Create Effective Safety Procedures and Operating Manuals

Clear, complete documentation can cut errors, improve training, and help to meet regulatory requirements.

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Part I of this article provides a summary of generally accepted procedure-writing guidelines, based on decades of experience in writing operating and maintenance procedures, and many years of human factors analysis. This part also includes steps that a company/writer can take to safeguard against written procedures not being followed.

Part II offers strategies for developing an operating manual that will comply with regulatory requirements (particularly with requirements of the U.S. Occupational Safety and Health Administration's (OSHA's) Process Safety Management (PSM) regulation 29 CFR 1910.119) for processes containing highly hazardous chemicals. This part also tells how to comply with other regulatory requirements, including developing procedures for all phases of operation, addressing safety and health considerations, and describing safety systems and their functions.

PART 1: REDUCING RISK OF WORKER ERRORS

Workers will not always follow written procedures. Although an unfortunate truism, this is caused, in large part, by deficiencies in the procedures themselves. Therefore, to reduce errors in performing tasks, we must first focus on creating written procedures that are accurate and complete, and that encourage workers to use them. Once we have done what is reasonable to create effective procedures, our second focus must then be to evaluate the written procedures to: (1) understand what happens when critical written steps are not followed; and (2) determine if there are sufficient safeguards in the job situation or process to compensate for these errors.

STEP 1 — REDUCING FREQUENCY OF ERRORS

This entails writing safe procedures that will be used. Based on our experience in writing operating and maintenance procedures for refineries, chemical plants, and pulp and paper mills, we recommend the following approach for developing procedures that are safe (complete, clear, accurate, and so on) and that the workers at your facility will want to use:

• Establish a format/style guide for the procedures;

• Gather accurate, complete information related to performing the tasks;

• Write with an appropriate, consistent level of detail;

• Use simple, understandable wording;

• Validate the procedures and revise them as necessary; and

• Make the procedures easily accessible.

Format/style guide

A procedure-writing project should begin with the development of a template that will serve as a format/style guide for the procedure writer(s) to follow. The template should be as detailed as possible, including: (1) any generic wording that should appear in all procedures; (2) examples of how to phrase the procedure

title, steps, precautions, and others; and (3) the types of visual cues and place-keeping aids that should be used. Ideally, the template will allow the procedure writer(s) to simply plug in task information from various sources in a consistent way.

Establishing a standard format and style for your procedures before writing them will minimize your procedure-writing efforts, especially if different personnel will be writing the various procedures. A standard procedure format also lessens the burden on the procedure user, because it provides a road map for locating the information that is important to the user. A consistent format, in effect, becomes a training tool, teaching the procedure users where to find the various types of task information (action steps, precautions, details, etc.) within a procedure. Without a standard format, the procedure user may find the procedures confusing or hard to use, making it less likely that the procedures will be used.

Procedure formats

A good procedure (a procedure that will be used) is one that allows an experienced worker to browse quickly through the basic steps of a task without having to spend time reading all the details. However, the details are important for a new worker (newly hired or new to a process area or job assignment), who may have the basic skills that are important for a task, but who lacks knowledge of the requirements specific to the task. Thus, a procedure must be formatted in a way that highlights the basic steps (important to the experienced worker) in the midst of the details (provided for the new worker).

There are many procedure formats in use, none of which is perfect for every application. Each format has its own particular strengths, but its effectiveness depends on the tasks or situations for which it is used. The following is a description of each of the basic formats for the step-by-step procedures currently in use in industry:

• *Narrative* — Long paragraphs that give a detailed account of how a task is performed; paragraphs may not be numbered; typically written in third-person, passive voice (like a novel); hides important information within lengthy text; reader must decide which information is important; not always structured with the correct sequence of steps;

• *Paragraph* — Short, numbered paragraphs, typically with a mixture of commands and passive descriptions; better than the narrative format, but still difficult to use;

• *Outline* — Phrases, sentences, and short paragraphs organized using indentation and varied numbering; logical grouping of information; provides visual cues that are absent in the narrative and paragraph formats;

• *Playscript* — Steps grouped according to who performs them or by logical subtasks; provides visual cues similar to outline format; allows coordination of simultaneous or multiuser tasks;

• *T-Bar* — Two-column format with basic actions in left column and details, notes, etc., in right column; separates information for ease of understanding; can be combined with outline format for better visual cues; left column is suitable to expert workers; right column provides additional information for novices;

• *Multicolumn* — A tabular format; multiple compartments of information; used most effectively for troubleshooting guides, task schedules, and activity tracking;

• *Flowchart* — A graphical format; structured with boxes, diamonds, and arrowheads; brief action and conditional statements; best format for problem-solving and decision-making; provides limited information; typically used in combination with a more-detailed format; and

• *Checklist* — Brief step descriptions; provides basic actions only; typically provides spaces for check marks, initials, or signatures; can be extracted from a more-detailed format; excellent for reference in the field.

To compare how different formats might be used, Table 1 shows how the same sample of task information might look in five different formats. The narrative and paragraph types are the least effective procedure formats. Using these formats has often resulted in errors of omission when either: (1) a procedure writer has omitted an important instruction or precaution; or (2) an operator has skipped a step that is buried within a paragraph. The outline format, playscript format, and T-bar format have proven to be more effective for presenting sequential instructions. Their effectiveness increases even more when supplemented with flowcharts, checklists, and graphics.

If the workers are already accustomed to a particular format, it may be very difficult (and unwise) to switch to an inherently superior one. Change can best be implemented if it is suggested by the users themselves. We recommend explaining the various format options for specific tasks to selected users and allowing them to choose the best one for their needs. This will ensure the support of all users and allow your organization to more fully reap the benefits of a particular format.

Document control features

Regardless of the chosen format, the procedure template should include document control features (typically in a header or footer) to ensure that the workers always have the current version of a procedure. The document control features usually include some combination of the following:
• Procedure number;
• Revision number;
• Revision date;
• Date printed;
• Copy number;
• Page numbers;
• End-of-procedure marker;
• "Controlled Document" indicator; and
• Approval/review signoffs.
In general, document control fea-

tures become increasingly critical for facilities with a large number of workers. When issuing procedures, each document should have a unique identifying number or label. Records should be maintained, indicating to whom each document is assigned and the revision number of the document. There should also be a clear-cut procedure in place for controlling documentation through approval, issue, filing, and modification. Auditing mechanisms should be implemented to search out and destroy uncontrolled copies.

