9.0 TECHNOLOGY OPTIONS

This section describes the technology options that EPA used in developing the Metal Products and Machinery (MP&M) effluent limitations guidelines and standards. EPA developed these options based on the technologies described in Section 8.0. Section 9.1 summarizes the methodology EPA used to select the technologies included in the options. Section 9.2 describes the technology options in detail. **The Agency selected the technologies included in each option for development of the MP&M effluent limitations guidelines and standards. EPA does not require sites to implement these specific technologies to comply with the MP&M effluent guidelines; sites can install any technology (or completely eliminate their discharge through contract hauling or recycling as long as they achieve the final effluent limitations.** EPA used these technology options to estimate pollutant loadings and reductions (Section 12.0) and compliance costs (Section 11.0) and to develop the MP&M effluent limitations guidelines and standards.

The MP&M technology options consist of groups of pollution prevention and wastewater treatment technologies identified to reduce or eliminate the generation or discharge of pollutants from MP&M sites. EPA identified these technologies from responses to the MP&M detailed and screener surveys, MP&M site visits and sampling episodes, and technical literature (including case studies and development documents for previously promulgated metals industry regulations).

9.1 Technology Evaluation Methods

MP&M sites generate wastewater containing oils, organic pollutants, cyanide, hexavalent chromium, complexed metals, and dissolved metals. The MP&M industry uses many different types of technologies to control and treat wastewater, including both in-process pollution prevention technologies and end-of-pipe treatment and disposal technologies. To determine technology options for each subcategory, EPA evaluated information collected from site visits, sampling episodes, and MP&M screener and detailed surveys. EPA then grouped the most prevalent technologies according to the type of wastewater which they treat (i.e., oily wastewater, metal-bearing wastewater, cyanide-bearing wastewater, etc.). The Agency evaluated treatment efficiency in terms of percent removal and final concentration (mg/L) from sampling episode data, discharge monitoring reports, and periodic compliance reports.

EPA classified the technologies into one of the four tiers of the Environmental Management Hierarchy (EMH) from EPA's Facility Pollution Prevention Guide (1). This hierarchy attempts to prioritize technologies in order of importance or benefit to the environment from source reduction (highest priority) to disposal (lowest priority). Tables 9-1 through 9-3, presented at the end of this section, provide data on the technologies considered for the MP&M options, grouped by their EMH classification as follows:

1. Table 9-1: Source reduction and pollution prevention technologies - EMH tier 1;

2. Table 9-2: Recycling technologies - EMH tier 2; and

3. Table 9-3: End-of-pipe treatment and disposal technologies - EMH tiers 3 and 4.

The tables present the following for each technology: a brief technology description; the number of sites visited by EPA using the technology; the number of survey respondents reporting using the technology; the estimated number of sites in the MP&M industry currently using the technology; and comments noting if EPA included the technology in the MP&M technology options (as discussed in Section 9.2) and, where appropriate, reasons why EPA did not include the technology. Each of the pollution prevention, recycling and treatment technologies are described in detail in Section 8.0.

The demonstration of source reduction and some recycling technologies in the MP&M industry was only quantifiable from the data collected in the MP&M 1996 detailed survey responses. However, as shown on these tables, EPA observed most of these technologies during visits to MP&M sites. The most frequently observed and/or reported source reduction and recycling technologies were:

- Centrifugation of machining coolants;
- Centrifugation of painting water curtains;
- Conductivity probes;
- Countercurrent cascade rinsing;
- Drag-out rinsing;
- Electrolytic recovery;
- Flow restrictors;
- In-tank filtration;
- Ion exchange; and
- Regeneration of process baths.

In addition, many of the sites that EPA visited used plant maintenance and good housekeeping practices that resulted in source reduction.

Table 9-3 presents some of the most common end-of-pipe treatment technologies in the MP&M industry:

- Chelation breaking/precipitation to remove complexed metals;
- Chemical emulsion breaking followed by gravity separation for oil removal;
- Chemical emulsion breaking followed by dissolved air flotation (DAF) for oil removal;
- Chemical precipitation and gravity settling for solids removal;
- Chemical precipitation and microfiltration for solids removal;
- Chemical reduction of hexavalent chromium;
- Cyanide destruction through alkaline chlorination;

- Gravity settling of wastewater (without chemical addition);
- Gravity thickening of sludge;
- Multimedia filtration (including sand filtration);
- Neutralization (without solids removal);
- Pressure filtration of sludge; and
- Ultrafiltration for oil removal.

In addition, an estimated 31,000 of the 63,000 water-discharging MP&M sites contract-haul some of their wastewater for off-site treatment and disposal. Many sites with treatment technologies in place also contract-haul wastewater treatment sludges for off-site disposal.

9.2 Technology Options

EPA considered a technology to be demonstrated in the MP&M industry if the technology effectively treated MP&M wastewater and if EPA observed the technology during at least one MP&M site visit or at least one survey respondent reported using the technology. EPA evaluated the performance of each technology using available analytical data from MP&M sampling episodes, analytical data from previous effluent guidelines data collection efforts, and quantitative and qualitative assessments from engineering site visits and literature.

EPA identified ten technology options for the MP&M industry subcategories. Table 9-4 shows the options for each subcategory and the technologies used to establish effluent limitations and standards. The following sections discuss the wastewater treatment technologies included in each subcategory. Figures 9-1 through 9-6 present the technology trains for the options.

9.2.1 General Metals, Metal Finishing Job Shops, Printed Wiring Boards, Steel Forming and Finishing, and Non-Chromium Anodizing Subcategories

EPA evaluated four wastewater treatment technology options for the MP&M industry subcategories whose unit operations primarily produce metal-bearing wastewater (but may also produce some oily wastewater). Each of these options are discussed below.

Option 1

Option 1 includes segregation of wastewater streams, preliminary treatment steps as necessary (including oil removal using oil water separation by chemical emulsion breaking), chemical precipitation using either sodium hydroxide or lime, and sedimentation using a clarifier. Segregation of wastewater and subsequent preliminary treatment allows for the most efficient, effective, and economic means for removing pollutants in certain wastewater streams. These streams contain pollutants (e.g., oil and grease, cyanide, hexavalent chromium, chelated metals, and organic solvents) that can inhibit the performance of chemical precipitation and sedimentation treatment, while increasing the overall treatment costs. For example, if a facility segregates its oil-bearing wastewater from its metal-bearing

wastewater, then the facility can design an oil removal treatment technology based on only the oily waste flow volume and not on the combined metal-bearing and oil-bearing wastewater flow, decreasing the size of the overall treatment system. Treatment chemical costs are also reduced because of the reduced volume. Preliminary treatment technologies for these types of wastewater streams are described below. (See Section 5.0 for a more detailed description of each of these wastewater streams).

- **Oil-Bearing Wastewater**. Alkaline cleaning wastewater and water-based metal-working fluids (e.g., machining and grinding coolants) typically contain significant amounts of oil and grease. These wastewater streams require preliminary treatment to remove oil and grease and organic pollutants. Chemical emulsion breaking followed by gravity separation of oil and water (oil/water separator or gravity flotation) effectively removes these pollutants.

