils, burnishing or brightening metal surfaces to achieve maximum luster. Metal and alloy parts, both as formed, to be painted or plated, many plastic and ceramic products, jewelry and inlays can be processed with steel media. Surface soils of almost all types including paint, ink, tarnish, oxides and scale can be removed. Steel media are used with nonabrasive cleaning and burnishing compounds which are formulated to protect the media from rusting or pitting in use or in storage.

Softer cold rolled steel and zinc media are used for both deburring and burnishing in rotary barrels. If an abrasive compound is added to the barrel load, the media surface becomes impregnated with the abrasive grain to give media a cutting action. At the end of the deburring cycle, parts and media can be cleaned free from abrasive with a special cleaning compound, usually an inhibited acid. A burnishing compound is now added and the process continued to develop a high luster on the deburred and smoothed parts. Steel pins, tacks and nails offer a means of removing fine or somewhat inaccessible burrs from threads, holes and small recesses particularly when used with loose abrasive compound.

**Media Selection**

**Size and Shape Considerations for Natural and Synthetic Media.** Proper media selection must be based on the size, shape and material of the parts to be processed. Recesses, angles, fillets, slots, holes and intricate contours must all be carefully evaluated. The type of metal and hardness, the size of burrs, and the surface finish requirements all govern the type of media to employ. Heavy, stubborn burrs are best processed in media with aggressive cutting capabilities. Larger media should be used for forming large radii; small sized media should be used to form small radii, or for edge breaking. It is the size and weight of the individual piece of media that governs the amount of radius to be formed, as well as the mass weight of the workload. Parts with rough edges to be smoothed require use of the largest size media possible without causing adverse effects such as distortion, roll-over of burrs or edges, or roll-ins at holes or slots. Soft metals, such as aluminum, brass, zinc, and magnesium, where surfaces or edges are more easily affected, should be processed in small media. If the media are too coarse or large, the action may be too severe and cause peening or nicking of the edges, or surface impingement.

Some basic factors to review in media selection may be outlined as follows:

1. Determine correct size and/or shape which will contact all critical edges and/or surfaces, yet permit satisfactory separation of parts from media.
2. Select media which will remove burrs, achieve required radius and surface finish, produce desired action on edges, corners and surfaces relative to one another.
3. Determine media type, media density, particle size so that an optimum media-to-part ratio can be implemented for the parts being processed.
4. Select media which will make possible minimum process cycle or machine time.
5. Select size, type and shape to avoid lodging in holes and recesses, and type which will not fracture and create lodging problems. Media should be small enough to flow through holes and slots, or large enough to remain outside such areas.
6. Select media with minimum wear rate for lowest operating cost, minimum amount of reclassification during use.
7. Consider availability of media in consistent quality.
8. Media must be able to process the range of products scheduled for a given machine.
9. Media must be of proper density to avoid parts migrations, achieve minimum part-on-part impingement.
10. Media which can carry out an abrasive operation, and, with a change of compound, perform a surface refinement cycle may be desirable.
11. Media should be able to achieve surface refinement both when new and when somewhat worn; should require no break-in to facilitate addition to existing load.

Large media last longer, accelerate the cutting rate but provide less cushion against part-on-part impingement than smaller media. However, variation of radii between workpiece corners and edges will be greater as will variation between edges and surfaces. Small media are more effective for producing a good surface finish, and may expedite the separation of parts from media after processing. Selection of proper shape maximizes media effectiveness. Random shaped media are recommended for parts with rough surfaces or for configurations in which there is no chance of wedging. The effective media packed density is an important variable. Use of media of substantially different density from that of the parts can increase the tendency for parts to migrate together, with danger of part-on-part impingement.

Preformed media of specific shape, either ceramic, plastic or steel, provide more consistent results, help avoid lodging problems. Triangles are used to deburr and burnish parts uniformly. Triangles are most effective for working slotted areas, and for reaching into corners. Triangles will retain their shape throughout media life. Sizes range from 3/16 to 2 in. (4.7 to 50.8 mm) on a side, available in almost any thickness. An angle-cut triangle is a refinement of the basic shape, being cut on an angle from 15 to 60 deg. to produce sharper corners and edges. These additional points provide deeper penetration into remote areas, and allow the media to retain a sharp edge. The notched triangle or arrowhead has the advantages of the regular triangle, plus the additional of the sharper points to reach slots or any edges to be deburred.

Cylindrically shaped media provide the best results when used on parts that have holes or half-spherical areas. Cylinders are available in a great many sizes from disc-like media to elongated pins. Cylinders exhibit good media flow in the finishing machine. Cylinders with ends cut at angles from 22 to 60 degrees can readily reach into recesses to remove burrs or improve surface finish. Cone shaped pyramid or tetrahedral shaped abrasive media perform their function with minimum lodging problems, and are most efficient. Spherically shaped media produce the greatest flow action of any media used in a finishing machine. The media provide good surface contact and are useful for burnishing in round and internal areas and slots. The media will blend and smooth the surface of a part uniformly. Spheres are supplied in a range of sizes from 7/32 to 13/16 in. (5.5 to 20.6 mm) in diameter.
The larger the individual media used, the rougher the cut and more violent the action. Precision or fragile parts are protected through the use of smaller sizes and lengths. Proper evaluation of media can not only prevent lodging in slots, holes, or recesses, but also can provide faster deburring and grinding, shortening cycle time.

**Size and Shape Considerations for Metallic Media.** Metallic media sizes are determined by part to be finished—part material, size, sizes of holes or recesses. Media should be small enough to pass through holes, recesses and prongs freely, or large enough not to lodge. Fragile parts may be bent or damaged if processed in large media. Shapes of metallic media should be selected so that the media will contact every part surface or area. One form normally suffices for finishing a particular part; but, rarely, some parts may require a mixture of 2, 3 or 4 forms and sizes depending on part size or shape. Generally, smaller sizes of all burnishing media shapes provide more surface contacts per pound of media, produce better quality surfaces, but require longer cycles.

Steel balls of smaller size provide more surface contact, but practical considerations will determine size and/or mixture selection. Top quality steel burnishing balls are manufactured to be spheres free from flats. However, in 90 percent of commercial burnishing operations, balls with a small flat spot at each pole are acceptable. Dead soft balls or media (rather than conventional case hardened balls) seem to be more efficient for deburring hardened steel parts such as radial and thrust ball bearings. Ball bearing rejects have surface flaws and are not suitable for use as burnishing media.

Diagonals are most effective for burnishing where lodging is not a problem. They can exhibit lack of dimensional uniformity. Diagonals can best be used when dimensional tolerances are not too critical. Ballcones have the same general burnishing characteristics as balls, but add the feature of a projecting point and a projecting edge. In some cases ballcones may be used rather than a mixture of balls and some other form. Ballcones are versatile and popular in vibratory finishing. Like the cone, ballcones can go into holes and corners without causing damage. Cones are designed to make contact in narrow, curved areas. The edges of the center flange can reach into sharper angles that steel balls could not contact.

Ovalballs are more effective than round balls (especially in vibratory finishing machines) in providing a more vigorous tumbling action in the burnishing mass during processing. Ovalballs and balls are used primarily for bright burnishing of softer metals. Pins in the \( \frac{1}{4} \) by \( \frac{3}{8} \) in. (3.2 by 9.5 mm) size are more popular, having a specific gravity near that of other media forms. Pins are sometimes used alone, but can also comprise some 16 percent of the media (with ballcones for example). Pins have a tendency to float on the media mass in rotary barrel processing. Pins are used only when necessary because of high cost. Peps are burnishing forms resembling rain drops. They are irregularly shaped with many curved surfaces to make contact with the angular surfaces of parts. Peps may be useful in finishing or burnishing certain hardened steel parts, but are not suitable for use on silverware.

Various types of nails, tacks, brads and roofing nails are used as media in barrel finishing systems. Tacks and nails may be used as manufactured, or can be hardened specifically for use in mass finishing. Tacks can be used alone or can be mixed with some of the slower acting ceramic media, such as porcelain triangles, to produce a mixture that picks at burrs in recessed areas and generates radii on exposed edges. Nail and brads can be combined with other media such as aluminum oxide shapes or random nuggets. Hardened tacks, particularly, can pick at recesses much as a dentist’s pick operates. The sharp point of the tack acts like a deburring knife to remove feather burrs with minimum radius generation. In centrifugal barrel operations, the hardened tacks, or nails are always mixed with other
media in accordance with the operations to be performed. Tacks or nails have a tendency to stick in urethane equipment linings, but this effect can be minimized by installing harder linings.

**TABLE IV**

**MEDIA SELECTION GUIDE***

<table>
<thead>
<tr>
<th>Effect Desired</th>
<th>Degree of Effect</th>
<th>Media Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deburring</td>
<td>Light</td>
<td>Steel or Ceramic</td>
</tr>
<tr>
<td></td>
<td>Medium to Heavy</td>
<td>Ceramic or Plastic</td>
</tr>
<tr>
<td>Rediusing</td>
<td>Light to Heavy</td>
<td>Ceramic or Plastic</td>
</tr>
<tr>
<td>Surface Improvement</td>
<td>Reduce Surface Roughness</td>
<td>Plastic or Ceramic</td>
</tr>
<tr>
<td></td>
<td>Produce Preplate Quality</td>
<td>Plastic or Ceramic</td>
</tr>
<tr>
<td></td>
<td>on Softer Alloys</td>
<td>Plastic, Ceramic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic, then Plastic (2 Steps)</td>
</tr>
<tr>
<td>Surface Reflectivity</td>
<td>Brighten or Highlight</td>
<td>Steel or Ceramic</td>
</tr>
<tr>
<td></td>
<td>Best Quality, Hard Alloys</td>
<td>Ceramic or</td>
</tr>
<tr>
<td></td>
<td>Best Quality, Soft Alloys</td>
<td>Ceramic, then Steel (2 Steps)</td>
</tr>
<tr>
<td></td>
<td>Best Quality, Plastics</td>
<td>Plastic, then Steel (2 Steps)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steel or Wood</td>
</tr>
<tr>
<td>Clean Surfaces</td>
<td>All Metals</td>
<td>Steel or Ceramic</td>
</tr>
<tr>
<td></td>
<td>Irregular Surfaces</td>
<td>Random-shaped Aluminum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxide</td>
</tr>
</tbody>
</table>

*Courtesy John B. Kittredge, consultant, Kalamazoo, Michigan

**FINISHING COMPOUNDS**

Compounds are mixtures of chemicals (liquid or dry powder)* used in water solutions to facilitate or modify the action of media on components or workpieces in accomplishing cleaning, burnishing, deburring, descaling, other processes. Compounds may be selected to perform one or more of the following functions, as required by the process and machine:

1. Condition water, control pH.
2. Wet surfaces, clean parts, keep parts and media clean during processing, emulsify oil, grease, shop dirt, suspend soils and metallic fines.
3. Separate and cushion parts against damage if required. Control foam.
4. Remove tarnish and/or scale.
5. Control part color.
6. Develop and/or maintain lubricity by forming a controlled film.
7. Prevent corrosion of parts, metallic media, and equipment.
8. Provide cooling.

*formulated to comply with OSHA and EPA regulations.

The finish obtained on part surfaces in a mass finishing operation is dependent on the amount and type of compound used. Compounds may be in liquid or powder form, either abrasive or nonabrasive, specified for ferrous or nonferrous metals, plastics, other materials. Liquid compound will mix rapidly with water to form the compound solution whereas powders require more time to dissolve. If parts have deep blind holes or narrow
slots and the finishing run is short, a powder compound may not dissolve entirely if it has
lodged in the blind holes or slots. Compounds should be added in accordance with
suppliers’ recommendations, and/or according to precise tests to determine the correct
additions per unit volume (cu. ft.) of the mass. Tests will determine the correct
concentration of compound solution for use in the flow-through system in vibratory
machines. If too little compound is used, cleaning will be incomplete, parts may be
attacked, damaged or coated with an insoluble smut. Also, if not enough compound is
added to soften the water, there will be a slow buildup of calcium and magnesium salts; no
protection against corrosion will be provided. If too much compound is used, the media
may become suspended in the resulting suds, reducing work efficiency drastically.

