PRACTICAL POLLUTION PREVENTION

Understanding a Process with Process Mapping

When people hear the term *process map*, all sorts of images flash through their minds. Many environmental managers envision a process flow diagram. The engineering manager pictures a process and instrumentation diagram (P&ID). Maintenance personnel are used to machine configuration drawings. Quality improvement specialists think of flowcharts. Everyone may think of a floor plan. However, none of these items is a process map.

What Is a Process Map?

A process map is a schematic depiction of a process. As discussed more fully below, the process depicted can be either a key process of your facility, such as parts manufacturing, or an ancillary or intermittent process, such as cleaning tanks. In a large facility that involves many processes, you may need to create several sets of process maps to cover all the activities.

A process map typically is prepared by a team consisting of people from several departments, including environmental, engineering, maintenance, quality improvement, and others. Preparation of a process map offers a structured approach to understanding and assessing what is actually occurring in your facility's processes. Process mapping is a proven analytical and communication tool that is designed to help you improve existing processes or implement new (improved) processes.

It is important for process maps to be created by a team rather than by one individual. Remember that individuals can only influence the effectiveness and efficiency of the process components for which they are responsible. For total system process improvement, you need a team.

Interaction and questioning within the team will allow you to create a better process map, and will help ensure that your assessments are objective.

Why Use Process Mapping?

Understanding how your current processes work is crucial to pollution prevention. After all, how can you improve a process if you don't know how it works in the first place? We often simply assume that we know how industrial processes work. However, most people do not really understand exactly how their processes function or whether they can be improved, simplified, or eliminated.

In most P2 programs, people study processes with checklists, questionnaires, and worksheets. Unfortunately, it is very difficult to see relationships among different work steps with these types of documents. Process mapping makes these relationships clearer and easier to understand.

Mapping provides structure to how you seek data, how you turn it into information, and how you use it to reach conclusions about P2. A process map distills the analysis and accumulated experience of many people.

Every element or work step in the process map directs the team on a search for information that will lead to understanding the *functionality* of the

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process. In any process, there is a functional sequence of work steps. One step initiates others, which in turn initiate still others, until the process has completed its overall function with a product or result.

Process mapping is used in pollution prevention programs to enhance the efficient use of resources and to eliminate losses (i.e., wastes). In most cases, when a mapping team is confronted with a complex process map, they will have a strong desire to simplify the process. This simplification will lead to fewer losses and more efficiency. Process mapping can also help people improve energy efficiency and reduce water use.

Process mapping is critical if your company wants to better understand and significantly improve a process—and, in turn, improve its bottom line and competitive position. Process mapping will give you a better basis for understanding the expenditures you incur with a process, and will allow you to more intelligently assign costs to various activities (i.e., activity-based costing).

You can also use your map to show others how a process works—and how your P2 team is improving it. Being able to communicate effectively about your P2 advances is essential to maintaining management commitment and keeping all the facility's stakeholders apprised of the progress that is being made toward becoming a waste-free facility.

Why Not Just Use a Checklist?

In my training sessions, I often start out by showing participants the following sentence:

"Important functional is sequence very."

You can see that this statement is in English. However, its meaning is not clear because the words are scrambled. Then I show the following, which uses exactly the same words as the sentence above:

"Functional sequence is very important."

The meaning is now quite clear. This example illustrates the difference between using the checklist approach and the process mapping approach as you try to understand a process.

A map identifies all the crucial elements of a process and allows you to see their sequence and relationship to one another. The work steps in the map show you how the materials flow through the process.

Trying Out the Tool

This column explains how process mapping can serve as a tool for identifying and characterizing a current process (i.e., an "as-is" process). It also discusses how process mapping can be used to provide a "to-be" road map for a pollution prevention alternative.

In order to fully understand process mapping, however, you need to actually apply it. It would be useful and instructive to take a case study from a recent issue of *Pollution Prevention Review* and try to prepare a process map of one of the processes described using the techniques discussed in this column. See if this improves your ability to understand what is going on within the process.

Using Maps

The concept of a *map* is quite familiar to all of us. Maps are generic enough in their design to be used and understood by almost everyone. In fact, a map is such a familiar and useful tool that it has been adopted widely as a metaphor for a variety of initiatives. Industry has been busy creating "road maps" to the 21st century. A company may devise a "road map" to help it increase its market share.

