REPORT ON POLLUTION PREVENTION IN MASS FINISHING OPERATIONS

DRAFT
Mass finishing is used by a variety of manufacturers to deburr and/or polish metal parts. Vibratory and tumbling operations are two common types of mass finishing. A result of any mass finishing operation is the generation of waste in the form of wastewater and sludge. Traditionally, waste streams from mass finishing operations have been chemically treated to meet sewer discharge requirements. In most instances and prior to chemical treatment, mass-finishing wastewater is mixed with other metal-bearing waste streams originating from very different manufacturing operations.

A new, preferred approach towards minimizing the generation of waste from mass finishing operations is called pollution prevention. Pollution prevention or source reduction means that waste should be reduced or eliminated at the source as opposed to end-of-pipe treatment. For the mass-finishing operation, pollution prevention measures include process modification and in-process recycling. Input materials such as the metal type, finishing media, and soap should be studied for possible modification to prevent potential waste. The type of mass finishing equipment employed in the process can also influence the amount of waste generated. In some cases, hazardous or toxic cleaning chemicals can be replaced by the aqueous-based rubbing or vibratory operation. Once all possible process modifications are made and waste streams segregated, the finishing solution can be recycled to further minimize waste leaving the operation. Simple, coarse, and membrane filtration techniques are available for achieving solution reuse. In some applications, the same soap solution can be reused for up to one year.

In the final analysis, pollution prevention techniques should be applied to mass finishing operations to eliminate the need for costly chemical treatment thereby reducing chemical purchase costs and minimizing the volume of waste sludge generated. Soap purchases, water/sewer fees, and environmental liabilities may all be reduced. In most cases, a reasonable payback is achieved on equipment purchases. Many Rhode Island companies have already successfully implemented pollution prevention into their mass-finishing operations with excellent results.
Background

Mass finishing is a mechanical process used to deburr, polish and/or clean a variety of manufactured parts and can be found in industries such as jewelry and machine tool manufacturing. The size of the parts range from small jewelry pieces that measure fractions of an inch to large, heavy metal parts that are several inches long. Table 1 lists some of the industries in which mass finishing operations are commonly found. In Rhode Island, many jewelry manufacturers rely on some type of mass finishing technology. Other industries that utilize mass finishing operations include buckle, fastener, and pen tip manufacturers.

<table>
<thead>
<tr>
<th>Table 1: Some Industries That Rely on Mass Finishing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft</td>
</tr>
<tr>
<td>Jewelry</td>
</tr>
<tr>
<td>Clothing Accessories</td>
</tr>
<tr>
<td>Automotive</td>
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<tr>
<td>Electronics</td>
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</tbody>
</table>

Many different metal types are used including aluminum, brass, zinc, and lead. Typical alloy formulations are shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2: Example Alloy Formulations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
</tr>
<tr>
<td>Zinc Die Casts</td>
</tr>
<tr>
<td>Brass Pen Tips</td>
</tr>
<tr>
<td>Costume Jewelry</td>
</tr>
<tr>
<td>Aluminum Handles</td>
</tr>
</tbody>
</table>
A few non-metal pieces such as golfball covers, eyeglass frames, and rubber ball check valves are also mass-finished. Although this report focuses on metal parts, most of the concepts can be applied to non-metal parts as well.

In order to deburr, polish and/or clean metal parts, water-based chemicals (liquid compounds) and ceramic or plastic media are typically used in either a vibrating basin (vibratory) or a rotating barrel (tumbling or tubbing), as seen in Figures 1 and 2. Centrifugal barrel and disc finishing (not shown) are high energy operations and provide for more efficient deburring/polishing action. The high energy is achieved with the added centrifugal force obtained by the high spinning rates of the basin.

What do mass finishing machines look like?

How do they work?