- **Cyanide-Bearing Wastewater**. The MP&M industry generates several types of wastewater that may contain significant amounts of cyanide, such as plating and cleaning wastewater. This wastewater requires preliminary treatment to destroy the cyanide, typically performed using alkaline chlorination with sodium hypochlorite or chlorine gas (3).

- **Hexavalent Chromium-Bearing Wastewater**. The MP&M industry generates several types of wastewater that contain hexavalent chromium, usually generated by acid treatment, anodizing, conversion coating, and electroplating. Because hexavalent chromium does not form an insoluble hydroxide and is not treated by chemical precipitation and sedimentation, this wastewater requires chemical reduction of the hexavalent chromium to trivalent chromium. Trivalent chromium forms an insoluble hydroxide and is treated by chemical precipitation and sedimentation. Sodium metabisulfite or gaseous sulfur dioxide are typically used as reducing agents for hexavalent chromium-containing wastewater.

- **Chelated Metal-Bearing Wastewater**. Electroless plating and some cleaning operations generate water that contains significant amounts of chelated metals. This wastewater requires chemical reduction to break the metal-chelate bond or reduce the metal-chelate complex to an insoluble state so that it can be removed during chemical precipitation. Sodium borohydride, dithiocarbamate, hydrazine, and sodium hydrosulfite are used as reducing agents.

- **Organic Solvent-Bearing Wastewater**. Option 1 also includes contract-hauling of solvent degreasing wastewater. Based on the MP&M surveys and site visits, most solvent degreasing operations which use organic solvents (e.g., 1,1,1-trichloroethane, trichloroethene), are contract-hauled for off-site

recycling. Some MP&M sites reported using organic solvent-water mixtures or rinses following organic solvent degreasing. EPA found contract-hauling of this wastewater to be the most common disposal method for these sites.

After pretreatment of the segregated streams, chemical precipitation and gravity clarification is used to remove total and dissolved metals. Chemical precipitation involves adjusting the pH of the wastewater with alkaline chemicals such as lime (calcium hydroxide) or caustic (sodium hydroxide) or acidic chemicals (such as sulfuric acid) to produce insoluble metal hydroxides. This step is followed by a gravity settling process in a clarifier to remove the precipitated and flocculated metal hydroxides by gravity settling (2). Segregation of wastewater streams, preliminary treatment, and final chemical precipitation and gravity sedimentation is widely used throughout the metals industry and is well documented as being effective in removing pollutants present in MP&M wastewater.

Option 2

Option 2 builds on Option 1 by adding in-process pollution prevention, recycling, and water conservation methods that allow for recovery and reuse of materials. These technologies can reduce manufacturing costs by allowing materials to be used over a longer period before they need to be disposed. Using these techniques or technologies along with water conservation also leads to the generation of less pollution and results in more effective treatment of the wastewater that is generated. Specific Option 2 in-process pollution prevention, recycling and water conservation methods include:

- Countercurrent cascade rinsing for all flowing rinses;
- Centrifugation and recycling of painting water curtains; and
- Centrifugation and pasteurization to extend the life of water-soluble machining coolants.

EPA observed these pollution prevention and water conservation technologies at MP&M sites during site visits and sampling episodes. These technologies were also reported in the MP&M surveys and documented in various literature sources (4,5).

Sites reducing their wastewater flow rates and increasing their influent pollutant concentrations will more effectively treat the wastewater, reducing the mass of pollutants discharged in the treated effluent. For example, a site that generates 2,600 gallons (10,000 liters) per day of raw wastewater containing 10 mg/L of pollutants prior to treatment, implements water reduction and recovery technologies that reduce the flow to 1,300 gallons (5,000 liters) per day and increase the pollutant concentration to 20 mg/L prior to treatment. If the long-term average effluent concentration of a pollutant was 0.1 mg/L, the site would discharge 1,000 mg/day of pollutant (10,000 L/day times 0.1 mg/L) prior to implementing flow reduction and recovery technologies, and 500 mg/day of pollutant (5,000 L/day times 0.1 mg/L) after implementing the technologies.

EPA based the BPT, BCT and BAT proposed effluent limitations guidelines on Option 2 for existing direct dischargers in the General Metals, Metal Finishing Job Shops, Non-Chromium Anodizing, Printed Wiring Board, and Steel Forming and Finishing Subcategories. EPA also based the proposed pretreatment standards for existing sources (PSES) on Option 2 for the General Metals, Metal Finishing Job Shops, Printed Wiring Boards, and Steel Forming and Finishing Subcategories. EPA did not propose PSES nor pretreatment standards for new sources (PSNS) for the Non-Chromium Anodizing Subcategory. EPA proposed new source performance standards (NSPS) for new direct dischargers in the Non-Chromium Anodizing Subcategory based on Option 2.

Option 3

This option differs from Option 1 in that an ultrafilter replaces the chemical emulsion breaking and oil/water separator for the removal of oil and grease, and a microfilter, rather than a clarifier, follows chemical precipitation. Ultrafiltration is a separation technology that allows water and small solute species to pass through a semi-porous membrane under pressure while emulsified oils are retained by the membrane and recovered as concentrate (2). EPA determined through sampling episodes that ultrafiltration systems are very effective for the removal of oil and grease at MP&M facilities. Ultrafilters sampled by EPA achieved oil and grease removals of greater than 99 percent. The emulsion breaking and gravity flotation system described in Options 1 and 2 removed approximately 96 percent of the oil and grease from the MP&M wastewater.

Microfiltration uses a pressure-driven membrane process to separate wastewater constituents based on size and shape. Using an applied pressure difference across a membrane, solvent and small solute species pass through the membrane and are collected as permeate. Larger constituents such as flocculated metal hydroxide particles generated during chemical precipitation are retained by the membrane and recovered as a concentrated solids slurry. EPA collected treatment effectiveness data for solids removal after chemical precipitation through microfiltration. Well-operated chemical precipitation and microfiltration systems sampled by EPA at MP&M facilities achieved an average removal of 99.6 percent for targeted metals. Well-operated chemical precipitation and gravity clarification systems sampled by EPA at MP&M facilities achieved an average removal of 96.7 percent for targeted metals.

Option 4

Option 4 includes technologies in Option 3 plus in-process flow control and pollution prevention technologies described in Option 2, allowing for recovery and reuse of materials along with water conservation. EPA based the NSPS and PSNS (new source) limitations and standards on Option 4 for the General Metals, Metal Finishing Job Shops, Printed Wiring Boards, and Steel Forming and Finishing Subcategories.