Procedure title

There are many acceptable forms to phrase a procedure title. For example, the title of a procedure for starting up a compressor may be expressed several ways, including:
- Start Up Compressor C-1300;
- Starting Up Compressor C-1300;
- Compressor C-1300 Startup; and
- Compressor C-1300 — Startup.

The procedure template should exemplify the standard phrasing of the procedure title. Standard phrasing of the title will not only reduce confusion, but also may help the procedure writer(s) eliminate overlapping procedures that have similar titles. Once the phrasing of the title is established, it will be necessary to decide how to make the title stand out from other text. The following are some examples of how procedure titles can be made to stand out:

<u>START UP COMPRESSOR C-1300</u>
Starting Up Compressor C-1300
COMPRESSOR C-1300 — Startup

Visual cues

Making the procedure title stand out is an example of the use of visual cues, or place-keeping aids. Visual cues include devices such as spacing, solid lines, varied text styles, indentation, and headings. When a procedure title is written in underlined, italicized, or bold type and separated by several spaces from other text, the procedure writer has effectively used

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<table>
<tr><td colspan="2" style="text-align:center">**Table 1. Different procedure formats present the same information.**</td></tr>
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Narrative

Before adding liquid diluent to the reactor, the Inside Operator and Outside Operator will agree that they are ready to start and contact the Shift Supervisor or Chief Operator for concurrence to proceed. The Inside Operator will start transferring liquid diluent to the reactor at a rate of approximately 300 according to the flow meter on Channel 2, after the Outside Operator has blocked in the gaseous diluent valve and ensured catalyst has been charged.

Paragraph

1. After charging catalyst, carefully add liquid diluent to the reactor at a rate of approximately 300 according to the flow meter on Channel 2. Be sure to close the valve for the gaseous diluent before adding liquid diluent.

Outline

1. Ensure that catalyst has been charged
2. Block gaseous diluent valve
    a. Zero output on DCS
    b. Close valve in field
3. Add liquid diluent
    a. Open valve in field
    b. Put in MANUAL on DCS
    c. Set flow meter to Ch. 2
    d. Adjust set point to 300

Playscript

OUTSIDE OPERATOR	1. Ensure catalyst has been charged
	2. Close gaseous diluent valve
INSIDE OPERATOR	3. Open liquid diluent valve in MANUAL mode
	4. Set flow meter to Ch. 2 and adjust set point to 300

T-Bar

STEPS	NOTES AND ALERTS
1. Ensure that catalyst has been charged	*Zero output on DCS;*
2. Ensure that gaseous diluent is blocked	*Valve closed in field*
3. Open diluent valve in MANUAL	
4. Adjust set point to 300	*Flow meter Ch. 2*

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visual cues to tell the procedure user, "You are here" at the beginning of the procedure. Visual cues can be planted throughout a procedure to continue reminding the user where he/she is. This is especially important for procedures that will be used in the field. Examples of effective visual cues include:
- Separating different types of information into designated areas of the written procedure. A template may include the following subheadings to indicate where the various types of information should be placed in a procedure:
1. References (documents containing information helpful to the procedure user);

2. Equipment description (the equipment involved in the task);
3. Precautions and prerequisites (things to verify before proceeding);
4. Hazards (general hazards involved in performing the task);
5. Special tools and equipment (things needed to perform the task);
6. Personal protective equipment (PPE) requirements; and
7. Steps (the actions to be performed).
- Highlighting *WARNINGS* and **CAUTIONS**. This may involve the use of graphical symbols such as stop and yield signs to call the reader's attention to important reminders.

- Using ALL CAPS to emphasize certain words, such as conditional statements ("WHEN temperature reaches setpoint, THEN hold temperature for 10 minutes").
- Using a consistent numbering scheme to indicate the order of steps (when sequence is important) and the association of substeps. For example, the procedure template may specify to:

1. Use numbers (1, 2, 3, etc.) for main steps that must be performed in the specified order;

2. Use capital letters (A, B, C, etc.) for substeps that must be performed in the specified order; and

3. Use bullets (•) for substeps when the order of substeps is not important.

- Indenting substeps. Consistent indentation will make it easy to understand the grouping of substeps, even if some of the steps are not numbered.
- Consistently varying line spacing. For example, the procedure template may specify three spaces after the procedure title, two spaces after a subheading, one space after each main step, etc.
- Using ragged right margins. Although this may not be as professional looking as full-justified text (that is, text even at the right, as well as left margins), differing the lengths of the lines of text will help the procedure users to keep their place if glancing at the procedure while performing the task.
- Providing a check-off box to the left of each instruction. Even if the procedure user does not put a check mark in the box, the box itself serves as a good place-keeping aid.

Task information

Regardless of the procedure format, a procedure can only be as effective as the task information it contains. A procedure can look good without containing accurate, complete information. Don't be fooled by a fancy format! In addition, the effort required to make a procedure look great is minimal compared to the ef-

fort it takes to create and maintain an effective procedure. In fact, maintaining an effective procedure program takes more time than most people are willing to invest, though doing so will yield large rewards.

Focused resources

One of the most critical variables in developing and managing effective procedures is the number of written procedures you have to create and maintain. Therefore, we recommend spending some time upfront to decide which tasks are critical enough to require written procedures. As a general rule, a written procedure is needed for any task which, if performed wrong, could adversely affect safety, quality, production, or the environment (depending on your company's objectives). Structured, risk-based analysis methods are available to help you decide which tasks are critical, but it may not be necessary to perform a detailed analysis. Usually, a team of experienced personnel at a facility can qualitatively judge which procedures involve the highest risks. Of course, the team will need guidance regarding the company's priorities (safety, production, etc.) and the acceptable risk level for each area (*i.e.*, the risk level below which no written procedure is needed). For example, if the company's focus is on chemical process safety, the company may choose to eliminate procedures for tasks that do not involve highly hazardous chemicals. Eliminating the noncritical procedures allows more time to analyze the limited number of critical (high-risk) tasks and develop procedures that contain the correct information.

Task analysis

Once the critical tasks have been selected, a detailed analysis of each should be conducted to obtain complete, accurate data from which to write the procedure. The goal of a task analysis is to gather the following facts:
- Specific task objectives — What

are the beginning and ending states of the subject equipment? What does performing the task "buy" the company? What is the desired outcome after the task has been completed?;
- Skills/knowledge/training required — What should each worker know or be able to do before being allowed to perform the task?;
- Hazards — What previous incidents have occurred during the task? What can go wrong during the task? How are the potential errors avoided/prevented?;
- Tools — Are there any special tools or equipment that make the task safer, easier, or less time-consuming? (The company should make sure that these items are readily available.); and
- Action steps — What major steps must be completed to accomplish the task objectives?