Figure 1: Vibratory Operation

Figure 2: Tubbing Operation
Vibratory machines can be as small as 1 foot in diameter or as large as 20 feet in diameter. Occasionally, metal-based media like steel shot is used. The parts are finished by shaking or rotating in a container which holds the metal parts, media, liquid compound, and water. The purpose of the finishing compound solution is to 1) provide a certain amount of lubricity between the polishing media and metal parts, 2) produce a desired finish appearance on the metal parts, and 3) ensure that the parts and media kept clean during processing. In some cases, no media is used; the metal parts themselves create the mechanical polishing action, also known as "part on part" processing. Table 3 lists media that are widely used.

**Table 3: Commonly-used Finishing Media**

<table>
<thead>
<tr>
<th>Media Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea Formaldehyde (UF)</td>
</tr>
<tr>
<td>Polyester-based</td>
</tr>
<tr>
<td>Ceramic-based</td>
</tr>
<tr>
<td>Steel, Stainless Steel</td>
</tr>
<tr>
<td>Agricultural Products (corn cob, wood)</td>
</tr>
</tbody>
</table>

The type and shape of media used depends on the material composition, size, shape and desired finish of the metal part. Finishing media come in many sizes and shapes such as cones, cylinders, and pyramids. Small metal parts are finished best with small media while large parts would generally require larger media. Another important part of the mass finishing operation is the type of water-based soap used.

A wide variety of finishing compounds exist, almost all of which are water-soluble. Some chemicals are better for burnishing (or polishing) while others are better suited for cutting and deburring. Depending on the metal alloy, some solutions are better than others. The pH range of finishing compounds is fairly wide; neutral (pH = 7), acidic (pH 2-7), and caustic (pH 7-13) compounds are used. The amount of soap and water solution used in the vibratory/tubbing operation depends on the machine type and size, the media type and the metal part being polished. Most vibratory machines are operated in the continuous mode where clean, soapy solution is trickled over the top of the media/metal mixture (Figure 1). By contrast, the
tumbling machine is run in a batch mode (Figure 2). Centrifugal barrel machines are run in the batch mode whereas the centrifugal disc machine is run continuously. Operating or cycle times vary: some parts require only a few minutes while other parts are processed for many hours. The waste effluent, whether from a batch or continuous process, consists of soapy water, pulverized media, and both soluble and insoluble metals of the type found in the metal parts being processed.

Typical Mass Finishing Waste Streams

Figure 3 describes the flow scheme of the typical mass finishing operation.

![Figure 3: Process Flow Diagram](image)

Depending on the finishing operation, the waste solution generated can vary. Analytical tests were carried out on used solutions at different Rhode Island companies. While the results vary, some general consistencies are observed. Most of the solids found in the waste stream consists of plastic or ceramic media. Since the hardness of the metal parts is much higher than that of most plastics and ceramics, the plastic and ceramic media tend to erode faster than the metal. However, significant metal levels of the metal type used in the finishing operation are still observed. For example, one company manufactures zinc alloy fasteners; the vibratory operation used to clean and polish these fasteners produces a waste stream that
contains 320 mg/l of zinc and 1770 mg/l of total suspended solids (TSS). In all of these cases, the solution cannot be discharged to the sewer without treatment because of high levels of metals, suspended solids and sometimes oil & grease. Traditional treatment has included end-of-pipe chemical addition to remove metals and solids prior to discharge.

**Traditional Treatment Technologies**

Chemical treatment technologies have been used by many companies to produce water clean enough for sewer discharge (see Figure 4). In most cases, different chemicals are used for pH-adjustment and metal flocculation. The end result is metal-free water and precipitated metal sludge that is usually dewatered with a filter press prior to off-site disposal as waste and sometimes even hazardous waste. In companies that rely on other waste-generating processes such as electroplating, the tubbing/vibratory waste is sometimes mixed with these other streams prior to end-of-pipe treatment. Depending on the capacity of the finishing operation and any other wastewater-producing process in the plant, the costs of these chemical treatment systems vary.