9.2.2 Oily Wastes Subcategory

EPA evaluated four wastewater treatment options for the Oily Wastes Subcategory. EPA defines the Oily Wastes Subcategory as those facilities that only discharge wastewater from one or more of the following unit operations: alkaline cleaning for oil removal, aqueous degreasing, corrosion preventive coating, floor cleaning, grinding, heat treating, impact deformation, machining, painting, pressure deformation, solvent degreasing, testing (e.g., hydrostatic, dye penetrant, ultrasonic, magnetic flux), steam cleaning, and laundering. EPA is defining "corrosion preventive coating" as the application of removable oily or organic solutions to protect metal surfaces against corrosive environments. Corrosion preventive coatings include, but are not limited to: petrolatum compounds, oils, hard dry-film compounds, solvent-cutback petroleum-based compounds, emulsions, water-displacing polar compounds, and fingerprint removers and neutralizers. Corrosion preventive coating does not include electroplating or chemical conversion coating (including phosphate conversion coating) operations. Technology options used to establish effluent limitations are discussed below.

Option 5

Effluent limitations for Option 5 are based on end-of-pipe chemical emulsion breaking followed by gravity separation using an oil/water separator. EPA performed sampling episodes at several facilities in the Oily Wastes Subcategory that employed chemical emulsion breaking followed by gravity flotation and oil skimming. These systems typically achieved a 96 percent removal of oil and grease. Breaking the oil/water emulsion requires the addition of treatment chemicals such as acid, alum, and/or polymers to change the emulsified oils or cutting fluids from hydrophilic colloids to aggregated hydrophobic particles. The aggregated oil particles, with a density less than water, can be removed by gravity flotation in a coalescing plate oil/water separator. This treatment train is widely used throughout the metals industry and is well documented as effectively removing machining coolants, emulsified hydraulic oils, and organic pollutants present in oily MP&M wastewater.

Option 6

Option 6 includes the technologies in Option 5 plus in-process flow control and pollution prevention technologies, which allow for recovery and reuse of materials along with water conservation. The specific Option 6 technologies include:

- Countercurrent cascade rinsing for all flowing rinses;
- Centrifugation and recycling of painting water curtains; and
- Centrifugation and pasteurization to extend the life of water-soluble machining coolants.

EPA based the BPT, BCT, BAT, PSES, NSPS and PSNS effluent limitations guidelines and pretreatment standards on Option 6 for the Oily Wastes Subcategory.

Option 7

Option 7 is based on end-of-pipe ultrafiltration. Ultrafiltration is a process that allows water and small solute species to pass through a membrane under pressure while emulsified oils are retained by the membrane and recovered as concentrate (2). Ultrafiltration removes oil droplets ranging from 0.002 to 0.2-microns and is expected to generate a concentrated oil phase that is 2 to 5 percent of the influent volume. Sampling episode data determined that, on average, ultrafilters will remove greater than 99 percent of all oil and grease in the influent stream. Ultrafiltration is widely used throughout the MP&M industry and is well documented as effectively treating machining coolants, emulsified hydraulic oils, and organic pollutants present in oily MP&M wastewater.

Option 8

Option 8 includes the Option 7 technology (ultrafiltration) plus the pollution prevention and water conservation alternatives described in Option 6. Although EPA is not proposing Options 7 or 8, they were evaluated as potential options for the Oily Wastes, Shipbuilding Dry Dock, and Railroad Line Maintenance Subcategories.

9.2.3 Shipbuilding Dry Dock and Railroad Line Maintenance Subcategories

EPA evaluated four wastewater treatment technology options for the Shipbuilding Dry Docks and Railroad Line Maintenance Subcategories. For these subcategories, EPA considered Options 7 and 8 in addition to the two technology options discussed below.

Option 9

Option 9 is based on end-of-pipe chemical emulsion breaking followed by DAF to remove flocculated oils. Breaking the oil/water emulsions requires adding treatment chemicals such as acid, alum and/or polymers to change the emulsified material from a hydrophilic colloidal dispersion to aggregate hydrophobic particles. In the DAF tank, air bubbles created as a result of a rapid pressure drop attach to the aggregated oil particles and pull them to the surface of the tank. A scraping mechanism collects the oil and solids from the surface of the DAF tank. This treatment train is demonstrated in both the shipbuilding dry dock and railroad line maintenance subcategories and is effective for removing emulsified oils and suspended solids.

Option 10

Option 10 includes the end-of-pipe treatment technologies included in Option 9 (chemical emulsion breaking followed by DAF) plus in-process flow control and pollution prevention

technologies, which allow for recovery and reuse of materials along with water conservation. The specific Option 10 in-process technologies include:

- Countercurrent cascade rinsing for all flowing rinses;
- Centrifugation and recycling of painting water curtains; and
- Centrifugation and pasteurization to extend the life of water soluble machining coolants.

EPA based the BPT, BCT, BAT and NSPS effluent limitations guidelines and pretreatment standards for the Shipbuilding Dry Dock and Railroad Line Maintenance Subcategories on Option 10. EPA did not propose pretreatment standards for new or existing sources in the Shipbuilding Dry Dock and Railroad Line Maintenance Subcategories.

9.3 References

1. U.S. Environmental Protection Agency. Facility Pollution Prevention Guide. EPA/600/R-92/088, Washington, DC, 1992.

2. Freeman, H.M. Standard Handbook of Hazardous Waste Treatment and Disposal. McGraw Hill Publishing Company, New York, New York, 1989.

3. Cherry, K.F. Plating Waste Treatment. Ann Arbor Sciences Publishers, Inc., Ann Arbor, Michigan, 1982.

4. Freeman, H.M. Hazardous Waste Minimization. McGraw Hill Publishing Company, New York, New York, 1990.

5. Cushnie, George C. Pollution Prevention and Control Technology for Plating Operations. National Center for Manufacturing Sciences, 1994.

Table 9-1

EMH Tier 1 - MP&M Source Reduction and Pollution Prevention Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[c]	Estimated Number of MP&M Sites Using the Technology[c]	
Conductivity Probes	Measure the conductivity of water in a rinse tank to regulate the flow of fresh rinse water into the rinse system. A solenoid valve on the rinse system fresh water supply is connected to the controller, which opens the valve when a preset conductivity level is exceeded and closes the valve when conductivity is below that level.	38	29	320	This technology reduces the amount of water necessary for rinsing. The MP&M cost model evaluates the level of rinse flow control in place prior to estimating costs for countercurrent cascade rinsing.
Countercurrent Cascade Rinsing	Series of consecutive rinse tanks that are plumbed to cause water to flow from one tank to another in the direction opposite of the work flow. Water is introduced into the last tank of the series, making it the cleanest, and is discharged from the first tank, which has the highest concentration of pollutants.	94	130	1569	This technology reduces the amount of water necessary for rinsing. This technology is included in the technology options.
Drag-Out Rinsing	Stagnant rinse, initially of fresh water, positioned immediately after process tanks. The drag-out rinse collects most of the drag-out from the process tank, preventing it from entering the subsequent flowing rinses.	58	139	1737	This technology reduces the amount of water necessary for rinsing. The MP&M cost model evaluates the level of rinse water use prior to estimating costs for countercurrent rinsing.
Flow Restrictors	Prevent the flow in a pipe from exceeding a predetermined volume. Flow restrictors can be used to limit the flow into a rinse system. For continuously flowing rinses, a flow restrictor controls the flow into the system, ensuring a consistent, optimum flow rate.	45	127	1581	This technology reduces the amount of water necessary for rinsing. The MP&M cost model evaluates the level of rinse flow control in place prior to estimating costs for countercurrent cascade rinsing.