Compounds (liquid or powder) may be used in finishing machines generally in one of three
ways:
1. Batch addition—for closed machines, barrels, small centrifugal barrels, vibrators
without drains. The machine is charged with compound and water, the process cycle is
completed, the compound solution is discharged.
2. Recirculation system. The solution is mixed in a tank and pumped into the machine.
During the process cycle, the solution drains back into the tank and is “recirculated.”
The solution deteriorates during its life (as the chemicals are consumed) and therefore,
results will vary with consecutive runs. This system should be avoided if possible.
3. Flow-through system—for vibrators with drains, other machines designed for
continuous addition and draining of solution. Fresh non-abrasive compound solution is
pumped into the machine at a predetermined flow rate, flows through the mass, drains
continually and is discharged. The concentration of compound used in this system is usually
less than half that in a batch operation, with improved cleaning, cutting and burnishing
efficiency. Automatic addition of liquid compound through a compound metering pump
further improves efficiency and consistency of the finishing process.

Because the use of a flow-through compound solution system permits close control and can
be automated, liquid compounds are normally preferred for consistent results. Powder
compounds can be economical for mass finishing in closed batch systems. Powder
compounds can include loose abrasives which enhance cutting capabilities of media.
Abrasives are seldom recommended for use in vibratory systems. If abrasives are used in
vibrators, closed systems must be used to prevent drainage and premature loss of abrasive.

The water level in barrel finishing equipment exerts a major control on the process. In
rotary barrels the water level can vary from below load level to several inches over the load
of media and parts, and is sometimes described as two inches under, level, four inches over,
etc. Low water levels produce a harsh action suitable for deburring and fine polishing. High
water levels result in more cushioning and a more gentle action for burnishing purposes.
Water level is an equally critical factor in vibratory equipment if a flow-through system is or
is not used. Water is added precisely by observing the effectiveness of the action, and
determining the correct level for best results. Too little water can cause part damage and/or
harsh action; too much water dampens and reduces vibratory action and efficiency.

**Compound Functions**

Although compounds are generally selected to perform one or more specific finishing
operations, they must carry out certain functions to make possible the desired operation on
workpiece surfaces.

1. **Condition Water. Control pH.** To produce uniform results from successive machine
runs, a compound must condition the water, forming a compound solution with the desired
pH. Compound must be capable of maintaining the proper solution pH required to protect the metal or material being processed for the entire duration of the cycle. There is a tendency for compounds to react with parts and media during long runs in rotary barrels, causing pH to change from alkaline to neutral or slightly acidic. For example, if a mild steel part is run for a long time with an aluminum oxide media, pH of the solution may change from 11.0 or 12.0 to 7 or 7.5 if the compound is not properly buffered. Change in pH from alkaline to neutral may result in pitting of the steel surface. Water conditioning is an important function of a compound; uniformly conditioned water is essential. If water hardness is not reduced to the proper value, an insoluble lime soap can appear on the equipment, parts and media; at the same time suds are suppressed resulting in possible damage to parts, contamination, and reduced media effectiveness (cutting can be stopped completely).

2. **Wet Surfaces. Clean Parts. Keep Parts and Media Clean During Processing. Emulsify Oily Residues, Suspend Soils and Fines.** Compounds are formulated to wet part surfaces, clean parts, and maintain cleanliness of parts and media during the cycle, to insure consistent results and take advantage of the appropriate media. This includes emulsifying oily residues, as well as suspending soils, metallic and abrasive fines of various kinds so they do not interfere with the finishing process and do not redeposit on part surfaces. Physical scrubbing action of the media on parts, both in vibratory machines, barrels, or other equipment assists in the emulsification process.

Generally, parts can be cleaned and surface finished simultaneously in vibratory equipment employing a flow-through compound system. Parts that have been lapped or machined acquire a magnetized surface attracting metallic oxides and fines which adhere to the parts, and are difficult to remove. Demagnetizing the parts prior to mass finishing is therefore necessary for efficient cleaning. Media as well as parts must be clean to reduce excessive compound usage. Media can be cleaned during a run, or prior to addition of the next load. When finishing the softer metal alloys of aluminum and zinc, the media may become coated with metal or dirt. This film can be removed by processing the media in the mass finishing machine for a short time in a strongly alkaline or acid solution, whichever is more effective in removing the film. Products for this operation are readily available.

Abrasive or solid soil particles, either released from media during the finishing cycle, added as a supplemental abrasive, carried in or broken from parts, are continually reduced in size by grinding and impacting action. Such particles can deposit on or embed in the parts being processed. The compound solution should surround these small particles, holding them in suspension until the end of the cycle, or until the solution is discharged. During processing of zinc or aluminum alloys with plastic media, soil from media breakdown combines with metal fines and deposits onto the part surfaces as a thin film of white or grey residue. This film can be wiped off, but cannot be rinsed off. The compound must prevent formation of this film by keeping the film-producing elements in suspension.

3. **Cushion Parts against Damage. Control Foam.** The suds-forming characteristics of a compound can and should differ greatly, depending on whether rotary barrel or vibratory equipment is being used. In rotary barrel operations the compound can form a dense, fine-bubbled foam that fills the empty area of the barrel. This foam blanket can act as a cushion to slow down the parts and media as they move down the slide angle of the barrel before entering the water, which slows them down further before they turn over near the lower wall of the barrel. Foam helps cushion fragile parts in barrel equipment and is instrumental in developing low microinch surfaces. The reverse is true for vibratory equipment; excessive foam reduces or can stop finishing action, and it should be held to a very low level. In all cases foam must be controlled at the level best suited to the machine, process and workpieces.
4. **Remove Tarnish and/or Scale.** Tarnish or scale on a part is a portion of the surface soil that must be removed to produce the clean surface required for subsequent electroplating or painting, for example. Strongly acid compounds, certain mildly acidic types, and some highly alkaline compounds will dissolve iron oxide or rust. Nonferrous metals also oxidize and require that oxides or corrosion products be removed during mass finishing by appropriate compounds. The compound selected should not attack the media used in the process; e.g., strong acids must not be used with cold steel shot.

5. **Control Part Color.** Under certain conditions, slow or noncutting media can beat surface oxides back into the part surfaces creating dark surface colors. Compounds are formulated to produce either a light or dark surface color, as desired. This effect is a result of combined chemical and mechanical actions on the surface.

6. **Develop and/or Control Lubricity. Form a Controlled Film.** Compound solutions must provide lubricity in rotary barrel operations to help burnish by reducing or stopping cutting action. Since lubricity impedes vibratory action, it must be controlled or eliminated in vibratory equipment by use of proper compounds so that the machine can perform its function. The compound in a rotary barrel should form a film which covers and lubricates the parts and media. The film makes possible removal of burrs, for instance, from corners of external threads without damage to the threads. Thickness of the compound solution film for deburring is greater than that required for burnishing in rotary barrels. The proper compound should therefore be selected to provide the optimum effect for desired operation.

7. **Prevent Corrosion of Parts and Metallic Media.** Mass finishing produces chemically active metal surfaces on which corrosion, tarnish or discoloration can take place. Compounds must inhibit or prevent this surface corrosion or tarnish. Ferrous metal parts may be protected from corrosion by strongly alkaline compounds (high pH) or those containing inhibited acid (low pH). A compound must be able to maintain corrosion protection during the run in closed systems such as rotary barrels, despite a tendency for the compound to become depleted. Compounds used with steel media must include corrosion inhibitors. Usually, mildly acid compounds (pH 4 to 4.5) will brighten the steel media and most metallic surfaces by preventing the slow buildup of oxide films on media and parts. Steel media, however, may require protection by a more alkaline film when not in use, or in storage for extended periods.

8. **Provide Cooling.** The water solution of compound cools the mass, absorbing some of the heat generated by the abrasive and/or rubbing action of media on parts. Although some increase in temperature promotes cleaning, too much heat promotes corrosion, oxidation and darkening of metal parts. In vibratory equipment the compound solution should be added at a flow rate sufficient to keep the mass from becoming hot, particularly when parts are being processed in steel media.

**Specific Compound Applications**

**Cleaning Compounds**—generally used for removing dirt and oil, or for deburring with abrasive media—are mixtures of alkaline salts, with organic detergents, soaps, etc. The compounds may contain rust or tarnish inhibitors. Cleaning compounds are often the first products used in barrel processing, or a mass finishing operation, since the surface soils must be removed from parts before other operations can be performed. In vibratory finishing the cleaning compounds must work rapidly to remove soils and prevent them from being embedded into the part surfaces and darkening the surfaces. Selection of the proper compound to remove a specific soil or group of soils is critical.
**Descaling Compounds** usually exhibit low or high pH (acid or alkaline), and are designed to remove heavy rust, scale and tarnish very rapidly. The compounds are sometimes used in self-tumbling, or with media to accomplish light deburring while the surface is being descaled. Acid compounds remove scale, rust and discoloration from ferrous and non-ferrous metals; highly alkaline compounds are used for ferrous metals only. A short run with an acid compound, following a long deburring cycle in a rotary barrel, restores a bright color to surfaces prior to burnishing or plating. Rotary barrels used with acid compounds must be properly vented. No open flames should be near the barrel when it is first opened at the end of a cycle. Hydrogen gas is usually given off during processing, and could cause an explosion. The problem is not encountered with open equipment, such as vibratory machines or open-end oblique barrels.

**Deburring Compounds, Nonabrasive Cutting Compounds** condition the water, keep the media and parts clean, prevent corrosion of the metals involved, creating a chemical environment in which deburring, cutting, grinding, etc., can take place. Compounds may be alkaline (pH above 9.5) or neutral (pH 7.0). These compounds are usually low foaming and are widely used in vibratory equipment with flow-through systems. The compounds do not contain abrasives and have no cutting properties of their own; their purpose is to clean media, thereby making it possible to use various available media to gain the benefits of inherent media properties. By keeping the media clean, optimum deburring and surface refining is obtained throughout the cycle.

**Deburring Compounds, Abrasive Cutting Compounds**—a blend of abrasives and chemicals to enhance deburring, radiusing, or polishing—are generally used in rotary or centrifugal barrels and vibratory machines with closed systems. The abrasive grains speed the cutting action of the media to reduce surface roughness, develop luster on the parts. When used in vibratory machines, care must be taken to keep the abrasive fines in a light slurry condition by adding small amounts of water periodically to the load. Otherwise, the slurry thickens and reduces the cutting efficiency.

Compounds with coarser abrasives cut faster than those with finer abrasives, produce a matte finish on metal surfaces. For long deburring cycles, a hard, long-lasting abrasive which maintains its cutting action for longer periods, is used. For softer metals, a softer type of abrasive with more rapid breakdown makes possible initial rough cutting followed by finer polishing. Even hard abrasives are ground finer and lose much of their cutting action after 12-15 hours of use in horizontal barrels and 3-6 hours in vibratory machines. Compounds must be replenished periodically to maintain the desired cutting rate throughout long cycles. The rate of attrition of abrasives depends on the hardness of the metal being processed, and the size and hardness of the deburring media. Larger and harder media will cause a faster breakdown of the abrasive. When parts are self-tumbled or deburred with metallic media, the abrasive compound supplies all of the cutting action.

