Program Development

LEL Monitoring During Hazard Surveys for Issuance of Hot Work Permits

The need for definitive requirements

By Steven P. Levine and James R. Thornton

FOR SAFE OPERATION of processes involving combustible materials, hazard surveys must be performed before hot work permits are issued. These surveys typically involve the use of combustible gas meters—also called lower explosive limit (LEL) meters. To perform the surveys properly, work instructions and standard operating procedures (SOPs) must be developed, implemented and documented. Training in LEL instrument use, instrument calibration, sampling strategy, continuous or follow-up monitoring, tracking of denied permits, communication between departments related to the content of processes, documentation of results, auditing of hot work permit procedures and results, and the continuous improvement of those SOPs must be addressed. This article reviews and critiques existing regulations and guidance documents and makes recommendations.

The Issue: Background

Hot work permits (HWPs) are required for any process that may produce an ignition source in a work area in which flammable vapors or gases may be present. Governmental regulations require this [OSHA(c); (d); (g); (a); (h); (f); (i)] and voluntary industry standards recommend it [NFPA(a); (b); API(b); (a)]. To issue an HWP, a hazard assessment must be performed. To do so, combustible gas and vapor concentrations must be determined for the work area and job classification in question, then compared to acceptable standards. As noted, combustible gas and vapor concentrations are generally determined using an LEL meter; these devices may be portable or fixed-location monitors.

As with all monitoring instruments, the user must have proper training in instrument calibration and use. Accordingly, SOPs must be developed for all aspects of instrument use. Many articles have been written on this and related points (Acer and Bayer; Huss; Blank; Muthukrishnan). The consequences of inadequate procedures for LEL meter use include loss of life, and diminished production and quality. This has been documented in investigation reports from companies, EPA and OSHA—for example, of the Pennzoil Products company fire and deflagration [OSHA(j); EPA].

Trusting informal training, word-of-mouth and/or hand-me-down instruction manuals is never a sufficient substitute for formal witnessed training, documented procedures and work instructions, and formal recordkeeping. This is known in every field of endeavor—from manufacturing quality to food safety to environmental management to occupational safety and health (ACC; BSI; NSF; Reason). Without exception, variance from approved procedures and work instructions results in poor quality products, degraded environ-

Steven P. Levine, Ph.D., CIH, *is an emeritus professor of industrial health at the University of Michigan, and an adjunct professor at the Institute of International Health of Michigan State University. Prior to his 20-year university career, he spent eight years working in the chemical, automotive and hazardous waste industries. Levine was president of AIHA in 2000. He has participated in many investigations of fires and explosions, and has focused on the issues of LEL instrument use, SOPs for safe work practices and OH&S management systems.*

James R. Thornton, CSP, CIH, *is director of environmental, health and safety at Northrop Grumman Newport News Shipbuilding. He was president of AIHA in 1999, and was appointed by the Secretary of Labor to OSHA's Maritime Advisory Committee on Occupational Health and Safety. During his almost 30-year career in shipbuilding, Thornton has developed and implemented programs to ensure safe entry and work performance in confined and enclosed spaces, both aboard vessels and in facilities. He has developed and taught several courses in the measurement and control of hazards associated with confined and enclosed space entry as well.*

mental metrics, and/or injured workers and loss of operational facilities (as well as the important problems of regulatory noncompliance, and civil and criminal liability). The issue of inadequate work instructions and procedures specifically in their relationship to unsafe acts is comprehensively addressed in Reason's *Human Error.*

The examples cited in this article and the discussion of incidents have been obtained from the records of several investigations/operations. These include a small shipyard in which a fire—and several fatalities—occurred; a small specialty steel additives company in which an explosion occurred, causing several fatalities; a large consumer products chemical and fabricating company from which lessons are drawn about the need for certain procedures for proper hazard surveys; a small petroleum refinery in which a fire occurred, causing several fatalities; and a medium-sized petrochemical company and three large multinational petroleum companies, each of which has had incidents involving flammable gas hazards resulting in losses. The identities of these facilities must remain anonymous.