Table 9-1 (Continued)

		Demonstration Status			
Technology	**Technology Description**	**Number of Sites Visited[a]**	**Number of Survey Sites[c]**	**Estimated Number of MP&M Sites Using the Technology[c]**	**Comments**
Spray Rinsing	Spray water on parts above a process tank or drip/drag-out tank; Uses considerably less water than immersion for certain part configurations. This technology can also be performed as countercurrent cascade rinsing with spray rinses instead of overflow immersion rinses.	64	187	1767	Not applicable at all sites because of part and process configurations; not included in the technology options.
Centrifugation of Painting Water Curtains	Removes the heavier solids from the water curtain allowing the water to be reused. The solids are collected as a cake in the basket of the centrifuge. This technology can achieve closed-loop reuse of water curtains.	3	1	12	Requires little maintenance, and has been demonstrated to achieve complete recycle with periodic removal of sludge. This technology is included in the technology options.
Filtration of Painting Water Curtains	Removes solids by filtration (cloth, sand, diatomaceous earth, etc.) followed by reuse. This technology can achieve closed-loop reuse of water curtains.	2	3	20	Generates more waste than centrifugation due to filter medium disposal or sand filter backwash. This technology is not included in the technology options.
Settling of Painting Water Curtains	Removes the heavier solids from the water curtains. This technology can be used in conjunction with other removal technologies to lessen the solids loading.	5	5	23	Equivalent technology (centrifugation) is included as part of the technology options; therefore, this technology is not included in the technology options.
Biocide Addition to Lengthen Coolant Life	Can impede the growth of microorganisms that cause rancidity. Machining coolant is often discarded as it becomes rancid.	9	27	216	Equivalent technology (pasteurization) is included as part of the technology options; therefore, this technology is not included in the technology options.

Table 9-1 (Continued)

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[c]	Estimated Number of MP&M Sites Using the Technology[c]	
Centrifugation to Lengthen Coolant Life	Removes the solids from the coolant to extend its usable life. Some high-speed centrifuges can also perform liquid-liquid separation to remove tramp oils and further extend coolant life.	18	10	78	This is a component of the coolant recycling system included in the technology options.
Filtration to Lengthen Coolant Life	Removes the solids from the coolant using filters such as cloth, sand, carbon, etc.	18	18	142	Equivalent technology is included as part of the technology options; therefore, this technology is not included in the technology options.
Skimming of Tramp Oils to Lengthen Coolant Life	Extends the coolant life. Tramp oil buildup often makes machining coolant unusable.	8	9	82	Equivalent technology (liquid-liquid centrifugation) is included as part of the technology options; therefore, this technology is not included in the technology options.
Pasteurization to Lengthen Coolant Life	Kills the microorganisms that cause rancidity. Machining coolant is often discarded as it becomes rancid.	1	2	18	This is a component of the coolant recycling system included in the technology options.

EMH - Environmental Management Hierarchy.
NA - Numerical data are not available.
Source: MP&M site visits, MP&M sampling episodes, MP&M surveys and technical literature.
[a]Indicates the number of MP&M sites visited by EPA using the listed technology. EPA visited a total of 162 sites.
[b]Number of survey sites based on data collected in 1996 only. The 1989 survey did not request this information.
[c]Indicates the estimated number of MP&M sites currently performing this technology based on the 1996 Detailed Survey Results. EPA estimates that the MP&M industry includes 63,000 wastewater discharging sites. EPA estimated numbers in this column using statistical weighting factors for the 1996 MP&M Detailed survey respondents.

Table 9-2

EMH Tier 2 - MP&M Recycling Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[b]	Estimated Number of MP&M Sites Using the Technology[c]	
Evaporation with Condensate Recovery	Leaves a concentrated residue for disposal and condenses the water vapor for reuse.	4	15	147	Energy-intensive. This technology is not included in the technology options.
Ion Exchange	Combined cation and anion exchange used to remove metal salts from electroplating rinsewater. Effluent from the ion exchange is returned to the electroplating rinse system. Ion exchange regenerants are either discharged to the end-of-pipe chemical precipitation unit for metals removal, or metals are recovered by electrowining.	29	33	437	Permeate contains moderate dissolved solids concentrations and may be reused in noncritical unit operations. This technology is not included in the technology options. While the technology may be effective for individual sites EPA cost estimates show that ion exchange is not cost effective for the industry as a whole.
Reverse Osmosis	Forces wastewater through a membrane at high pressure, leaving a concentrated stream of pollutants for disposal. Reverse osmosis may provide an effluent clean enough for reuse.	2	1	3	Similar in application to end-of-pipe ion exchange, but not as well demonstrated. This technology is not included in the technology options.

Table 9-2 (Continued)

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[b]	Estimated Number of MP&M Sites Using the Technology[c]	
Electrolytic Recovery (Electrowinning)	Recovers dissolved metals from concentrated sources. For rinses, electrolytic recovery is typically restricted to drag-out rinses. Flowing rinses are generally too dilute for efficient electrolytic recovery. This technology is effective on the concentrated regenerant from ion exchange.	19	23	142	Works in conjunction with drag-out rinsing and in-process ion exchange to recover metals from wastewater. This technology is not included in the technology options.

EMH - Environmental Management Hierarchy.
NA - Numerical data are not available.
Source: MP&M site visits, MP&M sampling episodes, MP&M surveys and technical literature.
[a]Indicates the number of MP&M sites visited by EPA using the listed technology. EPA visited a total of 162 sites.
[b]Number of survey sites based on data collected in 1996 only. The 1989 survey did not request this information.
[c]Indicates the estimated number of MP&M sites currently performing this technology based on the 1996 Detailed Survey Results. EPA estimates that the MP&M industry includes 63,000 wastewater discharging sites. EPA estimated numbers in this column using statistical weighting factors for the 1996 MP&M Detailed survey respondents.