Do not short cut the information-gathering phase of a procedure-writing project. A common mistake made by procedure writers is hastily jotting down the steps of a procedure from memory without consulting relevant sources to ensure that these steps reflect current practices. The unfortunate consequence is that once the information is incorporated into a formal, written procedure, any erroneous or missing information is unlikely to be corrected or included later. In fact, the errors may become amplified whenever the procedure is modified.

An effective task analysis involves evaluating the task information from all available sources and then reconciling any conflicting details. Task information can be gleaned from the following sources:
- Existing documentation — Depending on the task, this may include old procedures, vendor literature, equipment files, hazard analysis tables, incident reports, management-of-change files, etc.;
- Subject matter experts (SMEs) — These are usually the workers who perform the tasks, or those who have performed similar tasks. SMEs may include operators, mechanics, instru-

ment technicians, etc., depending on the nature of the tasks; and

• Observation of task performance
— The best way to assemble accurate task information is to record the actual steps as workers perform them in the field.

Employee involvement

Regardless of how the task information is gathered, involve as many experienced workers as possible in the information-gathering phase. Failure to do so will result in erroneous (or missing) steps and precautions, as well as an ineffective and inconsistent level of detail. Remember, an effective procedure must satisfy the needs of both the experienced and new worker. Only a detailed task analysis that involves the workers will give the procedure writer(s) the information needed to achieve both objectives.

Level of detail

The level of detail at which a procedure is written should be based on the expected skill level of new workers who may perform the subject task. (Task-analysis results should provide information regarding the skill level required to perform the task.) For example, if all new operators are expected to have a general knowledge of pump operation, the instruction, "Start the pump" may need no further explanation (even if the task analysis results provide more details). However, some pumps in the plant may have certain "nuances" that warrant more explanation. If new workers are expected to learn the unique operations of each pump, then the procedure writer must provide detailed instructions on how to start a particular pump safely. Detailed instructions might include the following types of information:

• Warnings, cautions, and notes
— These should reflect what the trainer would emphasize when training a new worker;

• Equipment locations and descriptions — To avoid confusion, the description should be as specific as

possible, including the exact component label/number that appears in the field;

• Pictures (equipment configuration, panel board layout, etc.) — As a general guideline, pictures (or graphics) are needed whenever the trainer might say, "I can show you better than I can explain it";

• Step numbers — These are not always needed. Step numbers should be included only when it is critical to perform the steps in a certain order (for safety, quality, etc.);

• Calculation aids — If a conversion is required, the procedure should describe the calculation and provide blank space to perform it;

• Acceptance criteria — These tell the worker (and supervisors) if an action has been performed correctly. Criteria may include a desired setpoint, a safe operating limit, a visually observed condition, a torque value, test results, etc.; and

• References — Other documents may contain more specific information about a particular component. The procedure should refer to these documents by the complete document titles and numbers, and should state where the documents can be found.

Once the details for the new worker have been developed, the procedure writer can use the format/style guide to separate the details from the main steps. This will also facilitate extracting the main steps from a procedure to create a checklist for use in the field. (The checklist, in effect, becomes the procedure for the fully trained, experienced workers.)

Procedures that are written with an appropriate, consistent amount of detail give the procedure users confidence that no assumed steps have been left out. In this way, the procedure leaves no room for the workers to guess the intent of a particular step or make up their own best way of doing the step. As a result, the written procedure reduces the chances for errors in the job, but only if the level of detail remains consistent throughout the procedure.

Use simple, understandable wording

A primary goal of a procedure writer is to mold the task information into step-by-step instructions that are easy to follow. There are some standard grammatical and vocabulary rules for procedures that can help the writer to achieve this goal. These guidelines are based on decades of human factors research ([1]) aimed at reducing the potential for procedural errors, especially during stressful situations (e.g., emergency shutdowns). The following paragraphs highlight a few of the important grammatical rules for procedures.

First, phrase each instruction as a command to the procedure user. This requires starting a step description with an action verb (or imperative) such as turn, open, shut, increase, or set. Examine the placement of the action verb in each of the following examples:

Poor — "The valve is turned ¼ turn toward the full open position."

Better — "The operator then turns the valve ¼ turn counterclockwise."

Best — "Open the valve ¼ turn."

The first example is undesirable, because it is written in passive voice and does not state or even imply who is supposed to turn the valve. The second example is better; it exhibits active voice and explicitly states who performs the action. The third example demonstrates the preferred, easy-to-understand phrasing. This instruction begins by stating the desired action and leaves no doubt as for whom the instruction is intended (i.e., the procedure user). It also requires the procedure user to read fewer words, improving comprehension of the intent. (In this case, the task analysis results allowed the procedure writer to take into account that the procedure user understands how to open the valve.)

Second, minimize the number of actions per instruction. For high-stress procedures in particular, the writer should try to include only one implied action per instruction. This

means that each instruction implies only one actor, one action, and one object being acted on. For example, a maintenance procedure step that states, "Remove the valve from the pipeline" may include several implied actions: disconnect any instrumentation from the valve, cut the valve out from the piping, attach a hoist to the valve, lift the valve, etc. The procedure writer must examine the task analysis results to determine whether a breakout list of the implied actions is needed.

Factors in this decision include: (1) whether more than one worker performs the various implied actions; and (2) whether the implied actions are considered prerequisite skills of the worker(s). If the implied actions are understood as basic skills and only one worker is involved in completing the implied actions, then simply stating, "Remove the valve from the pipeline" may be acceptable. The goals are: (1) to ensure that the procedure user will not overlook one or more of the "hidden" actions; and (2) to avoid boring (distracting) the user with information that person considers useless.

Third, use simple terms that carry the same meaning throughout the procedure. A common violation of this rule involves the interchangeable use of terms such as verify, confirm, check that, ensure, assure, make sure, and be sure. The basic meaning of all of these terms is, "Look at it, and if it is not right, make it right." Procedure writers should choose one of these terms that the workers at the facility understand and then use this term exclusively throughout the procedure.

Fourth, avoid using big words and plant jargon that may not be readily understood. A big word is any term that could be expressed more simply. Table 2 presents examples of common words that can replace big words.

Jargon may include acronyms, abbreviations, and nicknames that the experienced workers use daily. Such terms may be used if they will be commonly understood by all workers.