Various abrasives are used in abrasive compounds. For ferrous metals, large parts, and prolonged runs, aluminum oxide compounds are generally preferred. The aluminum oxide grains are tougher and resistant to breakdown. Silicon carbide is hard but more brittle and friable than aluminum oxide, will fracture more readily into sharper fragments. Silicon carbide is usually employed for light work; it is well suited for use with nonferrous metals and for deflashing plastics. Silicon carbide does not develop smut (aluminum oxide residue) during the process, is used where extreme cleanliness is required and to avoid the embedding effects of aluminum oxide. Silicon carbide finds application for parts that are to be welded or brazed. Other abrasives include quartz, pumices and limes for a wide range of applications.
Burning Compounds improve reflectivity or brightness and color of metal surfaces. These compounds are inhibited to prevent corrosion or tarnishing of both media and parts. The compound must also provide the correct amount of foam, lubricity, and protective film throughout the process. Burning compounds provide foam for cushioning the load to prevent impingement and promote burnishing in rotary barrels. Compounds used in vibrators must be low-foaming. Burning compounds are chemically mild (pH 4.0 to 9.0) to deoxidize, brighten and burnish metals without discoloration, and buffered to prevent smut formation in long burning cycles. Suppliers can recommend compounds for the metal and process involved. Compounds should be used at concentrations recommended by the supplier. Compounds solutions containing ½ to 2 oz./gal. (3.25 to 15 g/l) of compound in water are common.

Compounds for Finishing Sintered Parts. During mass finishing of sintered parts, compound and media residues can plug pores in the parts. Hence, the finished part can not perform its function of retaining and releasing a lubricating material, for example. If an alkaline film remains in the pores after mass finishing, oils will be saponified during impregnation. A free-rinsing liquid neutral compound along with media with little or no tendency to release fine matter should be specified. Alternatively, sometimes pores of sintered parts should be closed during the mass finishing cycle to facilitate subsequent soldering or brazing. Media fines can be retained in pores, closing the pores, by using a free grain release type of media, plus a burning compound which supplies a mild binder.

Compounds for Chemically-accelerated Metal Removal may be used in conventional rotary barrels of different types, vibratory and centrifugal barrel equipment. The process may be carried out in one or two stages, depending on the equipment, metal, abrasive, media, surface finish requirements, and plant processing conditions. Parts made from steel, stainless steel, aluminum, copper, zinc, nickel alloy can be mass finished using such compounds. The process is particularly useful—as a first step prior to final electroplating—for finishing complex-shaped and fragile parts containing deep holes or recesses (media used must be able to reach recessed areas), and parts which have been abrasive belted with 100 to 150 grit belts.

The process works on the basis of weakening the surface of the metal through one of several chemical mechanisms such as conversion coating, controlled etching, etc. The media used then removes the chemically reacted layer. This combined chemical-mechanical process continues until all desired surface imperfection is removed. The chemical compound used is essentially a substitute for the traditional abrasives employed in mass finishing. Since there are no abrasive fines produced, other than from media wear, the finished surface is much cleaner, making possible superior plating quality. Substantial time saving is achieved along with consistent, uniform finishes on surfaces, edges, interior areas. Parts treated by this system can have surfaces with lower rms readings than can be obtained by other means in reasonable time cycles. Close control of processing is required to secure optimum results with these materials. Additional operator safety measures are required. Since the effluent solutions may contain dissolved (and possibly chelated) metal compounds, additional waste treatment procedures and monitoring are essential. The process produces considerably less abrasive sludge than conventional processes, simplifying maintenance of drainage systems and waste treatment equipment.

PROCESS SHEETS

Process sheets specifying operating procedures, with information and instructions for operators, are prepared to make possible identical results from repeated mass finishing production cycles. Forms can be developed and adapted to fit individual needs. A
Fig. 26—Process laboratory report form for vibratory finishing. (Illustration courtesy Roto-Finish, Kalamazoo, Michigan).

A temporary process sheet may be outlined when a new job is received, or a sample processing sheet may be worked out by an equipment supplier. Then parts from the first finishing run are inspected, changes made if necessary, and the final process sheet completed.

A typical process sheet should include the part number, part name, material, and a simple identifying sketch of the part. Material identification aids in selecting proper method of part separation. Operation number and finishing process, such as burnish, deburr, etc., are listed along with instructions about loading and unloading. Any required cleaning before mass finishing can be specified. In shops with several barrels or finishing machines, machines may be selected according to production lot size or process, and numbered arbitrarily. Process steps, as appropriate, are numbered for identification and/or for reference to detailed instructions. Process sheets for rotary barrel operation can include the finishing cycle, barrel speed, maximum load, type of media, amount and type of compound. Sheet can show the “Examination Time” when part finish should be acceptable. At this point parts can be inspected and unloaded if acceptable. Sheet may also list “Maximum Run Time”—total time parts may be run in barrel without damage. Process sheet may include instructions for part separation (as appropriate), final rinsing and/or inhibiting, drying, final protective soluble oil dip or other coating. Special instructions about part inspection can be included.

Figure 26 is a process laboratory report form for vibratory finishing which can be expanded for use as a process sheet. The description of “process” may include instructions such as: “descall,” “remove flash or parting line,” “deburr,” “radius (amount),” “burnish to good luster,” “preplate finish (microinch specification),” etc. As can be noted, other essential information is specified on the form. Solution system, for example, may be flow-through, recirculating, or batch. It might be desirable to include comments on parts handling, drying, final treatments.

**SOME SUGGESTED EDGE AND SURFACE FINISH STANDARDS**

Manufacturers in the aerospace, automotive, and precision manufacturing industries have established specifications for edge and corner radii or conditions, and surface smoothness. ASA Standard B 46.1, published in 1955, entitled “American Standard for Surface
Roughness, Waviness and Lay,' describes methods of classifying and designating various part surface characteristics, so that precise specifications can be made. But no specific numerical recommendations are made. Standards for safety of various consumer products are included in some publications of the Consumer Product Safety Commission. As an aid for determining product safety, Underwriters Laboratories developed a "sharp edge tester" to determine if a given sharp edge would cut human skin. This is described in MR77-469, "U.L. Sharp Edge Tester," Society of Manufacturing Engineers, Dearborn, Michigan 48128. Industry information indicates that a sharp cutting edge has a radius of 8 to 10 microinches (0.20 to 0.25 micrometer) or less.

However, few standards for edge or surface condition are in use in the general manufacturing industry. Part drawings may include the instruction "break edge" or a similar comment—an instruction subject to individual interpretation. A standard calling for formation of a definite radius could result in production of parts with more uniform quality, improved safety. In like vein it is the aim of metal product finishers, in preplate finishing, to prepare a metal surface sufficiently smooth so that a leveling copper or leveling nickel electroplate will cover the surface scratches.

**Edge/Corner Standards**

If part drawings do not specify edge or corner radii, the following standards may be useful as a guide to uniform quality and improved product/part safety.

- **Edges and/or corners** — 0.001 in. (0.025 mm) minimum radius for safety in handling and/or use.
- **Edges and/or corners** — 0.004 in. (0.1 mm) minimum radius for easy and safe handling.
- **Edges of stampings** — 0.001 in. (0.025 mm) minimum radius up to a radius equal to half the metal thickness, as conditions dictate.

**Surface Smoothness Standards**

Since type of product and service use dictate "acceptable" or even "desirable" surface finish conditions, a general standard is perhaps not applicable, or at best, difficult to establish. However, the following examples of a few products and types of metal show typical surface finishes as fabricated and after mass finishing to an acceptable finish for the part in question. Although these parts were burnished with steel media in a round vibrator, comparable results can, of course, be achieved with other media and other mass finishing processes. The examples cited may serve as guidelines for acceptable surface finish standards for parts of the type mentioned, and for similar parts and metals for equivalent service applications.

<table>
<thead>
<tr>
<th>PART</th>
<th>SURFACE BEFORE BURNISHING (RMS)</th>
<th>SURFACE AFTER BURNISHING (RMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Die Cast Compressor Valve</td>
<td>12 microin. (0.3 micrometer)</td>
<td>9 microin. (0.2 micrometer)</td>
</tr>
<tr>
<td>Zinc Die Casting</td>
<td>28 microin. (0.7 micrometer)</td>
<td>20 microin. (0.5 micrometer)</td>
</tr>
<tr>
<td>Stainless Steel Air Compressor Stamping</td>
<td>40 microin. (1.0 micrometer)</td>
<td>35 microin. (0.89 micrometer)</td>
</tr>
<tr>
<td>Powder Metal Lever for Tape Dispenser</td>
<td>22 microin. (0.56 micrometer)</td>
<td>15 microin. (0.38 micrometer)</td>
</tr>
</tbody>
</table>

The surface finish achieved and indicated above was, in all cases, acceptable from standpoints of part function, appearance, and safety.
The ability of a leveling copper or a leveling nickel electroplating process to cover surface scratches is dependent on the use of proper plating techniques and also dependent upon the conditions of the plating solution. Scratch coverage by a leveling plating solution is subject not only to the depth of scratch, but also the shape and direction of the scratches. In all cases parts must be processed to take advantage of the characteristics of the electroplating solution employed. Also, random scratches deeper than those on the majority of the part surface may not be completely hidden.

Experience in the plating industry indicates that surface smoothness requirements to permit covering of scratches in a leveling electroplating solution can be classified generally as indicated below. A suitable deposit thickness is assumed. A deposit of sufficient thickness to satisfy the corrosion protection specifications is normally adequate to accomplish covering of the scratches.

<table>
<thead>
<tr>
<th>DESIRED RESULT or APPLICATION</th>
<th>SURFACE FINISH</th>
</tr>
</thead>
<tbody>
<tr>
<td>A finish on a flat surface which will reflect a mirror image</td>
<td>1 microin. (0.025 micrometer)</td>
</tr>
<tr>
<td>A high quality electroplated finish—surface scratches covered</td>
<td>4 microin. (0.1 micrometer) or less</td>
</tr>
<tr>
<td>An acceptable finish on irregularly shaped surfaces—surface scratches covered or not evident</td>
<td>8 microin. (0.2 micrometer) or less</td>
</tr>
</tbody>
</table>

**PROCESSING SYSTEMS**

Parts may be finished by batch, semi-automatic, or continuous automatic procedures. Automated mass finishing makes it possible to process more parts per unit time, produce parts of consistent quality, and/or reduce operating costs.

**Batch Processes**

Batch operations of a barrel or tub vibratory finishing machine are controlled by the operator. Media, parts, compounds and water (compound solution) are generally loaded manually into the machine, and the machine operated for the specified time cycle. When the run is completed, the operator discharges the entire load, separates media from parts, and returns media to the machine or to storage. Parts receive specified post-treatments and continue through the manufacturing process. Round vibrators can be loaded from a belt conveyor or vibratory feeder. Machine and loading conveyor are started; conveyor slowly feeds parts into the mass while spreading them around the entire chamber. This minimizes part-on-part contact and possible damage. Conveyor can be adjusted so that load is fed into the round vibrator during one revolution of the mass. Unloading of round vibrators, compound solution addition, media and parts separation, are generally simpler operations then in the case of rotary barrels or, in some cases, tub vibrators.

Centrifugal barrel and disc machines can be operated by batch process, requiring operator attention. Parts, media, and compound solution are added to the machine and the finishing cycle completed, after which appropriate unloading, media and parts separation are carried out. Most centrifugal finishing machine processes employ wet media; some are conducted with dry media. (Most barrel and vibratory processes involve use of wet media also.)

In the operation of spindle finishing machines, parts are mounted on fixtures or on machine spindles, and processed in a tub of media, with or without compound solution. Wet
processes in spindle machines are specified to accomplish rapid cutting, deburring and
radiusing of workpieces. Dry processes develop bright lustrous finishes. Some machines
employ several fixtures on which a number of parts are mounted. In such cases, an operator
can mount parts on fixtures while loaded fixtures are being processed in the machine. At the
end of the cycle, fixtures containing the completed parts are removed from the machine;
loaded fixtures are placed on the machine spindles for processing.

Continuous Automatic Processes
Complex, automated multi-machine systems include robotic handling of parts for spindle
finishing, automated handling of the barrels in a centrifugal barrel system, automation of
vibratory and centrifugal disc machines. There are advanced control systems that automate
the entire operation from parts loading to control of compound solutions, media level,
process and/or other cycle times, etc.