Table 9-3

EMH Tiers 3 and 4 - MP&M End-of-Pipe Treatment and Disposal Technologies

		Demonstration Status			
Technology	**Technology Description**	**Number of Sites Visited[a]**	**Number of Survey Sites[b]**	**Estimated Number of MP&M Sites Using the Technology[c]**	**Comments**
Chemical Emulsion Breaking Followed by Gravity Oil/Water Separation	Adds acids (typically sulfuric), polymer, and sometimes alum to oil-bearing wastewater to break oil/water emulsions for subsequent gravity separation.	11	56	958	This technology is included in the technology options.
Chemical Reduction of Hexavalent Chromium	Reduces hexavalent chromium to trivalent chromium using a reducing agent such as sulfur dioxide, sodium bisulfite, or sodium metabisulfite.	74	103	1,839	This technology is included in the technology options.
Cyanide Destruction Through Alkaline Chlorination	Destroys cyanide by adding chlorine (usually sodium hypochlorite or chlorine gas) to first oxidize cyanide to cyanate, then cyanate to carbon dioxide and nitrogen gas.	52	53	1,136	This technology is included in the technology options.
Chemical Emulsion Breaking Followed by DAF	Adds acids (typically sulfuric), polymer, and sometimes alum to oil-bearing wastewater to break oil/water emulsions for subsequent gravity separation. Removes oils and solids by bubbling gas through the wastewater, bringing solids to the surface for subsequent removal.	12	25	244	This technology is included and has been costed in the technology options for shipbuilding dry docks and railroad line maintenance subcategories.
Oil Skimming of Oily Wastewater Streams	Removes free floating oil by gravity separation and mechanical skimming. This technology does not remove emulsified oils.	38	89	2,087	Not as effective as chemical emulsion breaking followed by gravity flotation using an oil/water separator or DAF. This technology is not included in the technology options.
Cyanide Oxidation by Ozone	Ozone oxidizes cyanide to ammonia, carbon dioxide and oxygen.	0	1	4	The generation of ozone requires expensive equipment and safety controls. An equivalent technology (cyanide destruction through alkaline chlorination) is included in the technology options. Therefore, this technology is not included in the technology options.

Table 9-3 (Continued)

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[b]	Estimated Number of MP&M Sites Using the Technology[c]	
Chelation Breaking/ Precipitation to Remove Complexed Metals	Wastewater from electroless plating and some cleaning operations contains chelated metals which cannot be removed by chemical precipitation. Strong reducing agents such as dithiocarbamate are added to break the metal-organic chelate bond and precipitate the metal.	11	49	555	Used to treat electroless plating wastewater prior to chemical precipitation. This technology is included and costed in the technology options.
Ultrafiltration	Generally used to remove emulsified or free-floating oils. This technology also removes other solids. Uses a membrane of very small pore size.	17	23	351	This technology is included in the technology options for new sources.
Activated Carbon Adsorption	Removes dissolved organic pollutants by filtration through activated carbon. The dissolved organics are removed by the process of adsorption. This technology requires preliminary treatment to remove suspended solids and oil and grease.	8	21	165	Applicable to wastewater containing dilute concentrations of nonpolar organic pollutants. MP&M treatment influent streams typically do not contain dilute concentrations of nonpolar organic pollutants. This technology is not included in the technology options.
Aerobic Biological Treatment	Biochemically decomposes organic materials in the presence of oxygen. The decomposition is performed by microorganisms.	1	4	130	Applicable to wastewater with high concentrations of organic pollutants. MP&M treatment influent streams typically do not contain high concentrations of organic pollutants. EPA visited one site that operated this technology to treat nonprocess wastewater. This technology is not included in the technology options.
Air Stripping	Removes dissolved volatile organic pollutants by contacting the organics in the wastewater with a continuous stream of air bubbles. Volatile organic pollutants are transferred from the wastewater to the air.	0	2	14	Applicable to wastewater containing high concentrations of volatile organic pollutants. MP&M treatment influent streams typically do not contain high concentrations of volatile organic pollutants. This technology is not included in the technology options.

Table 9-3 (Continued)

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[b]	Estimated Number of MP&M Sites Using the Technology[c]	
Neutralization	Acidic or alkaline chemicals used to neutralize high or low pH wastewater to within an acceptable range. Common acids include sulfuric and hydrochloric. Common alkaline chemicals include lime (calcium hydroxide) and sodium hydroxide.	51	233	3,713	Adjusts pH, but does not remove suspended solids and dissolved metals. This technology is not included in the technology options.
Chemical Precipitation and Gravity Sedimentation	Removes metals by precipitating insoluble compounds such as hydroxides, sulfides, or carbonates. Precipitation as metal hydroxides using lime (calcium hydroxide) or sodium hydroxide is the most common. Precipitated and flocculated solids are removed by gravity sedimentation in a clarifier.	117	203	2,981	This technology is included and costed in the technology options.
Chemical Precipitation and Membrane Filtration	Removes metals by precipitating insoluble compounds such as hydroxides, sulfides, or carbonates. Precipitation as metal hydroxides using lime (calcium hydroxide) or sodium hydroxide is the most common. Precipitated and flocculated solids are removed by microfiltration through a porous membrane.	5	5	36	This technology is included and costed in the new source technology options.
Atmospheric Evaporation	Includes both natural solar evaporation and forced atmospheric evaporation by which the evaporation rate is accelerated by increased temperature, air flow, and surface area.	3	12	142	Usually occurs in ponds or lagoons with large space requirements. Also, atmospheric evaporators have significant energy requirements as well as possible cross-media impacts. This technology is not included in the technology options.
Ion Exchange	Polishing technique after metals precipitation to scavenge low concentrations of residual metals (cations). Anions remain in solution and are discharged. Concentrated metal containing regenerants are typically returned to the metals precipitation system.	13	39	251	Usually used in conjunction with another end-of-pipe technology (e.g., following chemical precipitation). Based on analytical data collected during the MP&M sampling program, this technology does not provide significant metal removals beyond chemical precipitation and sedimentation. This technology is not included in the technology options.

Table 9-3 (Continued)

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[b]	Estimated Number of MP&M Sites Using the Technology[c]	
Multimedia Filtration	Uses filter media of different grain size to remove solids from wastewater. Larger particles are removed by the coarser media and the smaller particles are removed by the finer media. Media include garnet, sand, and anthracite coal. The filter is periodically backwashed to remove solids.	11	16	354	Usually used in conjunction with another end-of-pipe technology (e.g., following chemical precipitation). Based on analytical data collected during the MP&M sampling program, this technology does not provide significant additional metal removals beyond chemical precipitation and sedimentation. EPA evaluated this technology in the BCT technology options.
Sand Filtration	Uses a sand filter to remove solids from wastewater. The filter is periodically backwashed to remove solids.	37	41	830	Usually used in conjunction with another end-of-pipe technology (e.g., following chemical precipitation). Based on analytical data collected during the MP&M sampling program, this technology does not provide significant metal removals beyond chemical precipitation and sedimentation. This technology was not included in the technology options.
Gravity Settling	Physically removes suspended particles by gravity. This process does not include the addition of any chemicals.	7	46	1,679	Only settles suspended solids and does not remove dissolved metals. This technology is not included in the technology options.
Centrifugation of Sludge	Uses centrifugal force to separate water from solids. Centrifugation dewaters sludges, reducing the volume and creating a semisolid cake. Centrifugation of sludge can typically achieve a sludge of 20-35% solids.	4	9	127	Energy intensive, and is therefore not included in the technology options. Equivalent sludge dewatering technologies (gravity thickening and pressure filtration) are included and costed in the technology options.