As a rule of thumb, if the procedure writer feels the need to define an acronym, abbreviation, or nickname, that term should not be used in the procedure. Instead, the writer should use the full name of the item throughout the procedure. In cases where the use of an acronym, abbreviation, or nickname is appropriate, the term should also be used consistently throughout all procedures to avoid confusion.

Validation

Validating the procedures will help to ensure that they are complete and accurate, and that they are procedures that employees from all shifts will follow. A procedure validation team should be composed of representatives of all the final users of the procedures (engineers, operators, maintenance personnel, quality control specialists, industrial hygienists, etc.) (2). The team should include employees who were not involved in the procedure-writing process to offer them a chance to make suggestions and to "buy-in" to the procedures before they are implemented. If these employees make suggestions that are accepted (which is likely), they will feel greater ownership of the written procedures and will be more likely to abide by them.

The validation team's approach should be to carry the procedures out or review their being carried out to ensure that all key items have been included, whether steps are in the right order, whether there is a better way (from a safety, quality, or productivity standpoint) of completing a task, whether more detail is needed, whether there are ample and prominently enough displayed warnings and cautions, whether the warnings and cautions appear at exactly the right spot in the procedures, and whether additional illustrations are needed to make the procedures easier to follow in the field. The validation team is also the best group to perform the hazard evaluation described later on in Step 2.

Table 2. Avoid using big words, rather, use common words.	
Instead of	Try
Approximately	About
Attempt	Try
Utilize	Use
Difficult	Hard
Erroneous	Wrong
Subsequent to	After
Mitigate	Reduce

Accessibility

Accessibility of procedures means more than simply placing copies of them in various locations in the facility. It requires a well-established procedure management system, including document control and management of change, to ensure that the correct versions of the procedures reside at specified locations. The ongoing success of a procedure management system hinges on the company's commitment to maintain, continually improve, and enforce the use of the written procedures. To quote Trevor Kletz, "Procedures are subject to a form of corrosion more rapid than that which affects the steelwork; they can vanish without a trace once management stops taking an interest in them..." (3)

Other than company commitment, there are a few basic characteristics of a successful procedure management system. These characteristics, which help ensure that up-to-date procedures are accessible to the workers, include the following:

• Frequent use — The only thing worse than having no written procedures is having procedures that are not used. In facilities where the workers refer to the written procedures daily, the procedures tend to stay up-to-date and readily available. Unfortunately, experienced workers at many sites believe that they do not need to refer to written procedures. Some of the advice provided earlier in this article should help;

• Worker authorship/ownership — Workers who help develop, and are given ownership of a procedure or group of procedures tend to take pride in them. The workers want to keep their procedures up-to-date and looking good because their peers and supervisors at the plant partly judge them by the quality of their procedures;

• Continual improvement — Procedures become perfected when they are continually updated with lessons learned on the job. The company should persistently encourage workers to feed these lessons into the procedures as soon as the lessons are learned. A solid management of change system must be implemented to avoid adding or deleting items (resulting from lessons learned) that might introduce new hazards. If a worker suggests a change that would make a step more convenient, but less safe, the management of change system should ask for an alternative suggestion before rejecting the idea altogether; and

• Teamwork — In companies that implement a team concept where workers on different shifts and of various disciplines cooperate, the teamwork extends naturally to the procedure management system. Each procedure is reviewed by all affected disciplines and validated by all shifts to ensure that the steps are safe, accurate, and complete. The team concept keeps the workers focused on the system's goal and minimizes individual tendencies to resist editing and criticism.

Making the procedures accessible to the workers is not really a matter of availability; rather, it is an exercise in human interaction and cooperation within a facility. As more workers begin participating in the procedure management system, the value of the written procedures as both training tools and on-the-job references will increase. In the end, all the workers may actually follow the same procedures.

STEP 2 — REDUCING CONSEQUENCE OF ERRORS

This means safeguarding against the procedures not being followed. What if all the workers do not follow the step-by-step procedures all the time? (Unfortunately, this typically is the rule rather than the exception.) What can be done to safeguard against (e.g., compensate for, engineer against) the inevitable reality of human error? Providing safe, accessible written procedures is an excellent starting point. However, many other factors influence an individual's performance on the job (some of which may be uncontrollable). These factors include:

• Situational characteristics — noise, work hours, availability of tools, etc.;

• Task and equipment characteristics — controls and displays, information load, task frequency and repetitiveness, etc.;

• Psychological stressors — threat of job loss, monotonous or meaningless work, distractions, etc.;

• Physiological stressors — fatigue, extreme temperatures, lack of exercise, etc.; and

• Organismic factors — personality and intelligence, motivation and attitude, emotional state, etc. (4)

Because of these other factors, it is necessary to implement safeguards to protect against the possible consequences of not following the written procedures. To identify existing safeguards and help decide what additional safeguards are needed, we recommend performing a hazard analysis of the procedures, similar to a hazard evaluation of process equipment.

Many companies do not currently perform hazard analyses of procedures, though most do perform some type of job safety analysis (JSA). Unfortunately, a typical JSA will not usually identify process safety issues or related human factors concerns. (From a JSA perspective, it may be perfectly safe for an operator to open a reactor's steam valve before opening its feed valve; however, from a process safety perspective, the feed valve may need to be opened before the steam valve to avoid the potential for overheating the reactor and initiating an exothermic decomposition.)

Typically, JSAs and other traditional methods for evaluating tasks are used to: (1) ensure that the procedures are accurate and complete; and (2) ensure that there are adequate safeguards for individual employees, assuming that they follow the procedures as written. These methods generally will not identify scenarios or safeguards related to not following the written procedures.

To identify these types of human errors (arising from failures to follow the written procedures), we recommend applying an established hazard evaluation technique (such as a hazards and operability (HAZOP) study or a what-if analysis) to the written procedures. Analyzing the procedures in this way has proven to be effective for evaluating potential procedural errors (5–8). Procedure analyses typically occur either during procedure validation or during a process hazard analysis (PHA).

To avoid overworking analyses of procedures, we stress a tiered approach (7). This approach involves first screening the procedures to decide which ones require the most detailed analyses. The most critical procedures, or those with extreme hazards, should be analyzed using a structured technique such as HAZOP. HAZOP-type guidewords for use in procedure analyses are presented in Tables 3 and 4.

Most written procedures contain only a few complex steps; the remainder are rather simple ones (though they may involve hazards). To analyze the complex steps of a critical or extremely hazardous procedure, we recommend using the set of eight guidewords (Table 3). These guidewords originated from HAZOP guidewords commonly used for analyzing batch processes.