Automated Barrel Systems
A two-compartment horizontal barrel machine (Fig. 27) can accomplish processing plus
parts-media separation in the same machine with appropriate timers and controls to aid in
automation. Machine may be loaded with parts and media through a load hopper at one
end by a skip loader or vibratory feeder. A timer can be programmed to add the required
amount of water or liquid compound solution initially and/or during the cycle. At the
completion of the cycle, parts and media are routed into the second compartment of the
machine by reversing direction of barrel rotation. The mass feeds into an exit tube
perforated to retain (and discharge) parts, drop media and liquid into a media storage
compartment. Liquid is discharged. Drum rotation is reversed again to the “working”
direction to return media to the processing compartment to join the next load of workpieces
and begin another finishing cycle. By installing two of the two-compartment barrels in
sequence, so that the parts feed by gravity from the processing barrel to the second barrel,
rinsing and/or surface treating and drying can be accomplished. Finished, dry parts can be
discharged from the second machine. Timers and controls can automate the cycles.

Automated Vibratory Systems
Vibratory finishing in either tub or round bowl machines can be automated by the addition
of handling and treating equipment to produce a complete parts processing system. For
example, a storage hopper may accumulate parts (sometimes from several production
lines), then feed a full load into a batch machine for a pre-set time cycle for finishing parts,
separation and drying. Or, the hopper may feed two vibrators filled with abrasive media to
cut and blend edges and surfaces of parts. Parts discharged from these machines can be
routed to a steel media burnisher for the specified cycle, if desired. Finally, all parts are
routed to a heated cob meal dryer for a continuous drying cycle. These systems, simple or
complex, are generally economical in cost and floor space. Other benefits can include
improved product uniformity and quality, greater operating efficiency, increased
productivity, reduced handling, lower inventory, reduced cost.

I. Vibratory Tub, U-Shaped Tub Systems
Vibratory tubs, both batch and flow-through types, can be designed for semi-automatic or
fully automatic operation. Elements or operations to be automated include: (1) parts
loading; (2) process control; (3) parts discharge; (4) parts/media separation; (5) material
handling; (6) post-process treatments, including drying. For example, a flexible mass
finishing system can consist of four tub vibrators with a programmable controller which
selects the appropriate machine, correct media, compound solution and process cycle for
the parts to be processed. At the end of the cycle, parts and media are unloaded, the media
reclassified and returned to the proper storage unit, while parts are rinsed, passivated and dried. Loading and unloading conveyors are also automated.

Parts loading operations can vary greatly due to specific vibratory equipment used, part sizes, distance from and type of previous operation. In semi-automatic systems, parts are generally loaded by using tote pans, parts hoppers or containers. Automatic loading is used in high-production flow-through systems. Ideally, parts should feed to the finishing machine from the prior process (stamping line, screw machine line, etc.) at the same rate at which the parts can be finished. Parts feeding hoppers can be used with variable speed drive belt conveyors (neoprene or steel-hinged), oscillating conveyors or electromagnetic vibratory feeders, to load parts into the vibratory machine semi-automatically or automatically.

Both automatic or semi-automatic electrical controls are used in vibratory machines and material handling systems. These controls can program parts loading, media feeding, flow of compounds, rinse water and rust inhibitors, operation of auxiliary material handling equipment, and all functions through the process to the start of a new cycle. For example, a finishing cycle using a conventional U-shaped vibratory finishing machine includes loading, cutdown, final burnish, separation of parts and media by an oscillator screener and return media conveyor, spray rinse and rust inhibit. Controls include timers, speed reduction mechanism, compound feeding pump controls, and all other controls needed for the auxiliary equipment. At cycle end, material handling equipment starts, machine unloads through air door, and parts and media are separated.

Workpieces and media are discharged from conventional end-discharge vibratory units by manual or automatic opening of the vibrator tub door at the end of the process cycle. This feature is ideal for semi-automatic operation. Flow-through vibratory machines are equipped with fixed discharge chutes or multi-position chutes. Parts and media are loaded into one end of the vibratory tub, which is designed with the opposite end lower, so that parts and media “spill” or are discharged automatically after being processed (spiraling) through the length of the tub. Time cycle and unloading are interconnected by the variables: (1) tub length and cross section; (2) vertical distance from the media level to the discharge chute lip. Tub length and cross section are determined by part size, desired process time, and production requirements. Variations in cycle time to achieve maximum finishing efficiency can be made by raising or lowering the discharge chute height—either by changing fixed discharge chutes or adjusting multi-position chutes to the desired position, or by adjusting eccentric weights, etc.

Following discharge from the vibratory tub, parts must be separated from the media. Most vibratory finishing systems incorporate a parts/media separating device, such as an...
oscillating screen deck which retains parts while media fall through the screen. Media are then returned to the load end of the processing tub by a conveyor. Oscillating separators may include two screen decks; the top screen to separate media from parts, the bottom screen to remove undersized media or "fines." If parts are generally of the same configuration, the natural drop at the transfer point from the tub discharge chute to the oscillating screen deck may be sufficient to remove all media. To help remove media from cup-shaped parts, a screen with an adjustable step deck (causing parts to tip over) can be incorporated to insure media separation (essential in processing cup-shaped parts).

Efficient handling of parts and media can do much to make a mass finishing installation an economic success. Material handling systems can convey parts to the machine, convey workpieces and media through part separation, convey media back to vibratory tubs or to storage, for example, in multi-compartment overhead hoppers with automatic gates. Four or more vibratory machines may be served by one handling system. If a bucket conveyor system is used, parts and media are discharged through the vibratory tub door onto the separating screen. Parts travel to the end of the separator and are discharged; media drop through the screen into the bucket loading area and are returned to the tub or to storage hoppers. A skip loader picks up the hopper containing the separated media and positions it above the vibratory tub, or returns it to the storage area. The system can be engineered to automate all major finishing steps including media selection from storage, media transfer, machine loading, addition of compound, processing, media/parts separation, media storage or reloading.

Automation in vibratory finishing systems can be aided by auxiliary devices. Feeders can be installed to automatically maintain proper media level and replenish media lost through attrition. Liquid compounds can be added to the processing tub by precision proportioning pumps. Flow meters are used to control desired amounts of water or other liquids, to maintain process consistency and eliminate operator judgement. Noise abatement devices such as sound hoods, domes and barriers, can be fitted to vibratory machines to insure conformance with allowable noise levels.

II. Vibratory Round Bowl Systems

Well-designed round vibrators, with easy separation capabilities, make possible automatic or semi-automatic systems. Systems involving the feeding of one machine from another are common. Example: hopper feeder, burnisher (conventional or long radius), rinse conveyor,
cob meal dryer and inspection conveyor. Superior separation systems, better lubrication systems and their safety controls, etc., help achieve the benefits of automation. Adjustable, in-use speed or amplitude changes at specific times during the vibratory process are possible.

Auxiliary equipment aids automation of round bowl vibratory systems. The parts dumper is designed to accept shop tote pans or parts containers, elevate and dump the contents either directly into the vibrator or onto a parts feeder. The operator loads the dumper any time it is empty, but does not need to be at the machine when parts are loaded into the vibrator. Parts feeders distribute parts uniformly through the finishing chamber—essential for best processing of critical surfaces. Dumping (loading) parts all in one place frequently results in defects too severe to be removed during the finishing cycle.

If parts can be finished to specifications in one trip around the circular vibratory machine channel, bowl machines can be operated on a continuous basis. Continuous cycles can be set up for about 1/10 to 1/5 min./cu. ft. (0.2 to 0.4 sec./l) of capacity. In a continuous operation the discharge gate is in a raised position all the time; parts are discharged automatically. Likewise, parts must be loaded continuously. A flow-through solution system automatically meters compound solution into the vibrator. The solution proceeds through the machine and passes out through drains. Sometimes compound solutions may be recirculated, but this is usually limited to some burnishing or long-wearing-abrasive applications. The flow-through system normally keeps parts clean so that an auxiliary washer is not required.

An important characteristic of round vibratory equipment is that it eliminates external separating screens and media return conveyors. Parts can be separated from media at the end of the cycle by passing the mass up and over a built-in (or auxiliary) gate and screen.

Fig. 29—Continuous-feed vibratory finishing unit features spiral bowl design, internal parts/media separation, automatic compound feed system, pneumatically controlled part discharge ramp. Capacity: 60 cu. ft. (1,700 l). System includes rinse/dry conveyor, heated rinse tank, heated air blow-off oven. (Photo courtesy UltraMatic Equipment Co., Addison, Illinois).
assembly. A number of replaceable screen decks can be used in accordance with media and workpiece size and shape. Magnetic separators may be used to separate ferrous metal parts from nonferrous media of about the same size. A magnetic drum with a short conveyor belt removes parts, which may unload through a demagnetizer unit, if required.

Through the use of a rinse station, a combined rinse aid and corrosion inhibitor is recirculated over the parts to prevent part corrosion and aid drying. Solutions can be heated to further reduce drying time. A round vibratory machine dryer using cob meal, or a vibratory pan dryer equipped with forced hot air, can be used to dry finished parts to minimize possible corrosion and facilitate part handling. Wire mesh or other conveyor dryers can be used also.

**Centrifugal Disc Automation**

The centrifugal disc machine, as well as the centrifugal barrel, is quite versatile, handling many types of parts to achieve a wide range of edge and surface conditions. The centrifugal disc is intrinsically well suited for flexible automation, rather than the much more costly in-line automation. Centrifugal disc machines can be semi-automated at lower cost than is the case of centrifugal barrels, and fulfill an important function in industry. Figure 30 shows a centrifugal disc finishing machine with semi-automated handling. Such machines can range in size from 1 to 24 cu. ft. (28 to 678 l) capacity (parts and media load). Some machines are designed so that the bowl tips to unload parts and media (Fig. 31); others are fitted with a door in the side of the bowl which opens to allow parts and media to flow out. The machine has an open top bowl so that semi-automated material handling is simple. Parts to be processed may be conveyed to the elevator-loader of the machine, and completed parts carried away as required, by various means.

The centrifugal disc finishing machine in Fig. 30 is loaded by feeding the correct proportion of parts and media through the open top above the bowl. An elevator lifts load in a pan, discharges into the machine bowl, and returns. Most modern centrifugal disc machines have infinitely variable speed disc drives so that the process cycle is programmed to run first at high speed for maximum deburring and abrading. Machine then switches to a slower

![Fig. 30—Cross-section sketch of a 4 cu. ft. (113 l) first generation centrifugal disc machine with dedicated material handling. Machine can discharge, separate parts and media, elevator-conveyor returns media to processing chamber. Machine details are: (1) Steel wall of tub, lined with urethane; (2) Spinner; (3) Water, effluent sump; (4) Spinner shaft; (5) Spinner support frame; (6) Sealed bearings; (7) Tub tilt gear box; (8) Drive motor and gear box; (9) Tilt motor; (10) Sump drain; (11) Sump shut-off valve; (12) Support frame and levelers. (Illustration courtesy Harper Surface Finishing Systems, Meriden, CT).](image-url)
speed to refine surfaces. Automated flow-through compound addition system is such that compound may be automatically switched from an initial cutting compound to a “coloring” compound, used while the machine is running at slower speed. At the end of the process cycle, the processing tub is inverted—rotating 130 deg.—feeding parts and media out into the material handling system. In the case of the machine shown, the machine discharges parts and media onto a separator deck (Fig. 31). Parts are removed from media, media may be classified and returned to the centrifugal disc bowl. Such a system is satisfactory if frequent change of media or media reclassification is not required, and if operator addition of fresh (replacement) media is acceptable. Automated systems feature a single material handling system to serve a number of machines, or versatile handling for single machine installations. A programmable controller can automate loading, unloading, parts/media separation and media classification, media storage and selection, and parts drying. Generally, more sophisticated material handling and controls are used for systems incorporating a number of machines.

**Automated Centrifugal Barrel Processes**

The centrifugal barrel has greater process flexibility, higher speed and ability to achieve finer finishes than the centrifugal disc machine. As a result, there are more automated centrifugal barrel machines in use. A centrifugal barrel machine for semi-automatic operation typically has two work containers (drums) for parts, media and compound solution. Water or compound solution may be added through the center of the turret, and distributed equally to each of the two drums. Turret and drums rotate in a horizontal plane. During the process cycle the machine can be run at a high speed for maximum deburring action, then automatically switched to a slower speed for fine finishing. Following a cycle at high speed, abrasive compound may be rinsed out and burnishing or finishing compound

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Fig. 31—Centrifugal disc machine rotates 130 deg. to discharge parts and media into separating system. (Photo courtesy Harper Surface Finishing Systems, Meriden, Connecticut).