Capital and operating costs can vary widely for different waste streams and flow capacities. The major capital costs include tanks, controls, pumps, and mixers. The major operating costs include chemical costs, labor, and sludge disposal. If the sludge is hazardous, the operating costs increase significantly due to higher disposal and labor costs. Liabilities are also much greater. Sound pollution prevention or source reduction measures can result in substantial reductions in costs and liabilities.
Pollution Prevention Options

Pollution Prevention is now the preferred method for environmental protection. In contrast to the end-of-pipe waste treatment approach, pollution prevention is defined by the U.S. Environmental Protection Agency as "the use of materials, processes or practices that reduce or eliminate the creation of pollutants at their source". Pollution prevention or source reduction, the major theme of pollution prevention, can be carried out in many ways. Where source reduction is successfully used, the need for treatment and disposal is minimized. Most of the technical-based solutions are process engineering modifications that require varying amounts of development research and testing. As is noted later in this report, there exist many effective technical solutions that have been developed by different organizations, information that can be readily shared with other companies. Some examples of process modifications include replacing waste-generating input materials with other materials that do not produce as much waste. In-process recycling of spent materials is also considered a viable source reduction measure since actual waste leaving the process has been reduced. Off-line recycling, such as the reclamation of waste materials at a different facility, is considered to be a secondary option to source reduction. End-of-pipe treatment and disposal is the last resort when source reduction and recycling are impractical (see Table 4).

<table>
<thead>
<tr>
<th>Table 4: Pollution Prevention Hierarchy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Source Reduction</strong></td>
</tr>
<tr>
<td>process modification to eliminate or reduce pollutants at the source</td>
</tr>
<tr>
<td>e.g., solvent elimination, better housekeeping, in-process recycling of spent materials</td>
</tr>
<tr>
<td><strong>B. Recycling</strong></td>
</tr>
<tr>
<td>off site processing of waste materials for reuse</td>
</tr>
<tr>
<td>e.g., sludge reclamation for metal recovery</td>
</tr>
<tr>
<td><strong>C. Treatment &amp; Disposal</strong></td>
</tr>
<tr>
<td>end-of-pipe treatment of waste prior to disposal</td>
</tr>
<tr>
<td>e.g., chemical treatment system that treats several waste streams prior to sewer discharge with hazardous sludge generation</td>
</tr>
</tbody>
</table>
Management plays a crucial role.

Process inputs and waste solutions vary from operation to operation. The combination of metal, media, soap, machine, and even the quality of incoming process water affect the waste stream. Changing one variable may result in significant pollution reductions; changing more than one variable may prove to be even more effective. The recommendations presented below are intended to provide the manufacturer with some potential options to reduce waste.

A. Management Approach

Company management is critical to the success of any pollution prevention program. Unless managers are willing to ensure that process modifications are implemented, changes will not take place and waste will not be reduced. Better housekeeping on the manufacturing floor will inevitably lead to less waste. Careful monitoring of process input materials (e.g., eliminating excess chemical use) will also prevent some waste generation. The success of any pollution prevention program, then, is the result of a cooperative working approach that involves management commitment and a well thought out plan. Even where effective processes have been developed to reduce pollution, success can be limited when proper implementation and supervision are lacking.

B. Mass Finishing Process Modifications

As shown in Figure 3, there are four basic input materials in the mass finishing operation: metal parts, media, soap, and water. The type and amount (or flow rate) of each input material are considered in the overall analysis of the process. Replacement or modification of process material types and quantities may reduce or increase the amounts of pollutants generated. The type of mass finishing machine must also be considered. While process modifications are considered to be true source reduction, much of the following discussion is about varying parameters that may not seem changeable at first. The most important aspect of mass finishing, final product quality, cannot be compromised. It is suggested that companies investigate any possible process modification that may reduce
waste. Once all possible process modification have been made, then in process recycling and off site recycling should be considered.

Metal Parts

Metal composition and part finish are usually dictated by the customer, so the entire operation is designed around customer specifications. Nevertheless, opportunities may exist to modify alloy compositions to reduce or eliminate the generation of pollutants and/or hazardous waste. As shown in Table 2, some metal alloys contain one or more of the "listed" metals that, if present in high enough concentrations, can render a waste sludge hazardous. Sludge from mass finishing operations would be characterized as hazardous if it fails the Toxicity Characteristic Leaching Procedure (TCLP) test for any of the eight listed heavy metals. The metals that are listed as potentially hazardous are shown in Table 5.