Table 9-3 (Continued)

Technology	Technology Description	Demonstration Status			Comments
		Number of Sites Visited[a]	Number of Survey Sites[b]	Estimated Number of MP&M Sites Using the Technology[c]	
Gravity Thickening of Sludge	Physically separates solids and water by gravity. Water separates from the sludge and is decanted from the top of the mixture. Gravity thickening can typically thicken sludge to 5% solids.	60	85	1,161	This technology is included and costed in the technology options.
Pressure Filtration of Sludge	Physically separates solids and water by pressure filtration. Most commonly performed in a plate-and-frame filter press where the sludge builds up between the filter plates and water is filtered through a cloth. Pressure filtration can produce a sludge cake with greater than 40% solids.	113	189	3,106	This technology is included in the technology options.
Sludge Drying	Dries sludge by heating, which causes the water in the sludge to evaporate.	22	48	835	This technology is energy intensive, and is therefore not included in the technology options. Equivalent technologies (gravity thickening and pressure filtration) are included in the technology options.
Vacuum Filtration of Sludge	The MP&M cost model evaluates the level of rinse flow control in place prior to estimating costs for countercurrent cascade rinsing.	8	9	193	Energy intensive and typically does not achieve as high a percent solids as pressure filtration. This technology is not included in the technology options. Equivalent sludge dewatering technologies (gravity thickening and pressure filtration) are included in the technology options.

EMH - Environmental Management Hierarchy.
NA - Numerical data are not available.
Source: MP&M site visits, MP&M sampling episodes, MP&M surveys and technical literature.
[a]Indicates the number of MP&M sites visited by EPA using the listed technology. EPA visited a total of 162 sites.
[b]Indicates the number of model sites that reported using this technology. Based on 691 MP&M survey respondents.
[c]Indicates the estimated number of MP&M sites currently performing this technology. EPA estimates that the MP&M industry includes 63,000 wastewater discharging sites. EPA estimated numbers in this column using statistical weighting factors for the MP&M survey respondents.

Table 9-4

Technology Options by Subcategory

	General Metals, Metal Finishing Job Shops, Printed Wiring Boards, Steel Forming and Finishing, and Non-Chromium Anodizing Subcategories				Oily Waste Subcategory				Shipbuilding Dry Dock and Railroad Line Maintenance Subcategories	
Treatment or Source Reduction Technology	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**	**Option 7[a]**	**Option 8[a]**	**Option 9**	**Option 10**
Chemical Precipitation	T	T	T	T						
Gravity Clarification for Metal Hydroxide Removal	T	T								
Microfiltration for Metal Hydroxide Removal			T	T						
Emulsion Breaking and Gravity Separation for Oil Removal	T	T			T	T				
Ultrafiltration for Oil Removal			T	T			T	T		
Emulsion Breaking and DAF for Oil Removal									T	T
Alkaline Chlorination for Cyanide Removal	T	T	T	T						
Hexavalent Chromium Reduction	T	T	T	T						
Reduction/Precipitation of Chelated Metals	T	T	T	T						
Contract Hauling of Organic Solvent-Bearing Wastewater	T	T	T	T	T	T	T	T	T	T
Countercurrent Cascade Rinsing		T		T		T		T		T
Centrifugation and Recycling of Painting Water Curtains		T		T		T		T		T
Centrifugation and Pasteurization to Extend Life of Water Soluble Machining Coolants		T		T		T		T		T

DAF: Dissolved air flotation
[a]EPA evaluated this option for Shipbuilding Dry Dock and Railroad Line Maintenance Subcategories along with Options 9 and 10.

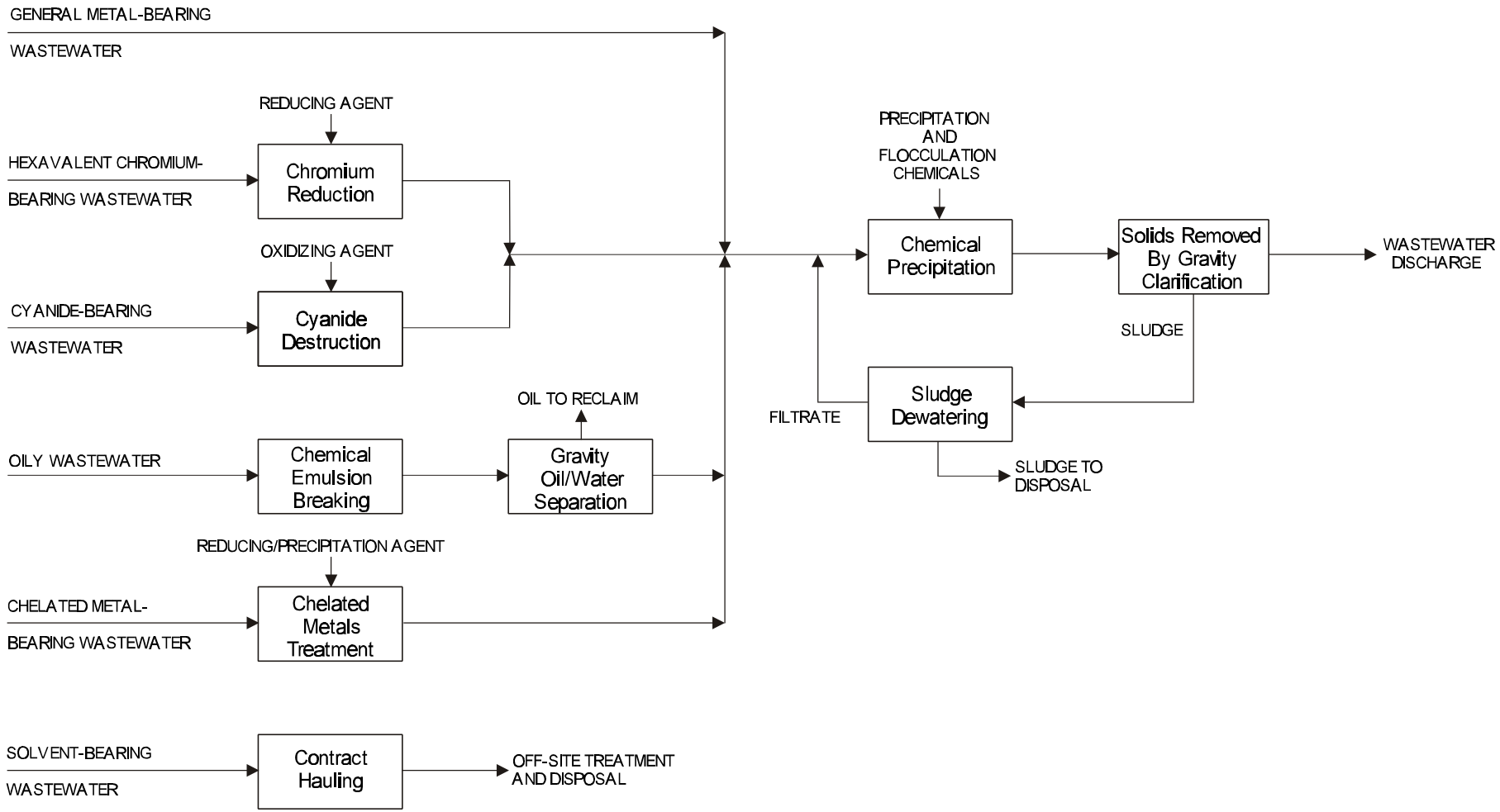

Figure 9-1. End-of-Pipe Treatment Train for Options 1 and 2 Considered for the Following Subcategories: General Metals, Metal Finishing Job Shops, Non-Chromium Anodizing, Printed Wiring Boards, and Steel Forming and Finishing