Think, if you will, of a road map that you keep in your automobile. The region covered by the map is presented at a relatively small scale. In the margins, there may be insets showing certain areas, such as larger cities, in greater detail at a larger scale.

Travel books may also offer detailed city street maps.

You might use a state or regional map to locate a destination, and then look at the city map insert to see which exit to take off the interstate highway. The regional map will also help you estimate the total distance and time of the trip. Road maps offer a structured visual layout to help us understand where we are now and where we are going, and they help us make some decisions on how to get there. Process maps serve similar functions.

Tracking Materials Flow

In P2 programs, the process mapping team will focus on the flow of materials through the process. A process map offers a convenient way to keep track of materials use and loss.

The end result of the throughput in a process is the product. Materials that are used in the process but not incorporated into the product are referred to as *non-product inputs*. Losses of materials from the process work steps *are non-product outputs*.

The Mapping Team

Ideally, the process map should be created by a "focus group" consisting of people from various departments within the facility. If a focus group mapping session is not possible, the P2 team itself can draw up the map.

Sometimes it is also useful to have an internal "supplier" and an internal "customer" of the process present during the preliminary mapping exercise.

Creating a Process Map

Unlike flowcharts and P&IDs, which use a variety of different shapes and symbols, process maps simply use boxes and arrows to depict the series of steps through which inputs must pass in the course of transformation into a product. See **Exhibit 1** for an example of a process map for an offset lithographic printing operation.

In a process map, the boxes represent the work steps in the process. Within the boxes, each work step is described by a phrase such as "Prepress." Arrows between the boxes represent the movement of materials from one step to another.

Process maps can also be used to depict how materials are used and wasted, as in **Exhibit 2**. In an input/loss map, the arrows pointing down to a box indicate the materials going into the step. The arrows leading down from the box indicate the waste and pollution created by the step.

If a variety of process sequences are taking place at one location over time (e.g., washing parts in an automatic cleaning machine), additional maps can be used to describe the various steps.

Process maps can be drafted as either conventional paper drawings or as computer graphics. A large number of computerized mapping routines are commercially available.

The mapping team facilitator is responsible for keeping track of the maps on paper or entering them into a mapping program. He or she will also prepare supporting text that describes the function of each work step, and a glossary of process work step definitions. (The sidebar box accompanying this column shows an example of supporting text for the prepress step in Exhibit 1.) Using agreed-upon glossary definitions can help maintain consistency throughout the facility or company.

A Hierarchical Mapping Process

A process map actually includes a set of several maps drawn to various levels of detail. The initial, top-level map is intended to provide a broad overview; it should not bog the user down with too many details. For this reason, the top-level map should include no fewer than three, and no more than six, work steps. This limit forces the process mapping team to create more detailed second- or third-level maps to describe complex process steps.

The mapping team generally begins by creating a top-level map that includes the major steps in the process being considered. In the case of the offset lithographic printing operation depicted in Exhibit 1, the top-level map contains only three steps: prepress, press, and postpress. Note that the steps in this top-level map are numbered 1, 2, and 3. (In order to avoid confusion, it is important to maintain a consistent numbering system as you create more detailed maps.)

Lower-Level Mapping

To truly understand a process, you will need to create more detailed second-level maps for each of the steps identified in the top-level map.

In Exhibit 1, directly below the top-level map, you will see a second-level map for the prepress stage. This second-level map contains three steps: Art/Copy Assembly and Design Production; Graphic Arts Photography/Image Processing; and