Fig. 32 (right)—Two-drum automatic centrifugal barrel machine. Loading elevator at left (just out of photo). Holding area and vibratory feeder above machine. Separation/classification deck below. (Photo courtesy Harper Surface Finishing Systems, Meriden, Connecticut).
can be added for a slow speed run. The capability to switch from maximum abrasion (deburring) to a very fine or super finishing cycle makes it possible for semi-automatic centrifugal barrel machines to achieve a fine finish in a single process cycle. Drums for the centrifugal barrel described above are “preloaded” prior to being placed in the machine for maximum machine utilization. Material handling systems for unloading and reloading the drums are built to suit the variety and nature of parts to be processed and the media and compounds to be used.

Automation of centrifugal barrel equipment for high production deburring and finishing can be accomplished with the machine shown in Fig. 32. This machine has two drums, each with a capacity of 350 lb. (159 kg). Parts and media are routed to the machine load area. An elevator is used to deliver a premixed or premetered amount of parts and media to a holding area on top of the centrifugal barrel machine. When the machine is in its load cycle, a vibratory feeder and/or a load cell allows a specific amount of parts and media to be loaded. This is normally program controlled. The machine is programmed to start running at a slow speed, while parts, media, compound and water are fed into the machine through the tube at the center top of the turret. Each drum receives the same load of parts and media. When loaded, the machine is switched to the appropriate high speed for a deburring or heavy stock removal cycle. Then, machine can be switched automatically to slower speeds with compound change for fine finishing. At the end of the process cycle, drum plugs in the base of each of the two drums open automatically to feed the total load into the conical base of the machine while the centrifugal barrel unit is still in slow rotation. Parts and media are funneled out of this cone to a separator/classification deck below. Parts are separated and carried away for drying or other treatment, media can be reclassified (if required) and automatically returned to the load area.

Fig. 33—One unit of flexible centrifugal finishing system is a four-drum machine. Gantry robot at left is ready to remove drum for transfer to lid remover, then to material handling unit for unloading, separation. Centrifugal machine is at center with protective doors open. Lid remover mechanism is at right. (Photo courtesy Harper Surface Finishing Systems, Meriden, Connecticut).
A large centrifugal barrel finishing system with 29 cu. ft. (820 l) capacity employs a central computer to control and monitor every aspect of the finishing process. As the machine turret rotates to process two loaded barrels, two other barrels are being unloaded, washed, reloaded with parts and media. Thus, turret downtime is only the time needed to remove two barrels of finished parts from the turret, insert the two preloaded barrels. Turret rotational speed, operating ratio (number of turret rotations for each barrel rotation), cycle time, separation, rinsing, etc., media reclassification and return are all controlled by the computer.

An automatic system designed to deburr and finish a range of different parts at various stages in a manufacturing cycle involves the use of two large centrifugal barrel machines. Parts and fresh media enter the system via the plant's material handling system. Barrels are preloaded and weighed accurately. After the process cycle, barrels unload into a separator. Processed parts are returned to the plant automation system. All finishing process operations are directed by a programmable controller which is coupled to the plant automation system.

A sophisticated flexible automated centrifugal barrel finishing system capable of finishing a wide variety of parts with total control of all process parameters is illustrated in Figures 33 and 34. The system includes four four-drum centrifugal barrel machines, each making use of a central material handling system. Process cycles are computer selected, and each machine has its own programmable controller receiving instructions from a central computer. As many as 16 different components may be processed simultaneously with as many as eight different types of media, different compounds, different process times and speeds. Different sizes of parts can be processed; various specified finishes can be produced.

Parts can be brought to the material handling system by the plant "automatic guided vehicles". Loading of the barrels or drums, each about 18 by 18 in. (457.2 by 457.2 mm) with
a capacity of about 2 cu. ft. (56.6 l) is precise—typically, plus or minus one part, plus or minus 1/2 lb. (0.2 kg) of media, exact water level and compound addition. Media can be selected automatically from the different types in the system. A robot transports the loaded drum to the proper machine, inserts drum in machine. The operation is repeated until the four drums have been inserted, after which the parts are processed for the time and conditions specified. Process cycles can range from 15 to 40 min. Machines can be loaded (reloaded) completely in 5 to 12 minutes.

At the end of the process cycle, robot removes barrels (drums) from the machine, transports them to a lid-remover unit, and then to the material handling system. To handle the most delicate, fragile parts without damage, drums are emptied onto a separating conveyor by rotating them about the center lip of the opening. There is no falling or impingement. The separator is multiple-tiered to be able to handle a wide variety of parts, reclassify media accurately. Media are returned to overhead storage, parts are washed and can be taken automatically to the next step in manufacturing.

**Automatic Spindle Finishing**

An automated spindle finishing machine with robot loading and unloading is suitable for parts large enough and so shaped that they can be grasped by the robot and the spindle of the machine. Parts can be conveyed to the machine either on pallets in specific locations, on a roller conveyor fitted with stop locks, or by automatic guided vehicles. Parts are loaded in specific locations on flat plastic carriers (“baskets,” “donuts,” “tombstones,” “ingots,”) either singly, so that they can proceed down a roller conveyor, for example, or in multiple if they are brought on pallets. The robot is programmed to pick up each part and deliver it to a spindle of the spindle finishing machine. At the same time, the spindle rotates up out of the media mass, and turns again as required to meet the robot. The robot places the part on the spindle where the part is fixed or held in position by means of an air collet. The spindle then reverses movement to place the part in the rotating mass of media in the spindle machine. At the end of the cycle, parts are unloaded by the robot into a conveyorized washer/dryer unit. A continuous filtration system recirculates compound solution through the rotating media mass.

**SOME MASS FINISHING OPERATIONS AND TECHNIQUES**

Some specific examples of the many manufacturing and finishing operations which can be accomplished by mass finishing are outlined below. Machines, media and compounds can be planned and/or specified for various processes and procedures. In some cases, operators may be able to adapt the processes to existing machinery and media. Skilled operators can devise other cycles and special processes which may be variations or extensions of the several operations mentioned.

**Cleaning**

Although a degree of cleaning is or can be a part of a mass finishing operation, cleaning can be carried out also prior to other processing. Media and compound solution appropriate to the metal or substance being cleaned can remove undesirable surface soils efficiently. For example, steel media with proper compound solutions is being used to remove oils from stamped or machined metal parts, to remove chips left on parts from machining operations, and to remove tarnish and/or light oxides from steel, copper, brass, zinc and aluminum. Many copper pipe fittings are cleaned in this way. Round bowl vibrators and a flow-through compound solution system, can accomplish this operation. Cycles of 7 to 12 min. are generally satisfactory. The steel media act as excellent small scrubbers provided with
Fig. 35—Spindle finishing machine with two-spindle unit, robot load/unload (at right), washer/dryer (at left). Programmable controller regulates rotational speed of the media mass, determines spindle positioning of parts. (Photo courtesy Almco, Inc., Albert Lea, Minnesota.)

abundant energy. The flow-through solution system carries away soils removed from the workpieces being processed, keeping the steel media clean.

Machining oil and metal chips must be cleaned from large cast iron and steel garden tractor components prior to assembly and painting. For safe handling and assembly, edge sharpness must be reduced. Components are cleaned and deburred during 12 to 15-min. continuous cycles with steel media and a special compound solution in a 47 cu. ft. (1,330 l) round vibrator. Bearing caps, pulleys, steel weldments, stampings, gears are processed similarly. The vibrator is charged with 16,000 lb. (7,300 kg) of ¼ in. (6.4 mm) steel ballcones. There is continuous separation of parts from media.

Deflashing, Conditioning Castings and Moldings

Edge flash formed on various moldings and die castings can be removed in mass finishing equipment. Castings are usually trimmed in a die. The resulting thin fins and flash around the edges are removed, and radii which could not be built into the die are generated. Residual sand, cold shots and similar surface imperfections can also be removed during processing. Type of metal, ceramic, or plastic and the condition of the workpiece will determine type of media and specific process required. Soft metallic or resin bonded media are usually preferred for processing zinc and soft aluminum castings, with buffered liquid compounds or soft abrasive compounds to avoid gouging or impingement of parts. Metallic media, or ceramic bonded media with low rate of cut are used on harder metals such as heavy brass castings, with liquid or abrasive compounds depending on the degree of surface refinement required.

Aluminum alloy control valve bodies are deflashed and given a uniform surface finish during a cycle of 12 to 13 min. in a 27 cu. ft. (764 l) vibratory tub operating at 7/32 in. (5.15 mm) amplitude and 1,750 rpm frequency. Porcelain base aluminum oxide angle-cut triangles (about 1½ x 1 in. — 25 by 25 mm) serve as media; a light alkaline cleaner compound is added continuously. Valve bodies feed into the vibratory tub automatically and, after deflashing, pass over a two-stage separator screen enroute to an integral washer-dryer oven. Media fall from the separator into the media return system.

Rough forgings for aluminum compressor pistons are deflashed at parting line, cut-off areas, and at knock-out pins to smooth parts sufficiently to make possible automatic feed to a subsequent grinding operation. Forgings are run part-on-part for about 10 min. in a tub vibrator.

Molded and fired ceramic electrical insulators require flash removal around core pins and parting lines. A continuous process in a round bowl vibrator, using steel media, removes flash in 1 to 4 minutes. Insulator electrical properties are not affected.
Relatively brittle phenolic plastic moldings used for iron handles, electrical insulators, etc., require deflashing without impairment of surface luster. Parts are run dry in a round bowl vibrator using steel media in a continuous cycle of 6 to 9 min. with an exhaust to remove dust and cool the mass.

**Descaling, Removal of Rust and Brazing Residues**

Following removal of organic soils, scale, rust and corrosion products can be cleaned from metallic surfaces using either acidic or alkaline proprietary compounds, inhibited to prevent attack on the basis metal. Oxides and other inorganic soils must be removed if clean, light-colored metal surfaces are to be obtained. Any media inert to the chemical action of the descaling compound can be used to loosen scale, separate the parts, and convey the solution to recesses, corners and internal surfaces. Closed horizontal barrels, if used, must be vented to prevent pressure buildup and explosions of the barrels. Oblique open-end barrels and vibratory machines may be used safely for this operation.

Brazing fluxes used for silver and copper brazing in open atmosphere leave residue of nearly insoluble oxychlorides and fluorides on the metal surface adjacent to the brazed area. A ring of carbon and other insoluble compounds is often formed at the edge of the heat-affected zone, leaving a dark band around the brazed area. Mass finishing processes remove these insoluble residues by a combination of media scouring action and chemical action of proprietary compounds which act to dissolve the scale. Copper plumbing fittings, heavily tarnished with heat treat scale, are cleaned and brightened in a round vibrator using a continuous 12-min. cycle. Proper sequencing of compounds and machine energy levels produces the desired result.

**Burr Removal**

Deburring is a major operation in mass finishing. During deburring, cleaning and improvement of the workpiece surface occurs also, along with, in some cases, a degree of edge radius generation. Centrifugal barrels, centrifugal disc machines and vibrators generally remove burrs more rapidly than rotary barrels—particularly in the case of burrs on internal workpiece surfaces. Barrels are effective for removal of exterior burrs. Use of small media will generally increase cycle time, produce smoother surfaces, cause less impingement.

_Burrs on hardened material._ If burrs have a relatively thin root, they can often be broken off with a thumb nail. Mass finishing of hard metal or hardened metal parts breaks off burrs and, by continued action, forms radii on part edges. Parts may be self-tumbled or processed with non-abrasive media and a suitable compound to keep parts and media clean.