<table>
<thead>
<tr>
<th>Table 5: Metals in Waste Form Regulated as Hazardous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
</tr>
<tr>
<td>Mercury</td>
</tr>
<tr>
<td>Chromium</td>
</tr>
<tr>
<td>Beryllium</td>
</tr>
<tr>
<td>Lead</td>
</tr>
<tr>
<td>Barium</td>
</tr>
<tr>
<td>Silver</td>
</tr>
<tr>
<td>Arsenic</td>
</tr>
</tbody>
</table>

The costs of generating hazardous waste are significant. Hazardous waste creates more paperwork, exposes companies to liabilities, costs more to dispose than non-hazardous waste, and may require a special permit for recycling or on site management. Reducing the use of hazardous materials can lead to considerable cost savings.

If potential hazardous metal constituents can be eliminated, source reduction is successfully applied. A manufacturer may have to modify its operation. Investigation into the use of the finished product may provide some helpful insight. Is it possible for alternative metal alloys to be used? Careful consideration into all the possibilities should be taken. Meetings with manufacturing personnel as well as customers may be necessary. In most cases, a test program is required to
How does finishing media contribute to the waste stream?

Media selection depends on both product quality and potential waste generation.

determine feasibility. A metal manufacturer has recently developed a "lead-free" white metal substitute which offers a potential material substitute to many costume jewelry companies. The incentive for successful metal replacement is reduced liabilities and waste management/disposal costs.

Finishing Media

Selection of the proper media plays an important role in the minimization of potential sludge generation. Listed in Table 3 are several types of media that are available for mass finishing. Two critical parameters are the shape and hardness of the finishing media. Media are selected on the basis of metal part type, shape, and desired finish. As part of the mass finishing operation, mechanical erosion of both media and metal occur continuously, causing the formation of metal and media particles in the soap solution. In addition, some metal is dissolved into solution. The resultant "dirty" solution contains potential pollutants that have been traditionally treated with chemicals to remove metals and suspended solids prior to discharge. While product quality may be satisfactory, some companies may be using media that is too soft and wears down quickly, thus creating excess waste and high media purchase costs. Consultation with the media supplier may open up opportunities to change the media to another type that still provides for the same product quality but does not wear down as fast.

Testing at various Rhode Island facilities indicate that solids from the waste solution are predominantly made up of finishing media when plastic and/or ceramic media are used. Solids analyses carried out at different companies revealed that over 80% (by weight) of the waste solids collected were non-metallic. If traditional chemical treatment is used to clean the waste solution prior to discharge, the total volume of sludge generated can actually increase by 100% because of the addition of precipitating chemicals. The more waste sludge generated, the higher the costs and potential liabilities of disposal, especially if the sludge is considered as hazardous waste.

A carefully designed test program can provide insight into the best possible media that not only provides the
best part finish but also allows for effective pollution prevention options. For any waste sludge that is produced, off site reclamation possibilities should be investigated. Many impurities, including the eroded metal itself, are present in the waste solids. While in some cases metal can be recovered, media recovery options are limited. Most finishing equipment suppliers will work with the manufacturer to find the best media and soap to minimize waste.

Mass Finishing Compounds

The type of soap in the finishing operation is an important variable that is dependent on the metal part and media used. As mentioned earlier, many different compounds exist. Some soaps are best for polishing while others are better suited for deburring, and the pH varies from chemical to chemical. Since an in-process recycling program is ultimately desired after all finishing process modifications have been implemented, it is critical to minimize the number of different soaps that are used (see In-Process Recycling section). If many different soaps are used, in-process recycling becomes more difficult and expensive because a separate recycling system would be required for each soap. Many companies use a different soap for each type of part that is manufactured. While certain compounds are more effective than others for certain metal parts, many soaps have a much broader range of applicability than often realized. Since the traditional approach has been end-of-pipe treatment and discharge, there was little concern about the number of different soaps used; everything would eventually end up in the sewer. J&L Finishing (Providence, RI), a mass finishing job shop that accepts parts of all types and shapes, was able to reduce their number of soaps from 4 to 2. After having eliminated their chemical treatment process, the company installed a large (500 gal/day) membrane filtration system for one soap, and a small membrane system for another compound. The company has thus been able to recycle soap and water much more economically (see In-Process Recycling section).