Exhibit 1. Process Map—Offset Lithographic Printing Operation

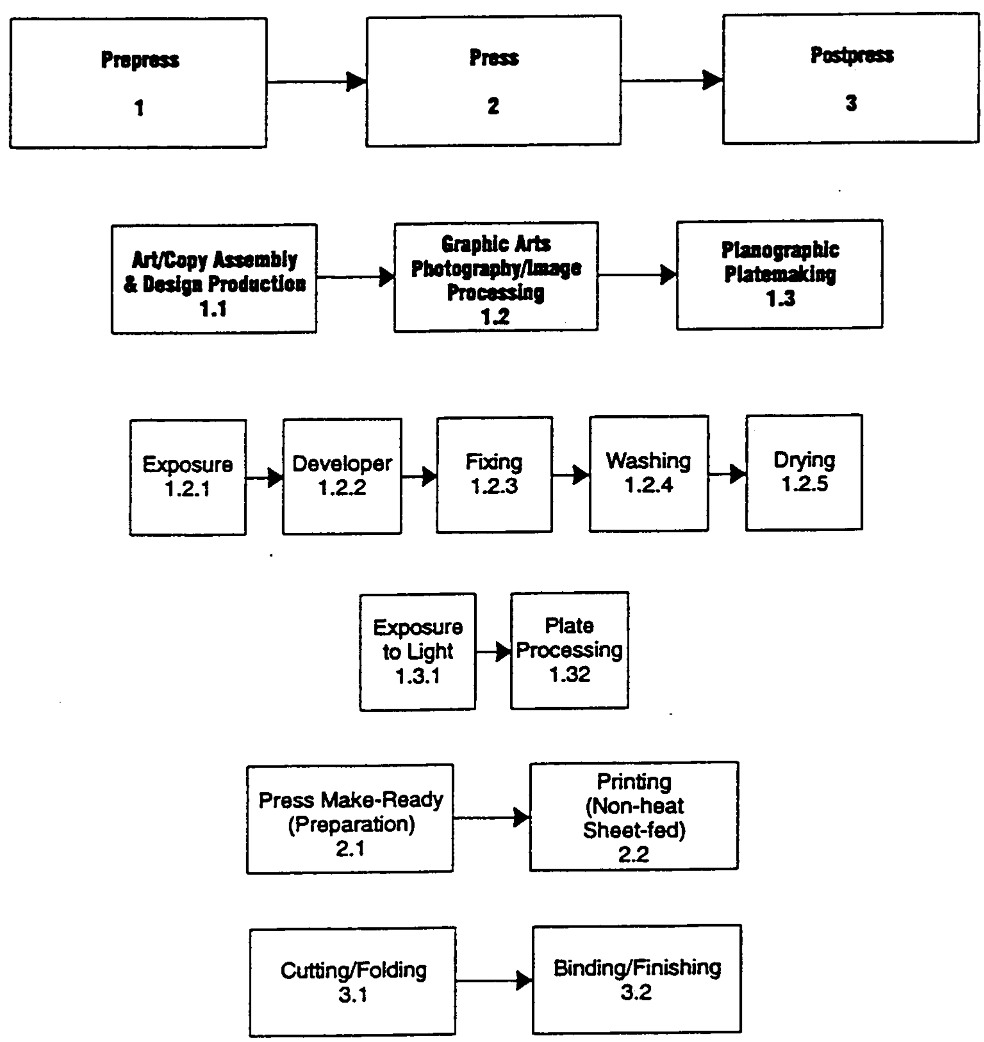
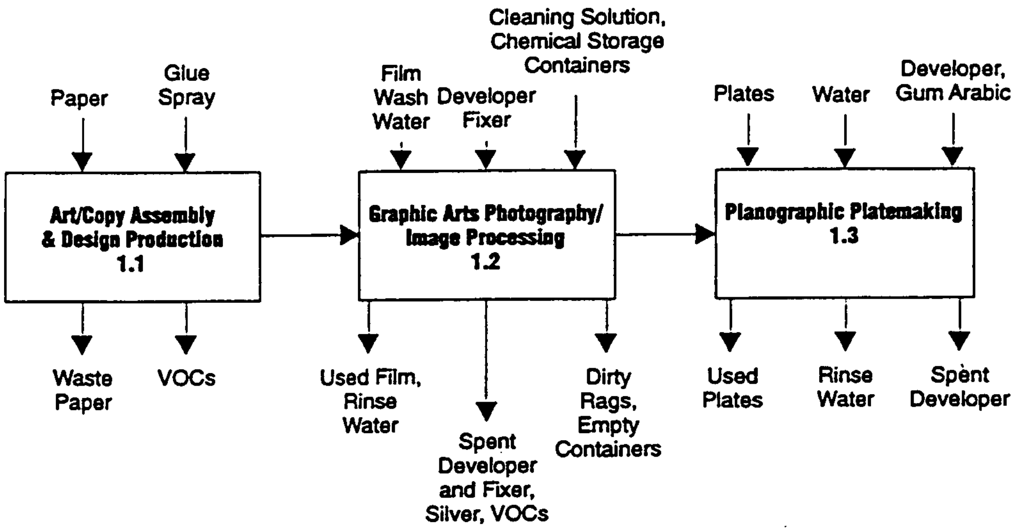