_Burrs on soft metals._ If the metal is soft, the burr may fold down against the part. Such parts can be deburred with low density plastic media. Plastic media can often speed up the process by cutting off the burr before it folds over. Compound is used to prevent embedment of fine particles of metal and abrasive in the part surface, suspend fine particles, keep media clean so that a fresh cutting surface is always presented to the workpiece surface.

_Extraud metal._ Burrs comprising extruded material caused by improper machining or stamping have a relatively thick root and must be ground away. In some cases preliminary hand grinding or polishing may be required prior to mass finishing so that extruded material may be removed without possible undesirable alteration of other part surfaces. Deburring of parts in this category is accomplished by processing in abrasive media. Compounds are used to perform the various functions described above.
Edges of steel chain links are deburred and radiused using a wet process in horizontally-mounted centrifugal barrel machines. Cycle time is 20 to 30 minutes. An additional 10-min. cycle with appropriate media produces a smooth surface finish and imparts compressive stress to the chain links.

Hot rolled steel door hinges 6 by 1 in. (152 by 25 mm) are cleaned, deburred to prevent injury to user, and edges blended smoothly to present a uniform appearance after final nickel plating. Load of 2,800 hinges is processed in a round vibrator charged with intermediate-cutting ceramic angle-cut triangle media during a 45-min. cycle.

Intricate aluminum die cast valves 3 by 2½ by 2 in. (76 by 57 by 51 mm) are brightened, trim is smoothed on parting line, six interior triangular openings are deburred in a small round vibrator. Time cycles of 30 to 45 min. with ⅛ in. (3.2 mm) steel ballcones and a high quality burnishing compound removes burrs, reduces edge sharpness.

Hardened steel transmission gears up to about 10 in. (254 mm) O.D. by 1½ in. (40 mm) thick and machined steel washers are cleaned and deburred lightly in 20 min. continuous cycles in a large round vibrator with aggressive random-shaped aluminum oxide media.

Aluminum and cast iron diesel engine components are deburred in 8 to 10 min. cycles in a large round vibrator with conveyor feeding and conveyorized parts unloading. Vibrator is charged with 8,000 lb. (3,600 kg) of ⅛ in. (10 mm) steel ballcone media. Flow-through liquid compound system.

Steel stampings, 6½ by 2½ by ⅜ in. (165 by 64 by 13 mm) are cleaned and deburred in a 16 cu. ft. (453 l) round vibrator in a 7 min. cycle using ⅛ in. (5 mm) hardened steel ballcones and an aggressive liquid cleaning compound at the rate of 3,500 parts per hour. Loading, unloading, parts and media separation are automatic.

Aluminum pistons with a critically machined outside diameter require removal of adhering metal chips and deburring of small interior holes. Parts are automatically loaded from the machining operation and make one pass around an 18 cu. ft. (509 l) round vibrator charged with 4,800 lb. (2,182 kg) of ⅛ by ½ in. (1.6 by 13 mm) steel pins. Deburring and cleaning cycle is 15 minutes. An auxiliary screen deck prevents part damage during the separation cycle.

Components for toys, stamped from prepainted and preplated steel strip, must be deburred to remove burrs and sharp edges for safety in subsequent handling without damage to the plated or painted finish. Parts are processed continuously in a round vibrator during a 7 min. cycle using steel burnishing media and a liquid compound with ultra-low toxicity. Rust inhibition is accomplished on exposed metal edges. System includes automatic rinsing and drying.

Load of 3,000 cold rolled steel hinge stampings is fed automatically into a 40 cu. ft. (1,132 l) vibratory bowl machine—distributed throughout 2,400 lb. (1,089 kg) of ceramic media. Liquid compound flows through the load at a controlled rate. After a 30 min. deburring cycle, the discharge gate rises and a magnetic belt conveyor is activated. Parts are picked up by the magnet, conveyed through a demagnetizer into a transport gondola.

**Generation of Radii**

A mass finishing unit can be used to generate radii to specification economically. In many instances, such radii cannot be formed in any other way. It is true that not all parts can be
radiused by mass finishing because of the geometry of the part, amount of burr or extruded metal present, radius required, etc. However, in many cases savings can still be achieved if the problem areas are hand deburred or radiused initially, after which workpieces are processed by mass finishing. Radii can be generated on workpieces in rotary barrels as rapidly as in vibratory machines, especially when abrasive compounds are used.

Factors influencing cycle time include:
1. Generally, time required varies in direct proportion to the square of the radius. Efficiency and economy suggest that cycles be set up to produce the minimum acceptable radius.
2. Media size. Smaller media require longer cycles since the cutting rate is lower. Parts with holes should be finished with media larger than the holes.
3. Load pressure. Higher load pressures result in faster cutting and/or radius formation.
4. Added abrasives. For fastest cut, compounds containing abrasives are sometimes added. The nature, amount and coarseness of the abrasives can affect the rate of cut. If an abrasive compound with a relatively coarse but friable abrasive is added, the initial cut will be rapid, removing burrs and forming a radius quickly. As the abrasive breaks down during use, the degree of cut will be reduced and the process will change to a polishing operation, producing a very fine finish. Abrasives are added to closed systems such as rotary and centrifugal barrels for most (99 percent) operations of this kind.

Inconel turbine wheels have V-shaped slots around the periphery, and each V is further machined with slots along the edge to form a “Christmas tree” cross section. Each wheel is attached to a fixture, placed in a spindle finishing machine, and rotated for 3 min. in each direction at 800 rpm in a tub of 30-mesh aluminum oxide abrasive. While the fixture is rotating, it is also swung like a pendulum 20 times per minute. The tub of abrasive vibrates to “fluidize” the media. A liquid compound is metered continuously into the tub. Process removes burrs and forms a true blending radius on all exposed edges within the 0.005 to 0.020 in. (0.13 to 0.5 mm) limits.

Intricate Swedish steel stampings used as intake valves on refrigeration compressors—about 1 in. (25.4 mm) in diameter with 47 to 53 Rockwell C hardness—require a full radius on all stamped surfaces so that valves may withstand millions of cycles in use. Quality control is critical. During a cycle of about 48 hours in rotary barrels with mixed sizes of fused aluminum oxide media and an aggressive aluminum oxide compound, 10,000 valves per compartment are processed to produce an edge radius equal to half their thickness of 0.007 to 0.10 in. (0.18 to 2.5 mm). Surface luster and color are improved by a final 1-hour burnish.

Stainless steel stampings for the yoke and slide bars supporting earphones must have an edge radius and burnished finish to prevent injury to user. About 2,000 yokes 3 by 3 by ¾ in. (76 by 76 by 9.5 mm), or 2,600 slide bars 4½ by 1 by ¾ in. (114.3 by 25.4 by 15.8 mm) are finished in a 10.7 cu. ft. (300 l) round vibrator with a high quality liquid compound and very hard random shape fused aluminum oxide media during a cycle of 80 to 90 minutes. Because of the tendency of the horseshoe-shaped parts to nest together, the discharge gate is left in the raised position. A specially-designed screen deck accomplishes careful separation of parts.

Edge sharpness of highly-polished stainless steel stampings 2½ in. (57 mm) O.D. by 5/16 in. (8 mm) must be eliminated to facilitate automatic assembly. Stampings are processed in an 18 cu. ft. (500 l) round vibrator using 5/32 in. (4 mm) steel balls and a special liquid compound. Product cleanliness and surface uniformity are also improved.
Precision ground hardened steel blades for hair clippers, 1\% by 1\% by 3/16 in. (44 by 37 by 5 mm) thick, require an edge radius of 0.0125 in. (0.32 mm) and must have clean, bright surfaces. About 25,000 blades are run in a 10.7 cu. ft. (300 l) round vibrator for 8 hours with an aggressive cutting fused aluminum oxide media and specified liquid compound. Strength and durability of blades are increased.

Cast 356-T6 aluminum diesel fuel injection pump housings are machined to tolerances of plus or minus 0.002 in. (0.05 mm). Using cone shaped plastic bonded quartz abrasive media and compound solution, housings are processed in a centrifugal barrel for 10 min. to deburr, impart uniform radii on all edges, improve surface finish on the seal surfaces, and enhance overall appearance. Large holes inside the pump housings are deburred and cleaned also.

**Material Removal and Size Reduction**

Mass finishing can remove varied amounts of material from surfaces in specific lengths of time, depending on part material and hardness. Normally, little stock is removed from flat surfaces; most is removed from corners and edges. Many parts can be designed oversize in certain dimensions, and brought down to size by finishing. For example, if in the process of developing a surface finish of 8 to 12 microinches (0.20 to 0.30 micrometer) on a hardened steel part, 0.001 in. (0.0025 mm) of stock is removed, the initial grinding operation can be specified so that the part can be mass finished exactly to size.

**Surface Finish Improvement**

Mass finishing can accomplish surface finish improvement with negligible stock removal. This process is particularly valuable for finishing irregularly-shaped parts, where it is hard for a machine tool to maintain a uniform finish. Finishes achieved may be 2 to 3 microinches (0.051 to 0.076 micrometer), or less than 1 microinch (0.025 micrometer), depending on the selection of equipment, media, compound solutions and time cycle. Mass finishing can improve surface finish without distorting the geometry of a surface. If a piece is to have two sides parallel and a surface finish of 3 to 4 microinches (0.076 to 0.10 micrometer), the piece should be machined to the desired parallelism, with the surface at a smoothness of 20 microinches (0.51 micrometer) or less. Mass finishing can then develop the desired finish of 3 to 4 microinches (0.076 to 0.10 micrometer) without distorting the geometry. If geometry is secondary, the part can be brought to the desired surface finish from a surface roughness of 60 to 70 microinches (1.5 to 1.78 micrometers).

Surface finish improvement can be carried out in rotary barrels operated at approximately 30 to 80 sfpm (0.15 to 0.4 smpms), vibratory units set at low amplitudes to provide a gentle action, spindle finishing machines, centrifugal barrels or centrifugal disc machines. Smaller media produce a lower rms surface finish, but a slower cut rate. Various types of abrasive or nonabrasive media can be used.

Zinc die cast plumbing fixtures are polished with 240 grit coated abrasive belts to remove excessive flash and cast-in imperfections, blend die mismatch and produce a more uniform surface. The parts are then run in a vibratory machine with resin-bonded quartz-filled media and a liquid burnishing compound (flow-through system). After a cycle of 40 to 60 min. the part surface finish will be 5 to 7 microinches (0.13 to 0.18 micrometer).

Watch-frame plate surfaces are improved, parts deburred in horizontally-mounted centrifugal barrel machines, with machine turrets rotating in a vertical plane, using a wet process with small abrasive media and a specified compound. Watch-frame plate hole sizes must be held to tolerances of 0.0002 in. (0.005 mm), for example, and many grooves must
have a surface finish of 2 to 3 microinches (0.051 to 0.076 micrometer). Pinions, wheels, other watch parts are similarly processed. Cycle times are generally 1 hour or less depending on the part being finished. Compressive stresses are created on the watch-frame plate surfaces; fatigue failure minimized.

Molds, blanks, and plungers used in the glass industry are processed to remove surface imperfections, eliminate directional scratches, and generate a 3 to 5 microinch (0.07 to 0.13 micrometer) rms surface by centrifugal barrel finishing. Large die molds are fixtured in the machine; fine abrasive accomplishes the desired surface improvement. Vertical or horizontal types of machines can be used, depending on size and shape of the molds to be finished. Surface finish of the mold prior to finishing should be 125 microinches (3.17 micrometers) rms or better. Molds should be free from grease and heavy carbon deposits. Generally a 30 min. cycle will produce a 5 microinch (0.13 micrometer) rms surface on significant areas. Some molds having an 80 to 100 microinch (2 to 2.5 micrometer) rms surface finish can be finished to a 3 microinch (0.07 micrometer) rms surface in 45 minutes. Type of machine and condition of the initial surface determine cycle time.