Case histories for fires and explosions caused by hot work appear in Appendix B of NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes [NFPA(a)]. These data underscore the importance of adequate procedures for atmospheric testing and LEL instrument use.

Government Regulations, Voluntary Standards & Industry Guidance Documents

The relationship between government regulations and voluntary industry standards is critical. Indeed, this relationship facilitates the effort to establish requirements and best practice guidance for LEL use. Two facets characterize this relationship: 1) Many government regulations are based on industry voluntary standards. 2) It must be appreciated that when a company agrees in writing to abide by a voluntary standard (becomes a signatory to the code), it takes on the responsibility to abide by the code's requirements. One of these voluntary standards is API 2009, Safe Welding, Cutting and Other Hot Work Practices in Refineries, Gas Plants and Petrochemical Plants, published in September 1995. The importance of this document is that companies in the petroleum industry are usually API members. As such, they agree to abide by the group's voluntary standards.

Some relevant quotes from that standard:

•2.2 . . . With proper procedures, restricting access to the work area, issuance and posting of detailed permits as appropriate, and adherence to site-specific safe work conditions, hot work can be safely conducted . . . the work area should be hydrocarbon vapor and gas free. . . .

•2.6 . . . The person assigned to a fire watch shall have no other duties. . . .

•2.7 . . . the welding machine and the grounding connection [must be] located in an area free of flammable vapors. . . .

•3.2 . . . The [hot work] permit . . . should include . . . [g]. Whether continuous monitoring is required . . . .

•Section 4 . . . Gas testing should include all low points such as sumps, drains, liquid boots, and so on . . . and . . . piping, vessels and the like. Long runs of piping should be tested at many locations [API(b)].

NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processess, is also applicable:

•3.2 . . . Before cutting or welding is permitted, and at least once per day while the permit is in effect, the area shall be inspected by the individual responsible for authorizing . . . to ensure that it is a fire safe area [NFPA(a)].

Note that NFPA 51B speaks to the issue of the hazard assessment needed for issuance of a HWP insofar as requirements are stated for establishing approved areas; designating an individual responsible for authorizing procedures; ensuring that only approved apparatus are used; ensuring that personnel are trained; selecting contractors with suitably trained personnel; and advising contractors about flammable materials and hazardous conditions. In addition, under section 3.2, an inspection must be made at least once per day, but as often as necessary, by a responsible individual who shall designate precautions in the form of a written permit. Certain details of requirements are also included, such as the requirement that combustibles be located at least 11 meters from the hot work. While this guidance seems to be complete, it is not. Issues such as work instructions for many aspects of HWP hazard assessments, particularly in the use of LEL meters, are not given in any detail.

Many government regulations address the storage, processing and handling of flammable materials. One example is 29 CFR 1910.106, Flammable and Combustible Liquids. This regulation is silent on the issue of HWPs or LEL meter use. Another example is 29 CFR 1910.307, Hazardous (Classified) Locations, which classifies areas based on electrical hazards that may or may not represent ignition sources; it is similarly silent on the issue of HWPs or LEL meter use.

Other relevant regulations include 29 CFR 1910.252, General Requirements: Subpart Q, Welding, Cutting and Brazing (1998). This regulation contains detailed requirements for hot work operations. However, for the HWP process, the only requirement is:

a.iv. Authorization. Before cutting or welding is permitted, the area shall be inspected by the individual responsible for authorizing . . . [who] shall designate precautions to be followed in granting authorization to proceed preferably in the form of a written permit [OSHA(g)].

The weaknesses in this are 1) the written permit is presented as a recommendation, not a requirement; and 2) no requirement or guidance is offered on how the inspection shall or should be accomplished.

OSHA's Process Safety Management regulation

(29 CFR 1910.119) contains strict requirements, but only for two of the relevant aspects of hot work. One is as follows:

> g.3. Training documentation. The employer shall ascertain that each employee participating in a hot work process has received and understood the training required . . . [and] the employer shall prepare a record which contains the identity of the employee, the date of training, and the means used to verify that the employee understood the training [OSHA(c)].