The simpler steps of a critical procedure can be analyzed effectively using the two-guideword set (Table 4). The two-guideword set is derived from the two basic human error categories: errors of omission (not performing a task) and errors of commission (performing a task incorrectly). Experience is required of the analysis leader or team in selecting the critical procedures and deciding when to use each guideword set. Procedures not considered critical or extremely hazardous can be analyzed using the less-structured what-if technique.

Typically, the most critical procedures to analyze are those for non-routine tasks or activities (e.g., emergency shutdown). Nonroutine tasks involve steps that workers rarely perform. Many organizations do not regularly update nonroutine procedures (although this is changing because of pressure from the OSHA process safety management (PSM) regulation and quality standards such as ISO-9000). Also, during nonroutine operations, many of the standard equipment safeguards or interlocks are disabled or bypassed. Because of these two points, analyses of nonroutine procedures frequently identify situations in which deviations from the written procedures are likely to occur and for which insufficient safeguards currently exist.

To conduct a procedure analysis, the analysis leader or team first identifies each individual action step in the procedure. Then, the team applies the eight-guideword set, two-guideword set, or what-if questions, as appropriate to each action to develop procedural deviations. The analysis team structure and meeting progression are identical to that of a HAZOP or what-if analysis of process equipment. An effective analysis requires active participation by one or more operators, as well as a team leader experienced in applying the analysis technique. It also requires the team members to stretch

their imaginations and put themselves in the position of a worker (particularly a newly assigned one) under stress. For each procedural deviation identified (using the guidewords or what-if questions), the team must dig beyond the obvious cause (human error) to identify possible human factors such as, "inadequate emphasis on this step during training," "inadequate labeling of valves," or "instrument display confusing or not readable," which may contribute to the error. Identification of the root-cause reveals to the team the true safeguards that are needed.

By helping to identify these safeguards, a procedure analysis can serve as an effective tool for reducing procedural errors. To obtain the greatest benefit from a procedure analysis, the analysis team should document the possible deviations from the written procedure steps, consequences of the deviations, the

existing safeguards identified, and any recommendations for additional safeguards. This type of documentation can be a part of a report for a complete hazard review of an operation, process, or activity (such as part of a PHA to support: (1) addressing hazards during all operating modes; and (2) coverage of human factors issues), or it can act as stand-alone evidence of a procedure review. In either case, the analysis results should also be fed back into the written procedures in the form of precautions, warnings/ cautions/ notes, and troubleshooting guidelines. In this way, the analysis results can help teach others about the potential consequences of not following the procedures and the safeguards against these errors.

(References for Part 1 at end of Part 2, p. 37).

Table 3. Set of eight guidewords for analyzing complex steps.

Guideword	Meaning
Missing	The written procedure is missing an action that is normally performed before, or as part of the specified step.
Skip	The specified step is not performed.
Part of	One or more simultaneous actions in the specified step are not performed.
More	A desired quantity is exceeded during the specified step.
Less	A desired quantity is not reached during the specified step.
Out of Sequence	The specified step is performed ahead of the previous step.
As Well As	A convenient action is performed simultaneously with the specified step.
Other Than	The specified action is performed on the wrong device, or the reverse action is performed on the specified device.

Table 4. Set of two guidewords for analyzing simple steps.

Guideword	Encompasses
Omit	Missing, Skip, and Part of.
Incorrect	More, Less, Out of Sequence, As Well As, and Other Than.

PART 2: ADDRESSING PSM REQUIREMENTS FOR OPERATING PROCEDURES

Until recently, many companies operated their plants based almost entirely on experience and on-the-job training, without following written operating procedures. With the advent of new regulations such as OSHA's Process Safety Management (PSM) regulation (29 CFR 1910.119) and the U.S. Environmental Protection Agency's (EPA's) Risk Management Program (RMP) regulation (40 CFR 68), these companies are asking themselves, "What do we need in terms of written operating procedures to satisfy the regulations?" The key to answering this question is to focus on the regulatory intent: reduce human errors that can contribute to catastrophic accidents. More specifically, companies must address two issues in the development and implementation of operating procedures to satisfy the regulations:

1. Committing to use procedures as an integral tool for training and on-the-job reference; and
2. Including the required information and conveying that information in a way that is the most useful to the workers.

Dealing with issue No. 1 is a matter of a company's committing its resources to implementing an ongoing training program based on written operating procedures. It may also require convincing some workers (who have previously relied almost entirely on their own experience and judgment) to work within the system by: (1) following and referring to detailed written procedures; and (2) suggesting and then managing changes to the written procedures (when the procedures conflict with what the workers believe is the best way to operate the process).

To address issue No. 2, a company should review industry approaches that have been successful (*i.e.*, where incident rates have been reduced) in conveying written instructions, and then customize those ideas for the company's particular work environ-

ment. Our experience in writing operating procedures for refineries, chemical plants, and pulp and paper mills, as well as the experience of many others, has shown us what generally works and what does not work. Although there is no single right way to provide the required information, we have developed strategies for documenting all the required information efficiently and effectively.

REGULATORY REQUIREMENTS FOR OPERATING PROCEDURES

OSHA and EPA refer to their regulations governing operating procedures as "performance-based," providing general rules that give a company flexibility in deciding how to implement the regulator's intent. (Actually, these are not true performance-based requirements, because the only performance or feedback criterion is having no incidents.) The general rules state that operating procedures must accurately address the following:

• Steps for each operating phase — These include all startups, shutdowns, and normal, temporary, and emergency operations;

• Operating limits, consequences of deviations, and steps to correct/avoid deviations — To clarify this, Appendix C to 29 CFR 1910.119 states: "... the operating procedures addressing operating parameters will contain operating instructions about pressure limits, temperature ranges, flow rates, what to do when an upset condition occurs, what alarms and instruments are pertinent if an upset condition occurs, and other subjects" (*1*). As will be discussed later, citations related to this requirement indicate that OSHA considers that not performing a step or performing a step wrong could also be a deviation from an operating limit;

• Safety and health considerations, including chemical properties and hazards, precautions, and control of inventory levels; and

• Safety systems and their functions.

This documentation must be consistent with the overlapping details of the process safety information (PSI). The relationship between operating procedures and PSI is clarified in Appendix C to 29 CFR 1910.119, which states:

"The process safety information package is to be used as a resource to better assure that the operating procedures and practices are consistent with the known hazards of the chemicals in the process and that the operating parameters are accurate" (*1*).