In the manufacture of hard steel ball bearings a two-drum centrifugal barrel machine is used to remove surface defects along with about 0.008 in. (0.22 mm) of metal from the bearing diameter prior to grinding, lapping, heat treating, final polishing. Each drum of the machine is loaded with 300 lb. (136.3 kg) of 3/4 in. (19 mm) steel balls, 1.5 lb. (0.7 kg) of fine emery abrasive and water to cover the load. Machine turret is operated at 175 rpm while each drum rotates at 53 rpm in the opposite direction, thus developing a “pressure” of 18 times the force of gravity. Stock removal is 0.006 in./hr. (0.15 mm/hr). Cycle time is 30 min. to 3 hr. depending on stock removal required. A smoother final surface finish is obtained; fatigue life of the bearings is greatly improved.

Burnishing

Burnishing with hardened steel balls and shapes can be carried out in horizontal barrels, round vibrators, or centrifugal barrel machines. The operation is used to produce a smooth mirror-like surface either as a final finish, or on parts to be plated with various metals, coated with clear organic finishes, etc.

Initial metal surface conditions can vary from a rough matte to various degrees of smoothness. A matte surface is composed of hills and valleys or grooves and ridges. The burnishing medium, applied against the part surface under pressure, “peens” the surface, producing surface flow and a smoother surface finish. The force applied by the burnishing media must exceed the elastic limit of the metal crystals or flow will not take place. If pieces of the same metal with different degrees of surface roughness are burnished, the ones with the better initial surface can be smoothed more readily than the others. If a part can not be burnished to the desired surface finish within a reasonable time cycle, then pre-burnish operations must be refined. Final brilliance and depth of color obtainable by burnishing are determined by the chemical conditions existing in the barrel or machine, and pretreatment of the parts before burnishing. Parts should be precleaned to remove grease, oils, lubricants, tarnish, scale, oxides, and abrasive materials. Flow-through vibratory systems are most suitable for an automated, continuous operation, since the cleaning solutions, rinse water and burnishing solutions can be automatically sequenced to the load.

Zinc base die cast appliance components are burnished to brighten, smooth, and remove surface and edge roughness in a vibrator which processes 600 workpieces per load during a 15 min. cycle. A media mixture of 3/16 in. (4.7 mm) steel diagonals and 5/16 in. (7.9 mm) steel balls is used with a biodegradable liquid compound (flow-through system). At the end of the cycle, parts are unloaded automatically; media remain in the machine.
Stainless bezels for instruments and automotive applications are deburred and burnished in a round bowl vibrator using hardened steel media and a suitable liquid compound solution. Cycle times of 10 to 30 min. achieve the desired surface finish, using either batch or continuous operation according to production conditions.

Preparation of Surfaces for Plating or Painting

Mass finishing of machined, extruded, cast, or die cast workpieces can prepare them for plating or improve adhesion of paint films effectively and economically. Burrs are removed, radii generated, and surfaces freed from oxides, mold release residues and surface imperfections. Generally preplate or prepaint mass finishing is carried out with resin-bonded, metallic, or ceramic media having no cut, or a very light, fine cut in order to obtain a low microinch finish. Proprietary compounds used are designed to condition surfaces chemically for plating or painting, prevent deposition of objectionable or hard-to-clean residues. Depending on the initial condition of the surface, one or more finishing steps may be required, sometimes using different types of media and compound, in order to achieve a uniform preplate surface with a low microinch finish and a bright luster. Substrates so processed are easier to clean in the plating or painting cycle. Bond adhesion on metals to be painted or lacquered can also be improved during mass finishing through chemical action of special compounds which form oxides, chromates or phosphate films on the metal surface.

Dry-process mass finishing can also be used to prepare metal surfaces for electroplating. Media composed of fine abrasive powders bound to random-shaped materials such as sized sawdust, corn cob granules, ground walnut shells or hardwood preforms are employed in rotary barrels, vibrators, spindle machines, centrifugal equipment. All or a portion of the relatively inexpensive granular media can be mechanically separated at the end of each cycle. This prevents a build-up of spent abrasive and metallic fines and soils. Steel garment clips are prepared for plating in a single-cycle dry process using hardwood performs mixed with granular media treated with special cut/coloring abrasives. Costume jewelry can be prepared for electroplating by means of a dry process using hardwood preformed media and granular media treated with polishing abrasives.

Steel jewelry and belt buckle parts can be given a preplate finish in rotary barrels, vibrators, or centrifugal equipment with 3/16 in. (4.7 mm) steel ball or ballcone media and a high quality anti-corrosive burnishing compound in cycles of less than 15 min. to 90 minutes. Steel functional parts for home appliances can be prepared for plating using ceramic media. Die cast furniture hardware is processed in tub vibrators for 1 to 2 hr. with silica-filled resin bonded media. Liquid burnishing compound is added via a flow-through system to keep media and parts clean throughout the process.

Cast iron transmission housings, weighing 30 lb. (14 kg) each, and 8 3/4 by 9 1/2 by 11 1/4 in. (222 by 235 by 292 mm) in size, after machining, are cleaned, deburred, surface finished to promote paint adhesion in a 47 cu. ft. (1,340 l) round vibrator during 15 min. continuous cycles. Vibratory burnisher is charged with 16,000 lb. (7,300 kg) of 1/4 in. (6.4 mm) hardened steel ballcones with a special liquid compound to remove organic soils. Unloading is automatic and continuous.

Investment cast steel golf club heads are polished manually on a 150-grit belt. Club heads are then mounted on fixtures and run in a spindle machine for 8 to 10 min. using wet random fused aluminum oxide media. Fixture heads are then run in another spindle machine with dry media such as corncobs or treated walnut shells for 8 to 10 minutes. Ten
Club heads are mounted on each fixture; four fixtures are run in the spin finishing machine at one time.

Forged steel golf club heads are machined, rough polished on an 80-grit belt, then polished with a 150-grit resin bonded belt. Club head surfaces are smoothed for plating in either a bowl vibrator or, mounted in a large fixture, in a tub vibrator. The tub vibrator holds one fixture containing 300 club heads. Media are 1/2 to 3/4 in. (1.27 to 1.90 mm) plastic cones. A biodegradable liquid compound containing a detergent and a rust inhibitor flows through the mass continuously. After a 3 hour cycle during which the fixture load of parts rotates slowly on its own axis in the machine, the steel club head surfaces are ready for electroplating. Club heads are also processed without fixtures in a vibratory bowl, using similar media and compound. Cycle time is 5 hours.

Die cast license plate frames are deflashed and smoothed for electroplating in a 60 cu. ft. (1,698 l) round vibrator. A load of 200 license plate frames is placed in the machine, which is charged with 3/4 in. (19 mm) cone-shaped plastic media containing silicon carbide abrasive. A biodegradable liquid compound solution is metered into the mass continuously at the rate of 32 gal./hr. (2.4 l/min.). Used compound and abrasive fines discharge through a perforated drain. After the 1 hour cycle is completed, the discharge gate is put in place and the parts are automatically unloaded from the machine; media is retained.

Polishing Plated Parts
Surfaces plated with the softer metals, such as silver, brass or copper, can be burnished to form a brilliant surface luster with, in some cases, reduced surface porosity for enhanced corrosion resistance. A bright, inhibited surface finish can be produced on brass plated steel door hinges by processing in vibrators with steel media. Electroplated silver can be polished using a neutral compound and steel media with a media: parts ratio of 12:1 (by volume).

Silverware Maintenance
Silver plated flat and hollow ware can be kept clean and bright by routine tarnish removal, with one of several proprietary solutions, and burnishing with steel or porcelain media. Scratches and dings, in which food particles could lodge, are removed and the brilliant surface restored. Vibratory machines of low amplitude or wood (hard maple) lined horizontal barrels are generally used; burnishing media added in a ration of 12:1 media: parts by volume. Barrels should be loaded to 50 percent of capacity, with the solution (water plus burnishing “soap”) covering the load. Media may include various sizes of steel balls and pins, or a mixture of steel ballcones and diagonals to reach corners and recesses. Cycles of 10 to 20 min. in barrels are common.

Changing Stress in Metals
When metals are blanked, formed, or machined, stresses which can become focal points for fatigue cracks and part failure are created. Surface tensile stresses are reduced or eliminated and surface compressive stresses sometimes imparted to workpieces in mass finishing. Parts receive a peening action from the impact of the parts and media in rotary barrels, or from the impact imparted by vibratory and centrifugal barrel equipment. Large, higher density media and long cycles are employed in rotary barrels. Vibrators can easily reduce tensile stresses by cutting away stress risers. In vibratory machines the amplitude should be as high as the structure of the part will permit without causing damage or impingement. Stress relief can be obtained in a much shorter time in vibrators and centrifugal equipment than in rotary barrels.
Many mechanical and structural components are treated to impart compressive stresses in the workpiece surface. Formation of minute surface cracks and fatigue failure through flexing of the surface during service is delayed or prevented. Among the many products mass finished in centrifugal barrels to develop compressive surface stress are transmission chain links, coil springs of all shapes and kinds, flapper valves, jet engine components, watch frames. The amount or degree of compressive stress developed depends on centrifugal barrel cycle time and force employed.

**Extending Forming Tool Life**
Mass finishing of parts after forming and prior to subsequent additional forming reduces wear on forming die pads. Removal of burrs, generation of radii, and smoothing of the metal surface, make possible increased forming tool life. In successive deep drawing operations, mass finishing between draws will remove annealing scale, relieve stresses from previous draws, improve the surface finish.

**Conditioning Parts for Automatic Assembly**
Automated assembly involving small parts such as rivets, screws and eyelets, depends on the smooth flow of parts through automatic machinery. Mass finishing can improve part uniformity by providing the parts with the required surface smoothness, imparting an increased fluidity to the mass of parts during automatic feeding and assembly. Parts are usually self-tumbled in open-end barrels or vibrators with burnishing compounds in relatively short cycles (30 to 60 min. in rotary barrels—possibly shorter cycles in vibrators).

**Developing a Lubricative Surface**
When a cylindrical surface is ground, the fine grinding lines run circumferentially around the surface. When this ground (or even ground-and-buffed) surface is rotated past a contacting surface, the lubricating oil film will squeegee ahead of the contact point and thus fail to lubricate the surface. Rapid wear of the contacting member can result. Random scratch pattern imparted by mass finishing creates a good surface to hold oils and other lubricants. A surface so treated has extended the life of a cam follower ten times that of one with a ground, highly polished surface.

**Conditioning Metal for Improved Spot Welding**
Some ferrous alloys can be mass finished to improve spot welding properties, but aluminum workpieces are processed most often for this purpose. A uniform film of aluminum oxide on the metal surface is essential for good spot (resistance) welding. Generally, ceramic bonded media with a nonabrasive compound capable of cleaning and chemically conditioning the surface are used in the finishing process. Cycles are short—1 to 4 hours in rotary barrels—shorter in vibratory or centrifugal equipment.

**Developing Nonreflective Surfaces**
Nonreflective or matte surfaces can be obtained on parts, such as tool handles, instrument panels, etc. by mass finishing. Parts are processed with aggressive media or coarse abrasive deburring compounds, using enough water to dampen the load. Uniform matte finishes can be developed, and consistent results obtained if operating conditions are held constant. Small burrs can be removed during the process.

**Cryogenic (Low Temperature) Mass Finishing**
Mass finishing in barrels or vibrators can remove flash from plastic or molded rubber flexible components (sometimes aluminum or zinc die castings) after parts have been frozen
to make them rigid and brittle. Soft and stringy burrs can be removed from parts machined from bars, sheets, or extrusions of flexible or semi-rigid material. If the base of the flash is to be cut loose, any type of abrasive media may be used. This will also generate radii. If only the flash is to be removed, self-tumbling (part on part) or tumbling with nonabrasive media will be effective. Vibrators make possible rough deflashing and/or radii generation in short cycles.

Cooling may be achieved by injecting liquid nitrogen into the equipment. Care is required in handling the cold parts and media. Temperatures as low as -320 deg. F (-196 deg. C) are used for some parts; temperature control during processing is essential. An open or well-vented machine is required to permit vapor to escape. Barrels and vibrators used for cryogenic finishing require special double-walled, insulated work chambers to conserve the coolant. Generally, media are cooled in the work chamber before the parts are added. The entire load is then chilled before starting the cycle.