This mandatory requirement is clearly written; if applied to hot work and the issuance of HWPs, it will ensure that the permit issuance process is both understood and implemented. Similarly, in the section on HWPs:

> k.2. The permit shall document that the fire prevention and protection requirements . . . have been implemented prior to beginning the hot work operations . . . [OSHA(c)].

Presumably, this would include a hazard assessment performed to ensure safe hot work, which of necessity must require the adequate and proper use of an LEL meter.

In addition, relevant professional standards and guidance documents are available. The standard on this subject—ISA RP 12.13—from the International Society for Measurement and Control (formerly the Instrumentation Systems and Automation Society) is both relevant and instructive. In Part I of the standard, requirements for the instrument instruction manual and other testing and performance requirements for the instrument are detailed. While these requirements are specified, the actual content of the instrument user's manual is not described in detail [ISA(b)]. Part II provides specifications for the installation, operation and maintenance of such instruments, with some specific work instructions for the instrument user [ISA(a)].

Therefore, when using an LEL meter for a hazard survey performed to evaluate whether or not an HWP should be issued, there are both relevant government regulations and parallel applicable voluntary industry and professional standards. This article enumerates the details of the requirements for LEL use.

Standard Operating Procedures

To ensure proper use of LEL meters, SOPs must be in place that:

- will prevent the ignition of flammable gases and vapors through the identification of sources and conditions of near-LEL concentrations;
- document procedures and results so that accurate decisions can be made before hot work is performed, and after-the-fact questions can be answered with certainty;
- ensure compliance and conformance to relevant regulations and standards.

For safe operation of processes involving combustible materials, the following SOPs must have been developed, implemented and documented:

1) training in instrument use;
2) instrument calibration;
3) sampling strategy;
4) continuous or follow-up monitoring;
5) tracking denied permits;
6) communication between departments related to the content of processes;
7) documentation of results;
8) auditing of HWP procedures and results;
9) continuous improvement of SOPs.

Training in Instrument Use

Thorough, documented training must be performed for the use of LEL meters. This is because the use of the LEL meter is central to the evaluation of the safety of processes and the lives of workers. This training must be required by order of executive or senior plant management and by the organization's corporate office. This is typically conveyed through written procedures.

Weakness in employee training most frequently manifests itself in the failure to calibrate such instruments. Anecdotal information, but not quantitative, objective data, demonstrates the widespread weakness of organizations in such training. This apparently applies most frequently to both small and medium enterprises (SMEs), and local governmental units such as fire departments. It also applies to large corporations, but possibly less often than to SMEs and governmental units.

Examples (in the experience of author Levine) of fires, explosions and/or loss of life stemming at least in part from weak training programs are:

- The fire department of a prosperous mid-sized midwestern city did not notice that the only employee trained in calibration of LEL meters had retired, and that inoperative LEL meters were stocked in emergency vehicles.
- The maintenance department of a metal formulating plant did not clean filters or air sampling lines for the plantwide combustible gas meter system, resulting in plugged lines and zero readings for an explosive atmosphere.
- The operators of a plantwide combustible gas meter system believed that the instrument could be used to monitor for combustible aerosols.
- Safety technicians at a chemical processing plant had no idea about instrument calibration, and the resulting miscalibration may have been a contributing factor.

Thus, training programs for operators of LEL meters must include:

- work instructions for basic instrument use;
- theory of instrument operation;
- instrument maintenance and calibration;
- recordkeeping for calibration and maintenance;
- work instructions for performing hazard surveys for the issuance of HWPs;
- processes in the facility for which HWPs may be considered;
- recordkeeping for the results of those hazard surveys and the issuance or denial of HWPs.

Too often, it appears, organizations depend

Trusting informal training and word-of-mouth instruction manuals is never a sufficient substitute for formal training, documented procedures and formal recordkeeping.

exclusively on the instrument instruction manual and on an informal briefing by an instrument vendor for all of their training needs. In addition, as employees change, this initial instruction is often handed down by word-of-mouth from employee to employee. This is a dangerous and inadequate practice. Specific training requirements and courses—and the requirement for witness signature (or equivalent) of same— must be detailed in organizational SOPs. Corrective and preventive action must be taken when records indicate that such witness-signature training has not occurred. While instrument companies must provide devices that perform as advertised and must provide instruction manuals, the primary responsibility for training, both initial and periodic, rests with the organization that uses such instruments.