Procedure information that may overlap, and must be consistent with PSI includes:

• Chemical hazard information (toxicity, permissible exposure limits, etc.);

• Diagrams or descriptions of the process;

• Lists of safe upper and lower limits (for temperature, pressure, flow, composition, etc.);

• Statements of the consequences of deviations from these limits;

• Statements of the consequences of potential procedural (step) deviations (*i.e.*, errors of omission and commission) identified during task or hazard analyses. (These deviations are similar in concept to deviations from safety limits, except in many cases the safety limit is exceeded as soon as the procedural [step] deviation occurs, or there are no indications or warnings to detect the deviation until it is too late. As discussed later, OSHA has written citations for not addressing the consequences of deviations from step-by-step instructions.)

Because regulations allow for some PSI (*i.e.*, process technology information) to be developed during process hazard analyses (PHAs), the information (particularly consequences of deviations and related safeguards) contained in the operating procedures must also agree with the results of PHAs. To quote the *Federal Register*:

"OSHA realizes that some operating procedures will change over time and will probably need revision when

the process safety information is collected and the process hazard analysis is conducted ..." (2).

Clearly, the regulator's intent is for operating procedures to be enhanced as needed based on the PSI and PHA results (as they become available).

In addition to the general requirements and consistency issues, there are general rules governing operator training that directly affect the content and structure of operating procedures. These rules require the following:

• Training employees in the operating procedures;

• Training employees in an overview of the process;

• Emphasizing specific safety and health hazards;

• Ascertaining that employees have the knowledge, skills, and abilities required to perform the tasks specified in the operating procedures; and

• Providing refresher training to assure that operators understand and adhere to the operating procedures.

These training requirements imply the need for documentation that: (1) describes the process; (2) emphasizes hazards specifically; and (3) states the knowledge, skills, and abilities required to follow the procedures. This documentation can be developed and maintained as an integral part of

Table 1. Structure of a typical operating manual.

I. Background
   A. Process Overview
   B. Hazards Overview
   C. Description of Equipment and Safety Systems

II. Normal Operations
   A. Routine Duties
   B. Temporary/Emergency Operations
   C. Troubleshooting Guide

III. Nonroutine Procedures
   A. Startup
   B. Shutdown and Preparation for Maintenance
   C. Emergency Shutdown

a manual containing operating procedures. The remainder of this article describes an approach for developing a manual that will address all the requirements for the operating procedures described above, including the implications regarding operator training. However, a discussion of how to build an effective operator training program is beyond the scope of this article.

RECOMMENDED APPROACH: THE OPERATING MANUAL

An effective (and popular) way to convey the procedural information required by the PSM and RMP regulations is to develop a comprehensive operating manual that can be used both as a training document and as a reference in the field. By developing a single operating manual, companies can reduce the resources required to maintain two or more sets of documentation (e.g., individual operating procedures, as well as separate training materials). There are numerous options for organizing an operating manual to provide all the required information pertaining to operating procedures. Based on our experience in writing operating procedures, we suggest dividing the operating manual into three sections: Background, Normal Operations, and Nonroutine Procedures (Table 1).

For large or complex processes involving numerous definable subsystems, the operating manual may contain a module for each subsystem; in this case, each module may be divided into these three sections. Table 2 shows which of these sections addresses each regulatory requirement.

Background section

The Background section of the manual (or module) is intended to provide general information related to the process and its operation. This gives new operators a general knowledge of this, as well as satisfying portions of the regulatory requirements. When supplemented with appropriate skills and abilities, this background

information should allow a new operator to understand and follow the operating instructions. The Background section should include overviews of the process, its hazards, and its equipment and safety systems.

Process overview — The process overview should describe all phases of operation and be detailed enough to give a new operator a basic understanding of what chemicals feed the process, how they are mixed, reacted, separated, etc., and how the products are stored or distributed. In particular, the overview should summarize how the process is controlled (e.g., automatically by a distributed control system). It may be helpful to: (1) include diagrams that describe the flow and the physical layout of the process; and (2) reference piping and instrumentation diagrams (P&IDs) or other drawings that depict the process in more detail.

Hazards overview — A hazards overview partially satisfies the regulatory requirement to address health and safety considerations. Developing a hazards overview can be as simple as compiling copies of the material safety data sheets (MSDSs) for the chemicals involved in the process (assuming that the MSDSs meet the criteria stipulated in the regulations). However, because MSDSs are not always easy to interpret, we recommend including in the manual a summary of the hazards unique to each chemical. Furthermore, the hazards overview should state the company's policies for handling each chemical, including general precautions and PPE requirements. This is the regulator's intent, evident from OSHA citations that have included wording such as, "... address the precautions necessary to prevent exposures, including ... personnel protective equipment" (3).

Description of equipment and safety systems — To adequately address the functions of safety systems, it is usually necessary to describe the process equipment that the safety systems protect. For example, listing the pressure relief valves in the process

means little unless this listing is accompanied by a description of the protected pressure vessels, pipelines, etc. Therefore, we recommend describing the equipment and safety systems together. This description should focus on the existing controls and safety devices for major tanks and pressure vessels, as well as for critical rotating equipment (compressors, pumps, etc.). It should also summarize the general safety features of the entire facility (combustible gas detectors, fire suppression systems, drainage and collection systems, flares, etc.). The objective of this description is to give new operators a general understanding of what the process controls and safety devices will do automatically to help prevent a catastrophic event. This gives the operators a deeper understanding of the role they themselves must play in controlling the process.

Normal Operations section

The purpose of the Normal Operations section is to describe the operating tasks or activities that may be encountered during the normal operation of the process. Instructions for normal operations may include checklists for completing routine operator duties (*e.g.*, daily rounds). They may also include daily orders that are issued to the operations staff or a batch sheet that specifies the recipe for a batch reaction. Because daily orders and batch recipes can change frequently (sometimes daily), these may be considered temporary operations. An operating manual typically gives only a general description of temporary operations and tells where the instructions for these operations are posted.