In some cases, the mass finishing operation presents opportunities to eliminate hazardous chemicals. For example, Miniature Casting Corp. (Cranston, RI) uses an alkaline
Mass finishing can sometimes eliminate the use of hazardous or toxic chemicals. A compound in their vibratory operation and had originally discharged to sewer. Due to local sewer requirements, the pH of the solution could not be above 10. Because the alkaline compound was not strong enough, some heavily-contaminated parts required pre-cleaning with mineral spirits, a hazardous solvent, prior to the vibratory step. While a stronger concentration of the alkaline soap could successfully clean all the parts, the pH of the solution would be raised to 11 and not meet discharge requirements. Recycling the solution, on the other hand, relieves the company from all discharge requirements since the solution is no longer being discharged. By employing an in-process recycling scheme, higher pH solution can be used, and the mineral spirits is eliminated.

Machine Modification

Two basic mass finishing machine designs are shown in Figures 1 and 2. Many variations exist depending on the application. More elaborate designs may prove to be more cost-effective and prevent more pollution by increasing efficiency; process cycle times and hence waste generation are reduced. There are now available new types of mass finishing equipment that have been designed to be more efficient in material use and pollution prevention. For example, in applications where large quantities of identical parts are manufactured, a machine is available that cleans each part individually and quickly with relatively little waste. A company can work with the machine supplier to determine which design is best for its operation. One company switched the majority of their mass finishing from barrel tumblers to small vibratory units which resulted in less soap/water use and less waste generation.

Water and Soap Conservation

In continuous feed operations where a continuous flow of solution is fed into the basin, the amount of finishing solution and water used may be reduced. Pilot tests at various companies have indicated that satisfactory part finishes can be obtained even when flow rates are reduced. Lower flow rates lead to decreased volumes of waste solution which in turn results in
lower equipment/operating costs. In addition, shorter cycle times can reduce water consumption. Some parts may not have to be run as long as previously believed for proper surface finish. Reductions in cycle time not only reduce water and soap use but also reduce the amount of sludge generated. Because each application is different, on site testing needs to be carried out to determine optimal flows and cycle times.

C. In-Process Recycling

In-process recycling, or recycling at the source, is another pollution prevention approach that can be implemented once all other possible process modifications mentioned above are made. The following discussion describes several techniques that have proven to be successful in many applications. While some recycling programs are more costly than others, each company should test all available options to determine the most cost-effective program.

Waste Stream Segregation

Before any recycling program is implemented, it is important to ensure that specific operations are separated in such a way that prevents solution mixing. If the waste stream from the original finishing operation is mixed with other waste streams prior to end-of-pipe treatment, the finishing solution must be captured prior to mixing with the other waste streams. Similarly, if more than one finishing solution is used, each of these streams must be separated and will require individual recycling systems. It is important that soaps are not mixed since the original soap solution is desired for reuse.

Solution Recycling Options

As shown in Figure 5, a properly designed material recovery system prevents waste solution from entering the treatment and disposal stream. Table 6 describes how significant savings in process waste can be achieved with recycling. The more times a solution is recycled, the less wastewater is generated. For example, if a company generates 1000 gal/day...
of waste finishing solution, reusing the 1000 gallons just once will reduce actual waste solution generation down to 50% of the original waste volume. Since mass finishing operations vary from company to company, several types of solution recycling systems have been developed to suit almost any application. The following techniques are based on actual tests and case studies at several Rhode Island companies.
Simple Recycle

As the solution is used and leaves the tubbing or vibratory machine, it is usually considered "waste" and no longer suitable for reuse. While the solution may appear spent or visibly dirty, in some cases, companies have captured the machine effluent and simply reused the solution after simple settling (see Figure 6). Final part quality is not affected, and the volume of waste solution is minimized. Table 6 shows how reusing the solution even once can cause a 50% reduction in the volume of waste solution that has to be treated or disposed of.