This is especially noteworthy because LEL meters are frequently in service for many years. Instruction manuals may become dated, or be lost or forgotten. Certainly, the training provided to initial users at the time of purchase will have rapidly decreasing utility as time passes.

Instrument Calibration

Manufacturers provide manuals that detail procedures for calibrating LEL meters. Calibration includes:

- clean air—zero point calibration;
- calibration of response, usually at the 5 to 10 % LEL concentration, with the appropriate span gas;
- checking and calibration, for actively pumped LEL meters, of the air flow rate in the system;
- fault detection and subsequent maintenance;
- recordkeeping.

In many cases, manufacturer instructions use the words "should" or "may" with respect to the act of calibration. In all cases, words that indicate mandatory requirement (such as "shall" or "must") must be used in applicable SOPs. Any decisions made to extend the period between calibrations or to lessen the rigor of calibrations must first be formally evaluated by qualified persons against the manufacturer's recommendations, industry best practices and governmental regulations. Requirements for specified, periodic calibration of zero, span and flow are mandates, not recommendations. This applies for all systems, but is especially critical for systems used in environments where air contaminants that may degrade the meter's sensing element may be present.

Meter calibration must be performed with the correct calibration gas. Failure to do so may result in instrument response that is incorrect to a factor of two or more. For example, an LEL meter that is calibrated with methane gas at 10% LEL, then used to detect gasoline vapors will respond to gasoline vapors at 10% LEL concentration with an output reading of 5% LEL. If the criterion for issuance of an HWP or for process shutdown and employee evacuation is 10% LEL, then that critical situation will not be detected until the concentration reaches 20% LEL.

Similarly, if the criterion is 1% LEL, and the limit of detection of the meter is 1% LEL, then that same miscalibration will require a 2% LEL concentration of gasoline vapor before any response is visible on the instrument readout. This is of central importance because many organizations will not issue HWPs if the LEL meter exhibits any reading other than zero. So, if correctly calibrated, the lowest possible reading above zero is 1% LEL. If improperly calibrated, as in the cited example, the lowest possible reading other than zero will be 2% LEL, read incorrectly as 1% LEL.

The reason for this is that LEL meters are not really "LEL meters." Instead, their response is the product of the heat of combustion of a flammable gas or vapor multiplied by its concentration. Since for different compounds heat of combustion is not proportional to LEL, the instrument must be calibrated with the analyte itself, or calibrated with a gas (such as methane) for which there is a multitude of known and published scale conversion factors with the response of the analyte. Such references include manufacturers' instrument manuals and various textbooks (e.g., DiNardi; Perkins; Plog, et al).

This issue is addressed in the *OSHA Technical Manual,* Section II:

> For gases and vapors other than those for which a device was calibrated, users should consult the manufacturer's instructions and correction curves [OSHA(k)].

While it is important that OSHA has specifically noted this in a guidance manual, it is imperative that the word "should" be replaced with "shall" or "must" in all SOPs dealing with LEL meter calibration.

OSHA addresses related issues in "OSHA Hazard Information Bulletin: The Use of Combination Oxygen and Combustible Gas Detectors. Like the *OSHA Technical Manual,* this bulletin gives warnings about variations in response that result in incorrect readings from such interferences as:

- oxygen concentration;
- gas pressure;
- sensor poisons (i.e., silicon, silicates and organic lead, acid gases) and sensor depressants (i.e., chlorinated hydrocarbons, acid gases);
- the fact that no reading will occur, or is even possible, for the detection of combustible airborne mists or dusts, such as lubricating oils, coal dust or grain dust [OSHA(i)].

Sensor poisons and corrosion promoters include silicone vapors, arsenic, lead, halogenated compounds, sulfur compounds such as hydrogen sulfide, nitro compounds and acids (Plog, et al; Perkins). The presence of these agents in the sampled gas may quickly change the instrument's response characteristics; thus, their presence must be accounted for.