Exhibit 2. Input/Loss Map for Prepress Processes



Planographic Platemaking. These steps are numbered 1.1, 1.2, and 1.3. The first digit in each number indicates that the map is elaborating on step 1 of the top-level map.

Gathering the information needed to create second-level maps will generally involve interviewing an expert on each work step identified in the top-level map. When I work with companies that are doing process mapping, I typically act as a facilitator for the mapping team as it talks with the expert.

During the interview, the second-level process map is drawn onto a flip chart or butcher block paper. The steps in the map will be based on the information received from the expert. Like the top-level map, the second-level map should contain no more than six steps. If you need to depict even greater detail, you can create third- or fourth-level maps.

In Exhibit 1, directly below the second-level map for the prepress process, you will see a third-level map depicting the Graphic Arts Photography/ Image Processing step of the second-level map. Note that the steps in this map are numbered 1.2.1, 1.2.2, and so forth. The first two digits of each number indicate that the map refers to step one of the top-level map (prepress), and step two of the second-level map.

Exhibit 1 also includes a third-level map for the Planographic Platemaking step, and second-level maps for the Press and Postpress steps.

Touring the Work Area

After interviewing the expert and creating a preliminary second-level process map based on this conversation, your team should tour the work area where the process you are mapping takes place in order to verify the sequence of the work steps and the materials used and lost. The differences between what you put on your initial process map and what you see when you visit the work area will form the basis for questions that will help you refine your maps.

By doing a preliminary map ahead of the tour, you will gain a basic understanding of the process. This will allow you to better allocate your time when you visit the work area to assess the process. The assessment phase can then be used to improve the map and collect information that will be stored in the map template.

What Processes Should You Map?

So far, we have been assuming that the process you are studying is a main or "core" process at your facility. But materials use and losses also occur in two other kinds of processes: *ancillary* and *intermittent processes.*

Ancillary processes are work steps that support the main process. *Intermittent processes* are those that occur from time to time (such as cleaning and maintenance) and that are necessary for the operation of the main process. Ancillary and intermittent processes have their own non-product inputs and outputs. (Don't overlook the importance of mapping ancillary and intermittent processes. They often create more waste than your main process.)

As you create your second-level maps and tour the work area, you should begin to prepare a preliminary list of the ancillary and intermittent processes associated with the process you are focusing on. Additional groups may need to be convened to provide details on these supporting operations.

With process mapping, the materials used or wasted in ancillary or intermittent steps can be linked back to the work steps in the main process that are responsible for them. All materials used and lost in a facility can be accounted for in this manner.

All the rules for process mapping discussed in this column are applicable no matter what process the map is focusing on. However, it is helpful to use a system to differentiate ancillary and intermittent processes from main processes. I typically use the prefix "AA" for ancillary and "AI" for intermittent processes. In addition, it should be noted that some ancillary and intermittent operations may violate the "three- to six-box rule" that was established for main processes.

Exhibit 3 depicts process mapping for the intermittent and ancillary processes associated with graphic arts photography.

A Dynamic Process

The creation of a process map is a dynamic process that requires close coordination between the facilitator and facility personnel. Throughout the mapping project, draft versions of the process maps and supporting documentation should be distributed for review and comment. As the mapping proceeds, each person on the mapping team should make comments about the process map in writing and submit them to the facilitator after review by the entire team.

Draft process maps should be reviewed in an iterative fashion by management, workers, and process mapping team members. When a resolution has been reached on all disputed items, the process mapping is complete, and you have a set of "as-is" process maps.

A tremendous amount of learning can result from examining processes using this proven structured technique and documenting company procedures.