The solution may be reused more than once with little or no filtration.

Since 1992, Miniature Casting Corp. has utilized a simple recycling program. The company reuses the same solution for many weeks with simple settling. After two to three months, the parts are not as clean and more advanced filtration technologies are used to "recharge" the recycled solution. A discussion of these other filtration techniques is presented in the following sections. The equipment costs for the simple recycle system include tank, pump, and piping costs. A small operation (less than several hundred gallons per day) can use drums whereas larger operations (thousands of gallons per day) would require the installation of holding tanks. Anticipated costs range from several hundred dollars to several thousand dollars.

Figure 6: Simple Solution Recycle
Bag or cartridge filters can be used to separate solids and clean the solution.

The solids that are periodically removed from the settling tank consist of mostly media and some metal. Depending on the nature of these solids, some off site reclamation opportunities may exist. But because chemical treatment is not used, the volume of removed solids is much smaller than what would be obtained with chemical flocculation.

**Coarse Filtration**

Many companies have utilized cartridge or bag filtration to clean the used finishing solution. Since most companies who recycle their solution ultimately use membrane filtration (discussed later), some type of coarse pre-filtration is usually required. "Coarse" filtration can be defined as removing particles that are larger than 30-200 microns in size. While settling is often considered to be one type of coarse particle removal, separation is not always well-defined. Different medias have different settling characteristics which are not relevant if a bag or cartridge filter is used. A filter separates particles of a specified size regardless of settling characteristic. Usually, settling is used prior to any filtration to remove the large particles and extend the lifetime of the filters (see Figure 7).

![Figure 7: Solution Recycle with Coarse Filtration](image)

**Membrane Filtration**

Membrane filtration is the best means of mechanically separating different constituents. Membranes can separate
micron-size particles (microfiltration), particles less than 0.1 micron in size or large molecules (ultrafiltration), and small molecules and dissolved metal (nanofiltration and reverse osmosis). For the most part, companies have relied on microfiltration and ultrafiltration for cleaning and reusing finishing solution. Since one of the primary objectives is to recover as much soap as possible, it is usually not necessary to make use of nanofiltration or reverse osmosis technologies which would separate out most of the soaps and are much more costly to operate. A typical process schematic for a recycling system using membrane technology is shown in Figure 8.

**Figure 8: Solution Recycle Using Membrane Technology**

Many Rhode Island companies are currently using the process described in Figure 8. While the previously-mentioned techniques are certainly viable and less costly, membrane technology allows for much longer recycling periods. For
example, as discussed in an earlier section, Miniature Casting makes use of simple recycling without any filtration for several months. The water begins to become so contaminated, however, that the parts no longer are clean after finishing. At this point, all of the recycled fluid is processed through a small ultrafiltration system. The solution is "recharged" and ready to be used for another 2-3 months of simple recycle (see Figure 9). Other companies have also implemented similar "hybrid" recycling programs where different filtration technologies are combined.

![Figure 9: Present Vibratory Recycle Operation at Miniature Casting](image-url)
Most companies prefer to filter all of the used solution with membranes (Figure 8) so the soap solution is as clean as possible before reuse. Certain metal parts are subject to very strict cleaning requirements, so the reused solution must be as clean as possible. Some on site testing should be carried out to determine the best process.

Table 7 shows the approximate costs associated with the implementation of membrane technology for mass finishing recycle. Initial capital costs include the membrane system, tanks, pumps, solids dewatering equipment, and installation. Operating costs include membrane/filter replacement, energy, and labor. Depending on the size of the operation and extent of automation in the system, costs can vary widely. If the operation is fairly small, (<100 gallons/day), filter bags can be used to dewater solids that are periodically removed from the operation. Companies with larger finishing operations have purchased filter presses which can handle larger amounts of sludge and dewater at a faster rate than simple filter bags.