Polishing Plastics

Plastic components formed from ABS, cellulosics, polyvinyl butyral, impact styrene, clear cast methylmethacrylate, acetates, polyesters, propionate, nylon, phenolics, can require not only deflashing but extensive surface refinement. Typical plastic products requiring surface improvement include eyeglass frames, sun glasses, buttons, costume jewelry, bottle caps and jar lids, electronic capacitor canisters, telephone housings, tool handles, acrylic castings, plastic drapery hardware. Specified surface refinement can be achieved by “dry process” mass finishing in hardwood preforms and/or other materials plus various types of abrasives. The surfaces generated are comparable in quality to those produced by hand buffing. Surfaces are uniform, varying little from part to part or load to load.

Depending on the roughness of the initial surface and the final result specified, mass finishing is usually done in three or four steps. A final waxing can be added to achieve maximum surface reflectivity. Generally, the first cycle deflashes and removes surface irregularities while radiusing edges. For this step an oil/powdered abrasive mixture is dispersed into the hardwood media. A second “cutting” step may be required, using finer abrasives, to produce the desired result. Workpiece surfaces should exhibit a soft, matte finish at this point. The plastic parts are then cleaned to remove abrasives and fines prior to final burnishing or polishing. Workpieces are then run in a clean barrel or machine with clean hardwood preforms to which burnishing cream is added. Final waxing, if desired, is accomplished in a clean barrel with clean hardwood preforms plus a waxing/polishing cream. Nature of the part determines type of finishing machine employed.

Drying Parts

Plated or mass finished parts can be dried with no water spotting in drum-type dryers, through-feed barrels or round vibrators operating continuously. Cob meal or other media is heated; two-minute cycles usually suffice. Surfaces are wiped, water spots are removed, parts are dried. This method is not recommended for parts with small threaded holes; cob meal can lodge.
WASTE TREATMENT OF MASS FINISHING PROCESS SOLUTIONS

Processing solutions and rinse waters from mass finishing operations may contain dissolved chemicals, metals, suspended abrasive or insoluble particles, foam, and/or other metallic particles. After initial collection in a sump the waste may go through cyanide destruct, chrome reduction, and neutralization steps to precipitate the metals. After a coagulant aid such as a polymer is added, the precipitated metals are settled out in a clarifier. The sludge is removed from the bottom. The clear effluent solution may be filtered to remove trace amounts of suspended material prior to discharge to a city sewer or waterway. The sludge may be further dewatered through filter presses and dryers prior to ultimate disposal in landfills. The EPA and other local regulations should be monitored to determine the local requirements for compliance with effluent and sludge disposal regulations. In particular, the sludge should be analyzed to determine its hazardous status relative to compliance with the RCRA and EPA regulations prior to disposal.

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ABRASIVE ENGINEERING SOCIETY
118 Main Street
P.O. Box 461
Connoquenessing, Pennsylvania 16027
(412) 789-9141

ALUMINUM ASSOCIATION
900 Nineteenth Street, N.W.
Suite 300
Washington, D.C. 20006
(202) 862-5100

AMERICAN ELECTROPLATERS AND SURFACE FINISHERS SOCIETY
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Orlando, Florida 32826-3298
(407) 281-6441

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SOCIETY OF MANUFACTURING ENGINEERS
BEST Division
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Dearborn, Michigan 48128
(313) 271-1500

SOCIETY OF PLASTICS ENGINEERS
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Brookfield Center, Connecticut 06805-0403
(203) 775-0471
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<td>5000 East 10th Court</td>
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<td>Hialeah, Florida 33012</td>
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<tr>
<td>ALLOYCRAFT LIMITED</td>
<td>12 Raitherm Road</td>
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<td></td>
<td>Toronto, Ontario M6B 1S6</td>
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<tr>
<td>AMERICAN CHEMICAL &amp; REFINING CO., INC.</td>
<td>A Handy &amp; Harman Company</td>
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<td></td>
<td>P.O. Box 120</td>
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<td></td>
<td>Waterbury, Connecticut 06720</td>
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<tr>
<td>AMERICAN CHEMICAL WORKS COMPANY</td>
<td>365 Charles Street</td>
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<tr>
<td></td>
<td>P.O. Box 6031</td>
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<td></td>
<td>Providence, Rhode Island 02940</td>
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<tr>
<td>AMERICAN PLATING SYSTEMS</td>
<td>2150 Maple Privado</td>
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<td></td>
<td>Ontario, California 91761</td>
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<tr>
<td>AMERICAN TRIPOLI</td>
<td>Div. of PMI</td>
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<tr>
<td></td>
<td>222 Oneida Street</td>
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<td></td>
<td>Seneca, Missouri 64865</td>
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<tr>
<td>AMERICHEM DIVISION</td>
<td>INTERNATIONAL METALS &amp; CHEMICALS, INC.</td>
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<tr>
<td></td>
<td>5129 Unruh Avenue</td>
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<td></td>
<td>Philadelphia, Pennsylvania 19135</td>
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<tr>
<td>AMES METAL PRODUCTS CO.</td>
<td>4323 S. Western Boulevard</td>
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<tr>
<td></td>
<td>Chicago, Illinois 60609</td>
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<tr>
<td>AMETEK, INC.</td>
<td>Hoveg Division</td>
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<td></td>
<td>900 Greenbank Road</td>
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<tr>
<td></td>
<td>Wilmington, Delaware 19808</td>
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<tr>
<td>AQUALOGIC, INCORPORATED</td>
<td>30 Devine Street</td>
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<tr>
<td></td>
<td>North Haven, Connecticut 06473</td>
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<tr>
<td>ATLANTES CHEMICAL SYSTEMS, INC.</td>
<td>303 Silver Spring Road</td>
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<tr>
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<td>Conroe, Texas 77303</td>
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</tbody>
</table>
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Detroit, Michigan 48207

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Buffalo, New York 14213

G S P METALS AND CHEMICALS CORPORATION
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Los Angeles, California 90040

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P.O. Box 558
Springfield, Massachusetts 01101

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Toronto, Ontario M8Z 5J7
Canada

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Chicago, Illinois 60618

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St. Louis, Missouri 63131

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509 N. Wolf Road
Wheeling, Illinois 60090

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Springfield, Massachusetts 01101

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Somerville, New Jersey 08876

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Waterbury, Connecticut 06720

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Belleville, Michigan 48111

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Chicago, Illinois 60628

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P.O. Box 44
Royal Trust Tower, Toronto Dominion Centre
Toronto, Ontario M5K 1N4,
Canada

INDUSTRIAL CHEMICAL & EQUIPMENT COMPANY
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Minneapolis, Minnesota 55413

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Whitehouse Station, New Jersey 08889

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Separations Technology Division
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Watertown, Massachusetts 02172

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2155 112th Avenue
Holland, Michigan 49424

JACKSON BUFF
A unit of Jason Incorporated
Highway 70 East
P.O. Box 699
Conover, North Carolina 28613

JASON ASSOCIATES
P.O. Box 150
Braintree, Massachusetts 02184
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Jenison, Michigan 49428

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P.O. Box 1287
Forest City, North Carolina 28043

K.L.N. SUPPLIES
335 W Oakbrook Dr
Birdsboro, Pennsylvania 19508

KIESOW INTERNATIONAL CORPORATION
201 Greer Drive
P.O. Drawer 808
Mauldin, South Carolina 29662

KINETICO INCORPORATED
P.O. Box 193
10645 Kingman Road
Newbury, Ohio 44065

KINGSPOR ABRASIVES, INC.
2555 Tate Blvd., S.E.
P.O. Box 2367
Hickory, North Carolina 28603-2367

KOCOUR COMPANY
4800 South St. Louis Avenue
Chicago, Illinois 60632

KONTIK ECOLOGY SYSTEMS INC.
4450 Corporate Dr.
Unit 6
Burlington, Ontario L7L 5R3,
Canada

KRAFT CHEMICAL COMPANY
1975 North Hawthorne Avenue
Melrose Park, Illinois 60160

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960 Close Avenue
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30 North 8th Avenue
Maywood, Illinois 60153

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181 Thorn Hill Road
Warrendale, Pennsylvania 15086

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237 East Aurora Street
P.O. Box 71
Waterbury, Connecticut 06720

LEA PRODUCTS COMPANY INC.
7355 Jean Valets Avenue
Montreal, Quebec H1E 3H4,
Canada

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272 Buffalo Avenue
Freeport, New York 11520

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3748 East 91st Street
Cleveland, Ohio 44105

DAVID K. LUCAS & ASSOCIATES
16918 Landing Drive
Spring Lake, Michigan 49456

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54 Waltham Avenue
P.O. Box 90247, Highland Station
Springfield, Massachusetts 01139

M & T CHEMICALS INC.
One Woodbridge Center
Woodbridge, New Jersey 07095

M & T CHEMICALS LTD.
1180 Corporate Drive
Burlington, Ontario L7L 5R6
Canada

MAC DERVID CHEMICALS INC.
1275 Crestlawn Drive
Mississauga, Ontario L4W 1A9
Canada

MAC DERVID INCORPORATED
245 Freight Street
Waterbury, Connecticut 06702

THE MATCHLESS METAL POLISH COMPANY
840 West 49th Place
Chicago, Illinois 60609-5196

MAURER-SHUMAKER, INC.
37025 Industrial Road
Livonia, Michigan 48150

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1250 Terminal Tower
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MEMTEK CORPORATION
28 Cook Street
Billerica, Massachusetts 01821
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840 Colfax Avenue
Kenilworth, New Jersey 07033

PLATING SPECIALISTS, INC.
18 N. Ft. Thomas Ave., Suite 6A
P.O. Box 370
Fort Thomas, Kentucky 41075

PLATING SYSTEMS INC.
538 Forest Street
Kearny, New Jersey 07032

PLATING SYSTEMS & TECHNOLOGIES, INC.
317 North Mechanic Street
Jackson, Michigan 49201

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P.O. Box 272
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Lawrenceburg, Tennessee 38464

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Aspen & Belmont Street
Easton, Pennsylvania 18042

QUADRA CHEMICALS LIMITED
2121 Agrentia Rd., Ste. 303
Mississauga, Ontario L5N 2X4
Canada

QUANTUM TECHNOLOGIES, INC.
Water Management Division
P.O. Box 223
Jones Mill Industrial Park
Jones Mill, Arkansas 72105

QUIN-TEC INC.
14057 Stephens
Warren, Michigan 48089

RACK PROCESSING COMPANY, INC.
2350 Arbor Boulevard
Dayton, Ohio 45439

RAMPE FINISHING EQUIPMENT COMPANY
Division of Raum Corporation
14915 Woodworth Avenue
Cleveland, Ohio 44110

RAND-BRIGHT CORP.
2940 S. 166th Street
New Berlin, Wisconsin 53151

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Graysbridge Road
Brookfield, Connecticut 06804

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1840 Fenpark Drive
Fenton, Missouri 63026-2922

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7930 Jones Road
P.O. Box 05070
Cleveland, Ohio 44105

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1605 E. Central
Arlington Heights, Illinois 60005

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4831 South Whipple
Chicago, Illinois 60622

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1215 2nd Avenue
New Hyde Park, New York 11040

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111 Westboro Street
P.O. Box 255
Dayton, Ohio 45401-0255

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101 South Waterman Street
Detroit, Michigan 48209

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Schaffner Center
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Muellerstrasse 170-178
1000 Berlin 65
West Germany
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14041 Meyers Road
Detroit, Michigan 48227

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P.O. Box 329
Westport, Connecticut 06881

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358 Romans Road
Elmhurst, Illinois 60126

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41 Blackstone Boulevard
Providence, Rhode Island 02906

VULCANIUM CORPORATION
3045 Commercial Avenue
Northbrook, Illinois 60062

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1236 Birchmont Road
Scarborough, Ontario M1P 2C8
Canada

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5311 W. River Road, North
Lorain, Ohio 44055

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1126 Wrigley Way
Milpitas, California 95035

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1703 S.W. Clay Street
Portland, Oregon 97201