Using Process Maps for P2

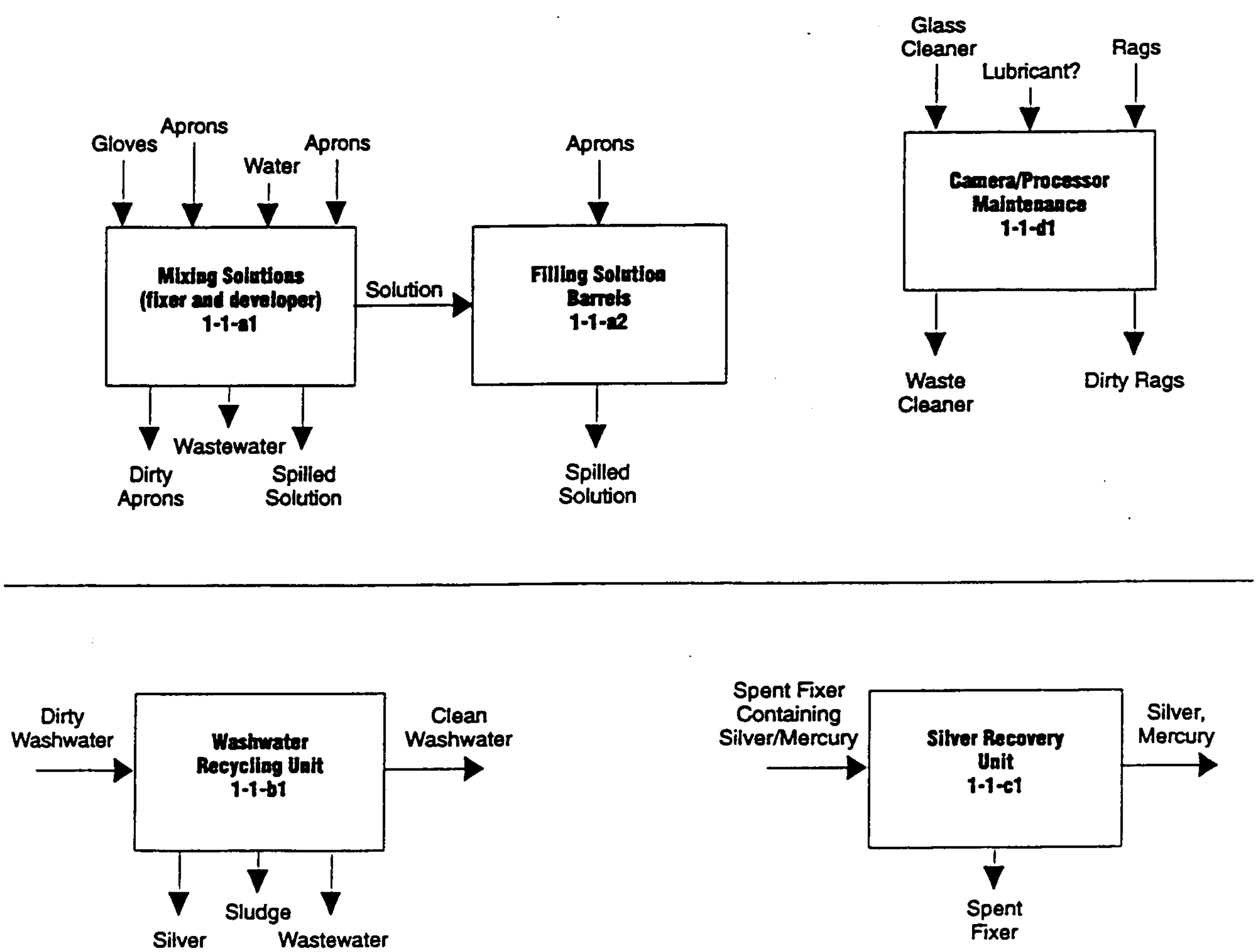
Process maps make great templates. All the materials used in a facility can be allocated to a particular work step, whether in the main process or in an ancillary or intermittent process. Process maps also identify all losses from the work steps.