The same is usually true for emergency operations, which may be initiated by an unanticipated, but necessary, change to the process or its operation. For example, manually venting a pressure vessel to the flare after discovering that the relief valve will not open might be considered an emergency (and temporary) opera-

Regulatory Requirement	How an Operating Manual Can Address the Requirement
Address each operating phase (process diagrams/descriptions must be consistent with PSI)	• The process overview in the Background section describes each operating phase based on diagrams/descriptions of the process included in the PSI • The Normal Operations and Nonroutine Procedures sections together provide detailed instructions for all operating phases
Address operating limits, consequences of deviations, and steps to correct/avoid deviations (safe upper and lower limits, and consequences of deviations must be consistent with PSI)	• The troubleshooting guide in the Normal Operations section includes the following: — Safe parameter limits that relate to information available from instrumentation or field samples and measurements — Consequences of deviating from safe parameter limits, based on consequences listed in PHA documentation — Actions to correct the deviations or avoid the consequences • The Nonroutine Procedures include precautions and warnings that state how to avoid the consequences of potential step deviations (*i.e.*, errors of omission and commission) identified during task analyses or hazard analyses of the procedures
Address safety and health considerations (chemical hazard information must be consistent with PSI)	• The hazards overview in the Background section describes safety/health effects of chemicals, as well as PPE requirements, based on the MSDSs included in PSI • The Nonroutine Procedures include precautions and warnings that state how to avoid certain safety/health effects (*i.e.*, chemical hazards) identified during task analyses or hazard analyses of the procedures
Address safety systems and their functions	• The Background section describes equipment and safety systems in language operators can understand • The troubleshooting guide in the Normal Operations section describes the function of each critical instrument

Table 2. The operating manual addresses each regulatory requirement.

tion. A typical operating manual only refers to the location(s) where emergency operating instructions can be found. Emergency operating instructions of a temporary nature are often found in management of change documentation or an operations log book.

For a continuous process, the Normal Operations section typically provides instructions for monitoring and troubleshooting the process. For a noncontinuous (batch) process, this section typically provides instructions for running a normal batch or campaign of batches. Typical batch instructions are in the form of step-by-step procedures. (This article's dis-

cussion of the Nonroutine Procedures section provides guidance on addressing operating limits in step-by-step procedures. Also, the first part of this article discussed how to develop effective step-by-step procedures.)

As Table 2 shows, monitoring/troubleshooting instructions (*i.e.*, a troubleshooting guide) can address several of the regulatory requirements. The following are excerpts from OSHA citations regarding a lack of instructions for monitoring/troubleshooting the process:

"The written operating procedures ... did not address all operating limits, consequences of deviations, and steps

Table 3. Example troubleshooting guide.

Instr. No.	Parameter	Norm	Safety Limits	Consequences of Deviation	Steps to Correct/Avoid Deviation
TI-1	Isostripper temperature, °F	150	Max: 185	• High level in accumulator V-1 • Possible overpressure of column • Accelerated corrosion, possible release of flammable/toxic hydrocarbon	• Check feed rate (FIC-1) • Check reboil temperature (TI-4) • Check for external heat source (fire) • Make sure accumulator level does not rise (LI-4) • Make sure column pressure does not rise (PI-1/2)
			Min: 115	• Low pressure in column • Low level in accumulator V-1 • Acid in alkylate, corrosion of butane sphere and release of butane and acid	• Check feed rate (FIC-1) • Check flow from reboiler (FIC-2) • Check reboil temperature (TI-4) • Maintain column pressure (PI-1/2) • Maintain accumulator level (LI-4)
FIC-2	Flow in isostripper reboil loop, (k lb/h)	1,100	Max: None	None	None
			Min: 370	• Overheat furnace tubes, tube rupture, possible uncontrolled fire/explosion	• Check FV-2 in field. If necessary, place FV-2 in MANUAL and adjust to desired flow • Check column level on LIC-3 • Check that reboil pump is running

required to correct deviations, exposing employee(s) to the hazard of a fire/release of highly hazardous chemicals" (*4*).

"The employer did not develop and implement written operating procedures that addressed ... the corrective action necessary to correct or avoid exceeding the maximum firebox temperature ..." (*5*).

Monitoring/troubleshooting information is usually presented in the form of a safe parameter limits table or a troubleshooting guide. A typical safe parameter limits table lists all the instruments or parameters of a process along with their safe upper and lower limits. It may also state the consequences of deviating from the limits. A troubleshooting guide is basically a safe parameter limits table that: (1) includes an extra column containing troubleshooting hints and corrective actions; and (2) focuses only on the parameters and deviations that are critical to safe operation. In these respects, we consider a troubleshooting guide the more-effective tool for both training and reference. Table 3 is a page that is taken from

an example troubleshooting guide.

Developing an effective troubleshooting guide — It is possible to develop a comprehensive troubleshooting guide that eliminates the need for a safe parameter limits table. The following paragraphs describe a proven strategy for compiling appropriate information to create an effective troubleshooting guide. This strategy relies on several sources of information, including P&IDs, PHA documentation (*e.g.*, HAZOP tables), instrumentation, samples and measurements, and experienced operators. This particular approach produces a user-friendly reference guide that directs operators in how to respond to certain parametric deviations that they may observe. The approach involves six steps:

1. List the critical instruments, samples, and measurements (*i.e.*, those that are critical to safety) that the operators routinely observe or would use during an upset. Instrument numbers can be found on the P&IDs or on the control panel. The PHA documentation (*e.g.*, the "safeguards" column of a HAZOP table) may imply whether a particular instrument, sam-

pling operation, or measurement is critical to safety or merely an operational convenience (PHA documentation typically does not include instruments that are provided only for operational convenience);

2. Write a brief description of the process parameter and equipment associated with each critical instrument, sample, and measurement (*e.g.*, flow in the reactor feed line). Experienced operators typically know the process parameter associated with each instrument and the reason for each sample and measurement. The P&IDs, PHA documentation, or control panel can be used to determine what equipment is protected by each instrument;

3. List the possible deviations (*e.g.*, high flow, low flow) that each critical instrument, sample, and measurement protects against. The PHA documentation typically lists these deviations in the form of guidewords or questions;

4. List the potential safety/health effects of each deviation (*i.e.*, consequences of the deviation), including both the worst-case and more-likely effects. These effects should be listed

in the PHA documentation (*e.g.*, in the "consequences" column of a HAZOP table). If there are no safety/health effects associated with a particular process parameter, then the instrument, sample, or measurement associated with that parameter probably is not a safety feature and should be omitted from the troubleshooting guide to help keep the guide focused on safety-critical issues;

5. List the safe parameter limit for each deviation. This limit is typically defined by an alarm or interlock set point that gives the operators a final chance to prevent the listed safety/health effects. The operators or technical personnel might refer to this as the "do not exceed" limit. Set points for maintaining desired product specification or production rates are usually not considered safe parameter limits. The following is an example of how to determine a safe parameter limit:

A compressor suction knockout-pot has a level-indicating controller with software alarms, as well as an independent high level alarm and high-high level trip switch. The safe upper limit is the set point of the alarm that gives the final warning before the trip occurs. (Typically, this is the independent high level alarm.) Why is the safe limit not the trip set point? If the level reaches the trip set point, the operator has already lost his/her chance to respond. The alarm gives the operator his/her final chance to respond, not only to prevent the trip, but to prevent the compressor damage that will occur if the trip does not work; and