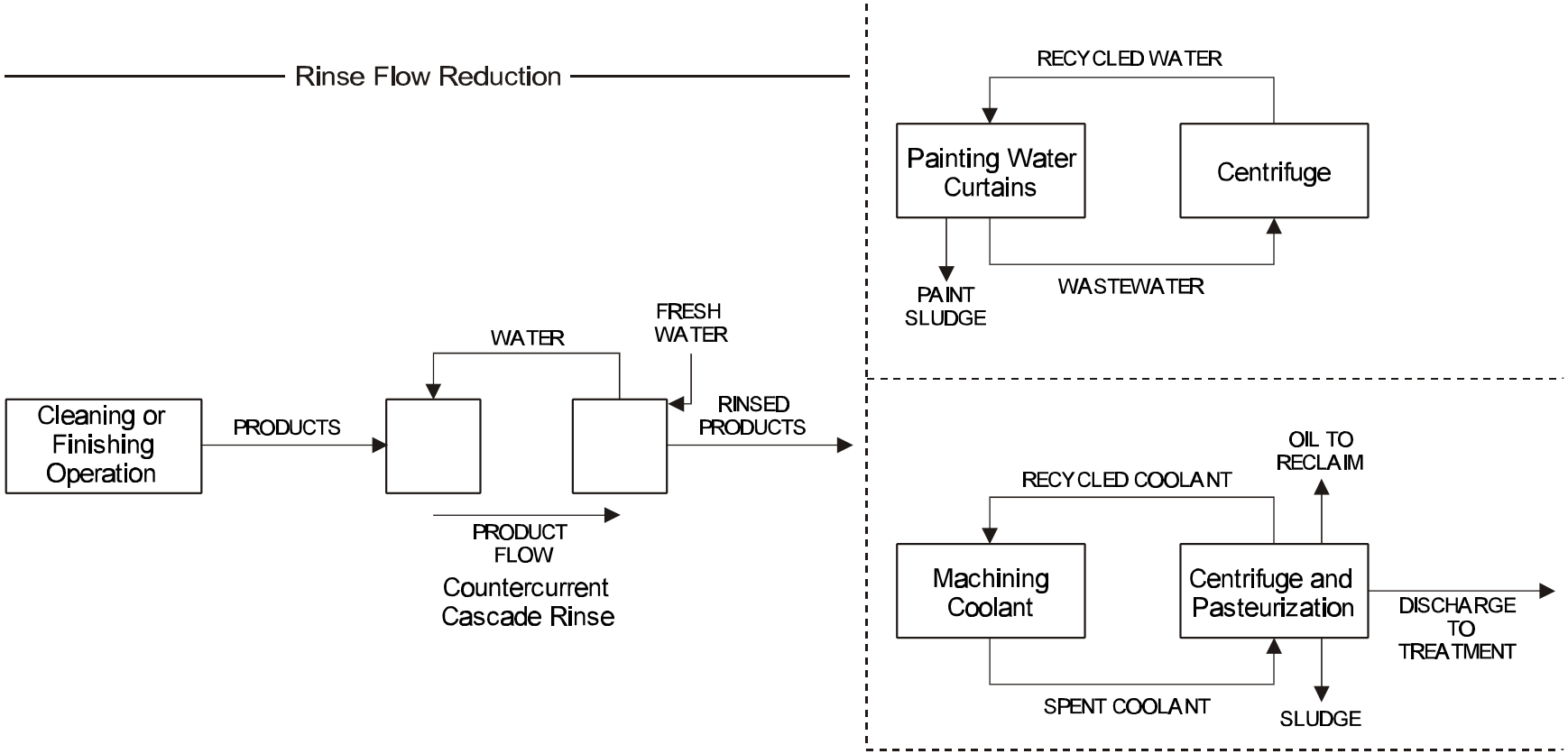

Figure 9-2. In-Process Water Use Reduction Technologies for Options 2 and 4 Considered for the Following Subcategories: General Metals, Metal Finishing Job Shops, Non-Chromium Anodizing, Printed Wiring Boards, and Steel Forming and Finishing