When process maps are computerized, the objects (i.e., boxes and arrows) can be linked to a file containing a glossary of work step descriptions, unique names of the chemicals used, and a listing of the losses, together with the medium to which the loss occurs. In this manner, it is possible to find all the work steps that lose, say, methylene chloride. Process maps identify all the losses from a process, not just the losses that can be identified in a tour of the workplace. A future article will explore the use of process maps for materials accounting.

It is possible to create a "book of process maps" for all the processes in a multifacility company. By linking these processes to the glossary word file, it would be possible to locate all the fugitive emissions of methylene chloride from a particular type of cleaning activity. This is particularly useful in targeting P2 activities and for leveraging the work accomplished elsewhere in the company.

A P2 team should see every loss from a process as an opportunity not to have that loss. Once losses are identified, the team can then use a variety of problem-solving and decision-making tools to create actionable plans for implementing an alternative process. (The last several Practical Pollution Prevention columns have described several of these steps in detail.)

Exhibit 3. Intermittent/Ancillary Processes—Graphic Arts Photography



Prepress Step Documentation

XYZ Corporation operates a small offset lithographic printing facility. The plant has 80 employees and operates 24 hours a day, 5 days a week. They produce $12.5 million worth of reports, magazines, newsletters, bulletins, brochures, and other information annually.

In 1996, XYZ joined a Printers Partnership Initiative in an effort to prevent pollution using the best management practices of the printing industry. By sharing information and resources with other printers in the region, XYZ's operation has become more efficient—eliminating or reducing pollution at several stages of the process.

This document describes the current offset lithographic printing process at this facility. A visual map supporting this description is attached. Essentially, there are three main stages of the printing process: (1) prepress; (2) printing; and (3) postpress. The prepress stage is detailed below.

Prepress

In prepress, the idea for a printed image is converted to the image carrier, or the plate. The specific steps in prepress are: (1) art/copy assembly and design production; (2) graphic arts photography/image processing; and (3) planographic platemaking.

1.1 Art/Copy Assembly and Design Production

During art/copy assembly and design production, the text, photographs, and artwork are assembled to produce a "rough" layout of the desired printed image. Today, XYZ does all of this work on a computer. Other than paper waste, this step uses no chemicals (save for the ink in the computer printer cartridges) and produces no significant waste stream. Some spray mounting does occur in the design room under a hood, but there are no other chemicals generally used in this step. The document is then saved on a disk and transferred to a computer in the production area of the facility.

Alternatively, a customer may bring in a camera-ready document that is brought directly to the lithographic camera in the facility. This is generally used for documents with type only. Photographs are generally scanned into the computer so they may be altered using Adobe Photoshop to create the desired intensity/contrast prior to computer layout. This eliminates the need for additional reducers/intensifiers in the film-development process.

1.2 Graphic Arts Photography/Image Processing

1.2.1 Exposure

Negatives are made of the camera-ready documents using a lithographic camera. For electronically produced documents (i.e., computer-designed), a separate machine creates negatives directly from the computer file.

The camera-ready document is taken to the photography room and attached to a backboard that is part of the lithographic camera. Depending on the size of the document, different-sized rolls of film can be selected. The camera automatically rolls out, exposes, and cuts the film to a specified size. Ten-by-twelve-inch film is the smallest size used. The exposed film is automatically sent to the photoprocessor, which is attached to the camera.

For computer-designed documents, a negative is made by a machine connected to the computer. The machine automatically exposes the film and rolls the exposed film into a light-tight canister. The canister is then removed and taken to a darkroom adjacent to the photography room where the photoprocessor is located. The film is fed from the canister into a slot on the photoprocessor through an opening in the darkroom wall.

1.2.2 Developing and 1.2.3 Fixing

There are two different photoprocessors, one for developing the line negatives from the lithographic camera, the other for developing the electronically generated negatives. They essentially follow the same steps in processing the negatives, however. All the processing steps are done within the same machine. The film proceeds on rollers inside the machine from one small compartment to another, first to developer, then fixer, wash bath, and finally, to the drying stage.

The developer and fixer are periodically mixed by the operator and stored in covered plastic barrels. This step produces some spilled inputs and dirty aprons as waste. The gloves and respirators are reusable. A hood above the mixing sink captures any vapors from the intermittent mixing operation.