6. Write instructions for how to correct each deviation or avoid the ultimate consequences of it. This should include checking for failure of devices (instrumentation, alarms, valves, controls, gages, etc.) that can cause the deviation (or give a false warning of the deviation), as well as responding to isolate or shut down appropriate equipment to reduce the consequences of the deviation. If the deviation requires quick operator response (*e.g.*, within 1 min), the in-

Table 4. PHA documentation can be reworded as troubleshooting instructions.		
HAZOP Worksheet Entry		**Troubleshooting Instruction**
Cause: Control valve opens too far	→	Make sure the control valve is working properly
Cause: Bypass valve is left open	→	Make sure the bypass valve is closed
Safeguard: Isolation valves	→	Isolate the vessel if necessary
Safeguard: Relief valve	→	Make sure the relief valve and relief path are open

structions should include a warning that states the time limit. Possible device failures that could cause the deviation are typically listed in the PHA documentation (*e.g.*, in the "causes" column of a HAZOP table). The PHA documentation should also list response activities associated with the deviation (*e.g.*, in the "safeguards" column of a HAZOP table). The examples in Table 4 show how PHA documentation (*e.g.*, entries in a HAZOP worksheet) can be reworded as troubleshooting instructions.

The completed troubleshooting guide should look similar to Table 3, providing specific upper and lower limits for each parameter, as well as instructions for responding to deviations from these limits.

Nonroutine Procedures section

This section is the meat of the operating manual. It contains detailed instructions for how to complete tasks outside of the normal phase of operation. This section must include specific step-by-step procedures that cover all types of startups and shutdowns, including recovery of off-spec batches (for batch processes).

Startup procedures — A startup procedure may involve different steps and hazards depending on whether it follows a turnaround, partial shutdown, or emergency shutdown. One or more startup procedures must be developed to cover all potential startup scenarios. If only one startup procedure is written, this procedure should

indicate which steps apply for each startup scenario. For example, OSHA citations regarding this issue have stated, "The employer did not implement written procedures that provided clear instructions for safely conducting activities involved in *startup after a turnaround, or after an emergency shutdown*" [emphasis added] (*5*).

Shutdown procedures — Shutdown procedures could also be initiated by numerous conditions, including scheduled turnarounds, malfunctioning equipment, and emergencies such as loss of electric power, loss of cooling water, etc. At least one normal shutdown procedure and at least one emergency shutdown procedure must be developed to cover all potential shutdown scenarios. As with startup procedures, the shutdown procedures must specify which steps apply for each shutdown scenario.

As described in the first part of this series, each step-by-step procedure should include: (1) skills/knowledge/training prerequisites; (2) precautions unique to the task; and (3) warnings associated with particular steps (as well as the steps themselves, in the proper sequence). Specifying prerequisite skills, knowledge, and training is especially important for emergency shutdown procedures, for which the regulations require assignment of shutdown responsibilities to "qualified" operators. These prerequisites can usually be gleaned from the results of a task analysis (discussed in the first part of this article).

Many procedural deficiencies have

involved inadequate instructions for startup and shutdown. Two examples of related OSHA citations follow:

"Written emergency shutdown procedures followed by employees were deficient in that ... shutdown responsibility was not assigned to specific operators or assistant operators" (4).

"The written procedures utilized by operators for startup of the ... heater found posted in the ... control room ... were not clear and precise ... as to how long to purge the fire- box ... prior to lighting the pilot, and which method (steam or air ventilation) should be used by the operator" (5).

Developing effective precautions — Including the proper precautions at the beginning of a step-by-step procedure can partially satisfy the regulatory requirement for addressing deviations and their consequences. The best source of precautionary information for a particular procedure is the documentation from a hazard analysis of the procedure (discussed in the first part). In the past, relatively few companies have chosen to perform hazard analyses of their procedures, though this trend is reversing. Other companies have relied on detailed task analysis results (as discussed in Part 1) to determine the necessary precautions and the consequences they prevent. Any less analysis effort has usually resulted in precautions being omitted, poorly written, or otherwise ineffective.

A properly written precaution includes both the precautionary action that must be taken and the consequence(s) that the action prevents or avoids. As an example, an unloading procedure involving a toxic acid presents a hazard to the unloading operator. A weak precaution might state, "Wear a respirator during this procedure," or "Avoid breathing toxic vapors." Each of these precautionary statements satisfies only half of the regulatory requirement for addressing deviations and their consequences. A better way to word the

precaution is, "Wear a respirator to avoid breathing toxic vapors." This specifically states what action to take and what consequence the action avoids. OSHA has emphasized this point in citations such as, "The written startup procedures for the ... heater ... did not address consequences of not testing the firebox ... with an explosion meter" (5).

Developing effective warnings — For a particular step within a procedure, a warning can function as a reminder that: (1) omitting the step or performing it incorrectly can lead to serious safety/health effects; or (2) hazards are especially imminent during the step. As with precautions, the documentation from a hazard analysis of the procedure (or to a lesser extent, from a task analysis) provides the best information for developing effective warnings. When properly written warnings are included judiciously and sparingly within a procedure, they can partially satisfy the regulatory requirement for addressing deviations and their consequences. As a simple rule of thumb, we recommend maintaining (on average) less than two warnings per page of instructions; include only the most critical warnings.

A warning should specifically state what action or condition to avoid as well as the safety/health-related reason for avoiding it. In Appendix C of the PSM regulation, OSHA states:

"These operating instructions for each procedure should include the applicable safety precautions and should contain appropriate information on safety implications" (1).

Also, the warning should be written as a strong command, using words such as "DO NOT ..." For example, one of the key functions of an operator during an unloading procedure may be to monitor the storage tank level. An effective warning might remind the operator, "DO NOT exceed 85% on the storage tank volume gage — flammable liquid could overflow into the work area." In this

example, the deviation (high level) and its consequence (overflow of flammable liquid) were determined from a combination of the PHA documentation (the PHA included a hazard analysis of the unloading procedure), task analysis results, and operator experience (*i.e.*, previous incidents). The safe upper limit (85%) was based on the set point of the storage tank's high level alarm. Recognizing the need to provide complete warning statements associated with particular steps of a procedure, OSHA has issued citations such as, "The written startup procedures did not address consequences associated with bypassing the 'Fireyes' or flame scanners of the ... heater" (5). ▊CEP▊

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