<table>
<thead>
<tr>
<th>Gallons/Day</th>
<th>Initial Capital</th>
<th>Annual Operating</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>$4,000</td>
<td>$500</td>
</tr>
<tr>
<td>150</td>
<td>7,000</td>
<td>1,000</td>
</tr>
<tr>
<td>500</td>
<td>18,000</td>
<td>2,500</td>
</tr>
<tr>
<td>1,000</td>
<td>34,000</td>
<td>4,000</td>
</tr>
<tr>
<td>10,000</td>
<td>80,000</td>
<td>10,000</td>
</tr>
</tbody>
</table>

Regardless of all the changes implemented to improve a particular mass finishing operation, some "waste" materials inevitably must be dealt with. Some sludge is formed (discussed next section), and the solution becomes unusable after a certain time period. Most companies clean and reuse the same solution for up to a year before cleaning out the system. While membrane technologies can actually clean up water to be better than city tap water, these membrane types (nanofiltration and reverse osmosis) are more expensive to use and do not lend themselves...
Sludge is usually sent off site. Some sludge can be sent off site for metal reclamation.

Sludge Handling

While certain steps can be taken to ensure that the amount of sludge generated is minimized through process modification, some solid waste inevitably is produced. The avoidance of chemical treatment reduces potential waste and disposal costs. Optimizing finishing times and type of media will help minimize waste sludge. The solids that are removed from in-process recycling programs consist of mostly media and some metal of the type(s) found in the metal parts. In some cases, the removed sludge can be sent back to the metal supplier for metal reclamation. Some companies are able to send back the sludge that is removed from the recycling process to their metal supplier along with scrap metal that is leftover from their manufacturing operation. Companies that are able to mass finish "part on part" without media (very small metal parts, usually) end up with sludge that is pure in metal, and off site reclamation becomes more feasible.

Off site reclamation becomes more difficult if the metal portion of the sludge is of a mixed variety. The sludge is a
mixture of metals because many companies manufacture different metal parts that contain a mixture of metals. For example, brass contains zinc and copper; or some "White" metals contain a mixture of lead, antimony, and tin.

Summary of Pollution Prevention Approaches

The following figure summarizes the available pollution prevention options for the mass finishing operation:

- All possible process modifications have been implemented:
  - input material replacement
  - optimization of soap/water use
  - optimization of finishing time

- In-Process Recycling
  - simple settling
  - coarse filtration
  - membrane filtration

- Off site reclamation or disposal of sludge
- Unusable finishing solution
  - on site treatment & disposal or
  - off site disposal

Figure 30: Summary of Pollution Prevention Sequence

Once all process modifications have been made, in-process recycling measures can be implemented. The final waste materials, sludge and unusable finishing solution, either have to be treated and/or disposed of. In any case, the amount of waste-bearing materials has been reduced substantially because of the implemented pollution prevention measures.
D. Economics

The implementation of pollution prevention techniques can incur a wide range of costs, ranging from minimal labor costs for simple process modifications to tens of thousands of dollars for membrane filtration equipment. Most companies base equipment purchases on cost-effectiveness and payback. For example, if it is determined that a particular company's operation requires $10,000 in equipment purchases, the company would like to see annual or bi-annual savings of at least $10,000. These savings may come in the form of disposal cost reductions, soap/chemical purchase savings, and water/sewer fee reductions. Table 9 summarizes the economic savings achieved at one company where a payback of less than one year was obtained.