The developer and fixer are generally changed at least every six months, depending on the volume of negatives produced. The operator judges when the baths should be replaced based on the quality of the negatives produced; there are also sensors on each processor that indicate when the baths need to be changed. Spent developer is safe enough to go down the drain. Fixer must first pass through a silver/mercury reclamation unit before being poured down the drain. Silver and mercury plate onto a drum in the reclamation unit. A contractor scrapes down the drums every month.

Annual waste-stream samples are taken and sent to an independent lab for analysis every year. Results must be reported to the state regulatory agency.

As stated before, they do not use reducers or intensifiers in a separate stage. The developer and fixer chemistry itself has been optimized, rendering further alteration using chemicals unnecessary.

1.2.4 Washing and 1.2.5 Drying

The washing and drying steps also occur in the processor. The negatives are rinsed for a set amount of time in the wash compartment of the processor. The wash bath is recycled through a silver reclamation unit containing a biocide until it is spent, at which point it is poured down the drain. Each processor uses about six gallons of fresh water per day. The negatives are then dried by air jets. Negatives that may be needed in the future are filed away. Used film and negatives are stripped and then sold back to a recoverer.

1.3 Planographic Platemaking

As an offset lithographic printing operation, XYZ uses planographic plates to transfer ink in the form of an image to the substrate. The term *planographic* means that the image and nonimage area on the same plane and are distinguished by their physiochemical properties. Specifically, the image areas are treated to be hydrophobic (water-repellent) and oleophilic (oil-loving) resin, and the ink will adhere to these areas. The non-image areas will be hydrophilic (water-loving) and will accept only the dampening fountain solution and not the ink.

Surface, deep etch, and bimetal plates are the three main types of planographic plates used in lithographic printing today. The length of the press run determines the type of plate used. As a relatively small printing operation, XYZ uses surface plates, which are made of aluminum and the least durable. XYZ buys the plates pretreated with a naturally oil-receptive, light-sensitive coating.

To render the image on the plate, the "subtractive" surface plate is drawn to a negative (produced in graphic arts photography) using a vacuum suction and is then exposed to light. Following exposure, the plate is placed in developer solution so that the coating on the nonimage area dissolves. The developer used in platemaking (polychrome 855) is different from the developer used for processing images in the graphic arts photography step. This platemaking developer contains no silver and thus can actually be flushed down the drain. However, XYZ recaptures and reuses the developer—only intermittently replacing the solution. After development, the plate is washed and then gummed with gum arabic. Once gummed, the plate is ready for the printing press.

Before implementing a new process, you can also use process mapping to depict the new process with a "to-be" map. By linking spread sheets to computerized maps depicting the "as-is" and "to-be" scenarios, it is also possible to calculate the difference in activity-based costs between the operational scenarios.

Comparisons of "as-is" and "to-be" process maps are central steps in any successful P2 program. By its nature, a P2 program aggressively attempts to eliminate, simplify, or improve the work steps in a process. A successful P2 process-improvement effort will yield a positive answer to the key process design or improvement question: "Is this the most efficient and effective process for accomplishing the process goals?"

Other Applications for Process Maps

Process maps can also be used to depict things people do at a facility (activities), as well as the impact of environmental compliance or other requirements. An example of this is *regulatory process mapping*. State and federal regulators are using this technique to study how they conduct inspections, issue permits, write rules, and track enforcement actions. Companies can use this form of process mapping to determine all the steps necessary for regulatory compliance activities such as monitoring.

Environment, health, and safety compliance programs are far more effective when they use process maps. A process map allows you to see, for example, every process step that contributes to your facility's fugitive emissions. Work steps that are subject to stringent (and costly) regulations become immediately apparent. Regulatory compliance efforts are a major contributor to the overhead burden of a facility. Eliminating the conditions that trigger the need for compliance offers an effective way of lowering facility costs.

Process maps are very useful for identifying all aspects in an ISO 14001 environmental management program. Each process loss that has the potential for environmental impact represents an aspect. Eliminating the aspect by process improvement satisfies the ISO 14001 requirement for "the prevention of pollution." Mapping is also useful for documenting processes for purposes of ISO 9000, the quality standard.