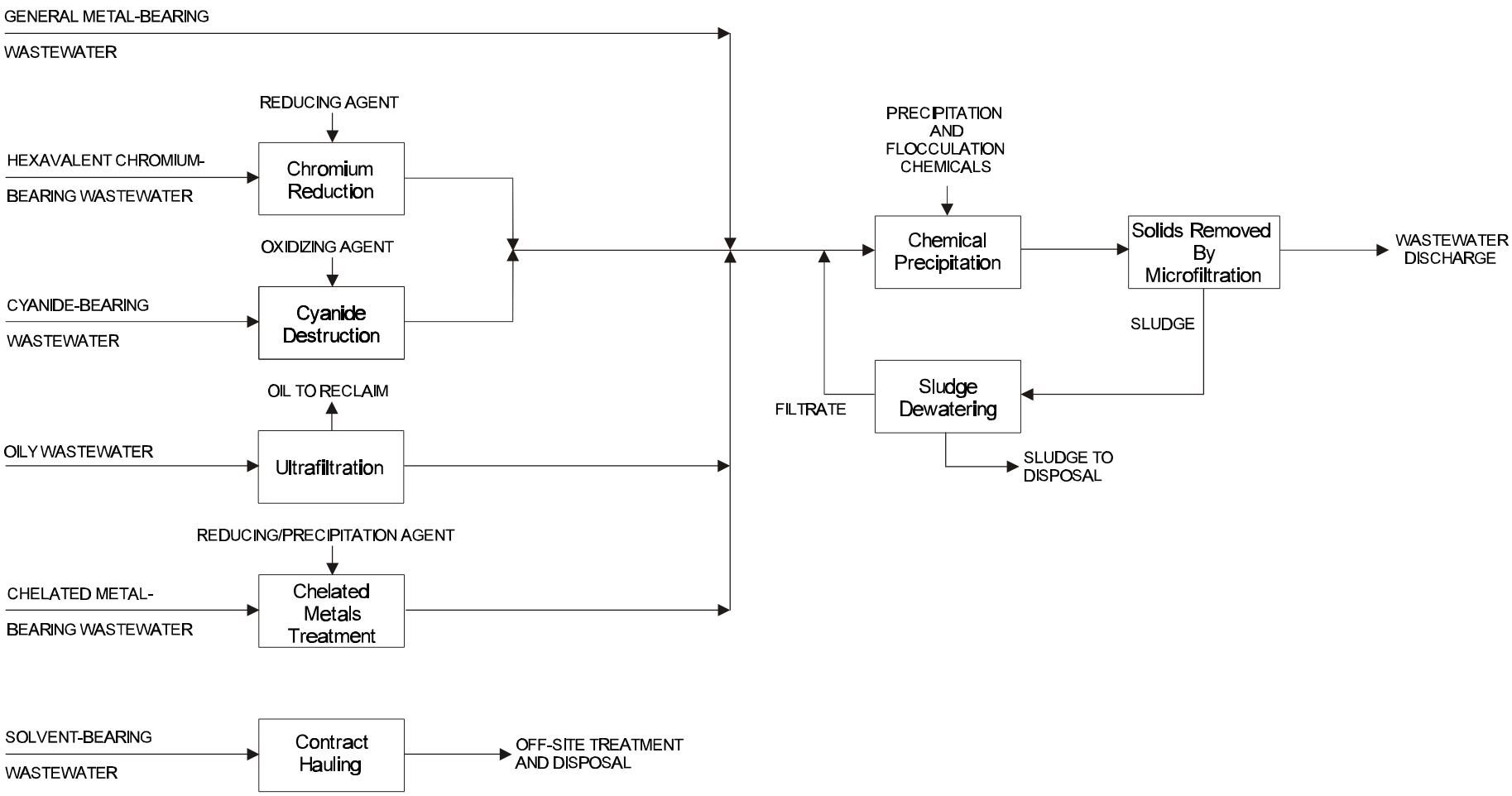

Figure 9-3. End-of-Pipe Treatment Train for Options 3 and 4 Considered for the Following Subcategories: General Metals, Metal Finishing Job Shops, Non-Chromium Anodizing, Printed Wiring Boards, and Steel Forming and Finishing

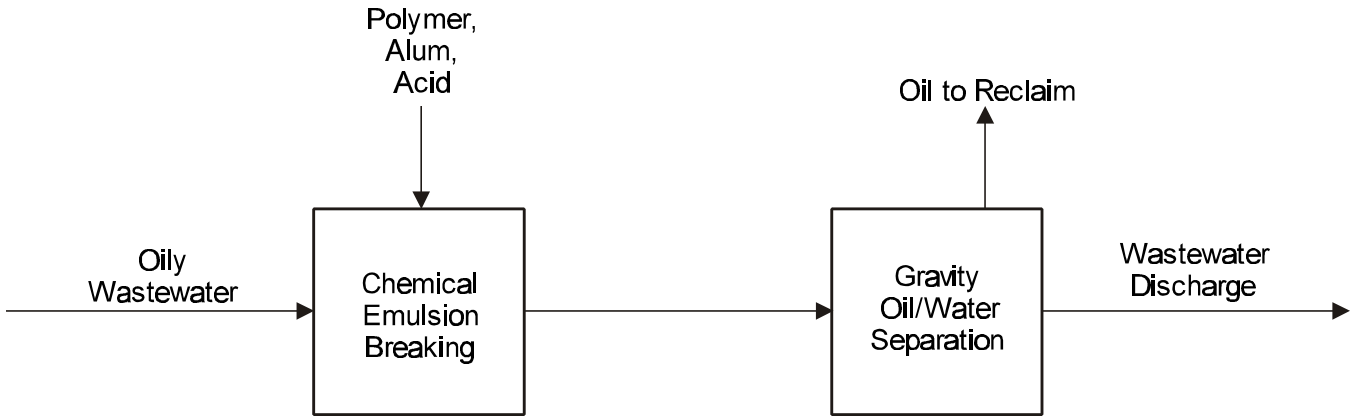

Figure 9-4. End-of-Pipe Treatment Train for Options 5 and 6 Considered for the Oily Wastes Subcategory

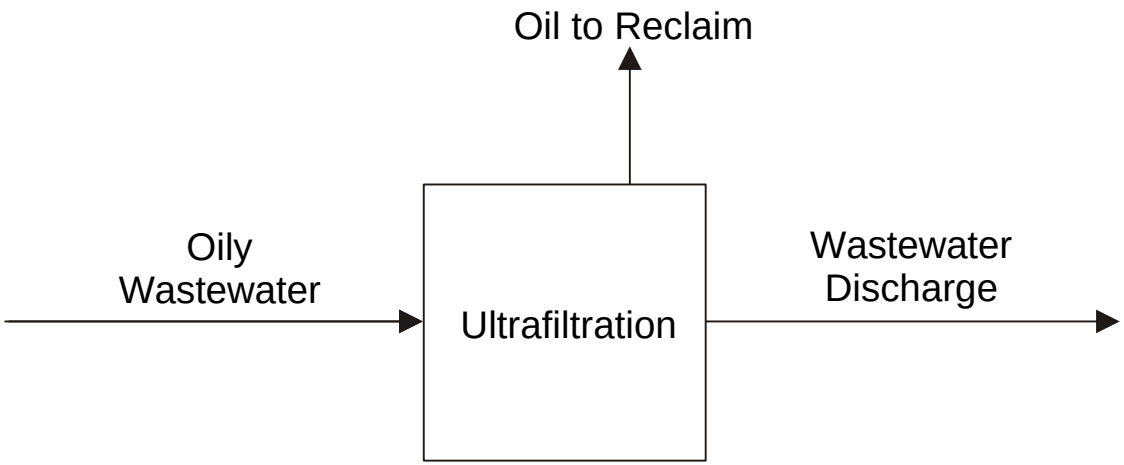

Figure 9-5. End-of-Pipe Treatment Train for Option 7 and 8 Considered for the Following Subcategories: Oily Wastes, Railroad Line Maintenance, Shipbuilding Dry Dock

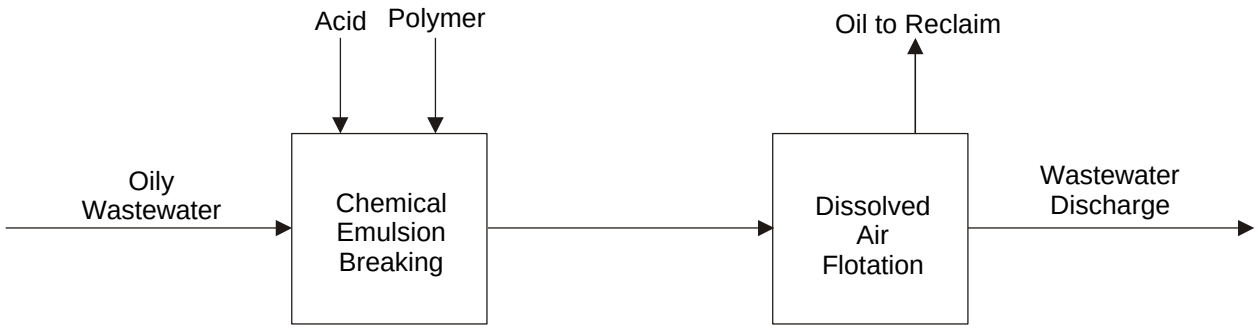

Figure 9-6. End-of-Pipe Treatment Train for Options 9 and 10 Considered for the Railroad Line Maintenance and Shipbuilding Dry Dock Subcategories