Table 9: Economic Analysis of Pollution Prevention Project

<table>
<thead>
<tr>
<th>Before Pollution Prev.</th>
<th>After Pollution Prev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Equipment, including</td>
<td>$5,500</td>
</tr>
<tr>
<td>membrane system</td>
<td></td>
</tr>
<tr>
<td>tanks</td>
<td></td>
</tr>
<tr>
<td>pumps</td>
<td></td>
</tr>
<tr>
<td>filters/housings</td>
<td></td>
</tr>
<tr>
<td>Annual Operating Costs</td>
<td>(estimated)</td>
</tr>
<tr>
<td>soap</td>
<td>$1,526</td>
</tr>
<tr>
<td>mineral spirits</td>
<td>1,015</td>
</tr>
<tr>
<td>cartridge filters</td>
<td>1,189</td>
</tr>
<tr>
<td>membrane replacement</td>
<td>0</td>
</tr>
<tr>
<td>energy</td>
<td>negligible</td>
</tr>
<tr>
<td>labor</td>
<td>4,742</td>
</tr>
<tr>
<td>water</td>
<td>161</td>
</tr>
<tr>
<td>sewer fees</td>
<td>300</td>
</tr>
<tr>
<td>analytical tests</td>
<td>224</td>
</tr>
<tr>
<td>Total Annual Operating Costs</td>
<td>$9,157</td>
</tr>
</tbody>
</table>
In some cases, however, because of regulatory pressure, companies are required to implement pollution control equipment. Material recovery and the minimization of environmental discharge are the best approaches to dealing with compliance problems (in-process recycling) since liabilities can be significantly reduced immediately. In the Appendix is a series of short case studies that describe some of the Rhode Island companies who have implemented pollution prevention into their finishing operations.
Glossary

acid: one of a large class of chemical substances whose water solutions exhibit a pH less than 7

aqueous: made from, with, or by water

cauist: alkaline material such as sodium hydroxide; when mixed with water, exhibits a pH greater than 7

effluent: any gas or liquid emerging from a pipe or similar outlet; usually refers to waste products from chemical or industrial plants as stack gases or liquid mixtures

filtration: a means of separation where constituents are separated usually by physical methods

flocculation: the combination or aggregation of suspended colloidal particles in such a way that they form small clumps; usually used in conjunction with additive chemicals (floculants) to treat waste water

membrane: a microporous structure which acts as a highly efficient filter that allows passage of water but rejects suspended solids and colloids; depending on the membrane type, ions and small molecules may or may not be rejected (see ultrafiltration)

mineral spirits: light petroleum distillate used for cleaning/degreasing

off-site recovery/reclamation: the transport of unusable materials away from the site of operation to a facility that makes use of a process that transforms the unusable material to a usable feedstock for any given operation

pH-adjustment: the act of changing the pH of an aqueous solution by adding acid or caustic

pollution prevention: the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source

source segregation: the act of separating process chemical effluents or wastes at each individual point of origin to facilitate materials recovery

ultrafiltration: the process that utilizes membranes to achieve separation of various constituents; a typical ultrafiltration membrane will allow water, ions, and small molecules to pass through while rejecting large molecules and suspended solids
The following is a partial list of vendors that supply equipment and provide start-up assistance. The Rhode Island Department of Environmental Management does not endorse any particular vendor or product. The list is not complete and is provided for informational purposes only.

**Mass Finishing Equipment Suppliers**

Rampe Finishing  
18751 E. Michigan Ave.  
Marshall, Michigan 49068  
(616) 789-0786

Roto-Finish  
1600 Douglas Ave.  
Kalamazoo, MI 49007-1690  
(616) 327-7071

Vibra Finish  
11844 Glencoe Blvd.  
San Fernando, CA 91340  
(818) 898-2221

**Membrane System Suppliers**

Infinitex Inc.  
10100 Main St.  
Clarence, NY 14031  
(716) 759-6983

Koch Membrane Systems, Inc.  
850 Main St.  
Wilmington, MA 01887  
(508) 657-4250

MSC Liquid Filtration Corp.  
10 Dusthouse Rd.  
Enfield, CT 06082  
(203) 749-8316

Romicon, Inc.  
100 Cummings Park  
Woburn, MA 01801  
(617) 935-7840

Sanborn Inc.  
25 Commercial Dr.  
Wrentham, MA 02093  
(508) 384-3181