When designing improved processes and facilities, it is important that the design team use "as-is" process maps as a basis for improvement. Many designers find it useful to simply design bottlenecks out of the existing system rather than design a whole new system. A number of "to-be" design scenarios can be developed and reviewed as a component of the design effort.

Process mapping is particularly helpful in Design for Environment programs, which focus on reducing materials use and losses from new processes. By using a multifunctional process mapping team, the designers can tap into a wealth of knowledge that will help them make the best changes. Once the design is completed, process maps can provide visual documentation on how successful the design effort has been.

R&D personnel could also profit from the use of process maps. There are many ways to make most materials and articles. Each pathway can be mapped, together with the activities necessary for regulatory compliance, operation, and maintenance. By assigning activity-based costs, R&D personnel will soon learn that the cheapest operational pathway is not always the least expensive from an overall viewpoint. At that point, more R&D activities can be undertaken to lower initial costs or operation and maintenance costs.

Process maps can also be used to track energy use to certain departments and processes. Process energy can be recorded directly on the materials flow process maps. This is important since the cost of nonprocess energy use (e.g., lighting and area heating/cooling) needs to be assigned to the department that controls that usage. Process water usage can also be tracked directly on process maps. As with energy, nonprocess water usage (e.g., area cleaning) needs to be charged back to the department responsible for it. There are now technologies available which allow you to meter water and energy usage in individual departments. Remember the old saying, "What gets measured, gets managed." Process maps help integrate energy and water use programs into the overall efficiency program at the facility.

Process maps also allow you to make a direct link with production materials requirements planning (MRP) activities and systems. An MRP system tracks every item used in a process and assigns it a part number, sometimes using a bar code reading system. This system allows each item to be tracked to the department and work step that uses it. It is also possible to give every loss a "part" number and track it in the same manner.

Because an MRP system is tied into the facility's sales forecast, it is possible to predict what wastes the facility will generate as much as three months before these wastes are created. If the environmental manager is not given access to the MRP system for this activity, information from that system can be downloaded in spreadsheets and used to populate the spreadsheets linked to the process maps.

Re-engineering programs use process maps to depict the flow of information and the activities people do within facilities. While re-engineering has been effective in lowering direct labor costs by downsizing the number of employees, it often has not been effective in substantially lowering overhead costs. By focusing on materials flows and lowering the activity-based costs necessary to manage these materials (both before use and after the loss), the process-mapping team may make substantial contributions to the re-engineering effort without laying off people. A small reduction in overhead can make a substantial contribution to the bottom line of the operation. In this manner, the environmental manager can offer a significant value-added service to the firm.

Process Map Simulation

Process maps can further contribute to understanding at all levels of the organization by utilizing simulation tools. A process map simulation is an analysis that focuses on changes that occur over time. Generally, process map simulation addresses the dynamic properties that are often of greatest interest to process improvement, such as reducing the use of regulated materials and eliminating losses.

Process map simulation provides a relatively low-cost means of examining process improvements before substantial capital is invested in a new product or process improvement effort. Process map simulation can also be integrated with activity-based cost analysis and activity-based management to increase the possible dimensions of your cost/benefit analysis. This will enable effective management participation in the process improvement efforts.

Updating Your Process Maps

To demonstrate continuous improvement in their P2 programs, many facilities update their computerized process maps on an annual basis, usually one or two months prior to the beginning of the reporting year. Updating process maps can often lead to new ideas on which P2 projects can be initiated or continued in the coming year. It also gives you an opportunity to communicate with other groups in the firm that are trying to prevent waste and find out what they may be doing that will impact the P2 program. Finally, updating process maps helps you maintain management commitment to your waste-reduction programs.

Process Maps as a Foundation for Further Steps

Any P2 program must begin with a clear understanding of facility processes. Process mapping offers one of the best means to gain this understanding.

Process mapping provides a foundation for all the problem-solving and decision-making tools used in the "systems approach" to pollution prevention. Several of these tools have been described in recent articles in this column.

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Process maps and a written description of the prepress step appear courtesy of Harvard graduate students: Angelina Zappia, Kristin Loerzel, Pamela Dziuban, and Eric Schupper.