In addition, the portion of the calibration SOP that deals with instrument airflow rate must include not only guidance statements, but also requirements. For example, SOPs and/or work instructions must contain an absolute requirement that for actively pumped (as opposed to passive diffusion) instruments, the blocked flow alarm must be tested before and after each use. This applies to portable systems. For fixed location multipoint monitors, periodic, systematic flow rate checks, and checks of blocked flow alarms, must be performed for each sampling location. While this is a requirement for all such systems, it is especially critical for instruments used in dusty environments.

Chapter VII, "Verification, Calibration and Laboratory Considerations," in *Manual of Recommended Practice for Combustible Gas Indicators and Portable Direct-Reading Hydrocarbon Detectors* provides detailed work instructions and data in relating specific gases and their physical properties to their LELs (Chelton). This is the level of detail needed in the work instructions of organizations that use LEL meters. However, this publication is now 10 years old, and the structure and language of this chapter are somewhat academic and archaic; as a result, it is of limited use as a contemporary tool for routine inplant use. Also, as with many such documents, the element of compulsion is not clearly delineated since most of this chapter (and indeed the manual) is written as a guidance "should" document and not as a requirement "shall" or "must" document.

NFPA 306, Standard for the Control of Gas Hazards on Vessels, contains this explicit requirement:

> 2-2.1. The calibration of all instruments . . . shall be verified before each day's use by using a known concentration of test gas in a manner consistent with the manufacturer's recommendations [NFPA(b)].

Although this is a requirement, it depends on the adequacy of the manufacturer's recommendations.

Another such document is the Industrial Safety Equipment Assn.'s "Statement on Verification of Calibration for Direct Reading Portable Gas Monitors Used in Confined Spaces." In this document, ISEA calls for OSHA to issue a position statement on verification of calibration (ISEA).

Sampling Strategy

In the absence of an SOP for sampling strategy or techniques with any instrument or device, the instrument user has inadequate guidance even if s/he knows which buttons to push to make the instrument work. In the field of industrial hygiene exposure assessment, this question is dealt with at great length and depth in the seminal book, *A Strategy for Assessing and Managing Occupational Exposures* (Mulhausen and Damiano). Researchers, professionals and governmental hygienists have a clear and definitive reference for SOPs for exposure assessment. No such reference exists for the performance of HWP hazard surveys. Inquiries to several major chemical companies revealed that none had specific work instructions on how to perform a survey with an LEL meter. While the methodology may be "obvious" to an experienced, credentialed industrial hygienist or SH&E professional, no definitive SOP exists for this issue.

Indeed, in depositions related to one fire, employees stated (paraphrased):

- *Employee:* There was no prescribed time in our hot work procedure for how long I was supposed to stop and hold the probe in the same position.
- *Supervisor:* There is no, and was no, written protocol about how my people were to sample for combustible gases.

Therefore, any organization at which surveys are performed with LEL meters, sampling for combustible gas must follow a written, established protocol that describes sampling procedures, sampling locations, and required sample dwell or collection time. Minimal guidance on this issue is available from OSHA, but this is a largely undeveloped area of practice.

ISA RP 12.13 Part II addresses this issue in section 11, "Special Operating Considerations." It says: "11.1.b. In areas where gases or vapors may be stratified rather than uniformly mixed, checks should be made at different elevations" [ISA(a)].

Again, however, this specification is made as a recommendation, not as a requirement, and no work instructions are appended to this specification. Therefore, the operational definitions of "stratified," "areas where [such stratification may take place]" and "different elevations" are left entirely to the HWP technician. Nowhere is a sufficient level of detail provided to operationally define what this means.

Additional guidance is found in 29 CFR 1910.146, Appendix B: Procedures for Atmospheric Testing. This document provides guidance "should" statements on this subject in two sections:

> 3) Duration of testing. Measurement of values for each atmospheric parameter should be made for at least the minimum response time of the . . . instrument. . . .
>
> 4) Testing stratified atmospheres. When monitoring operations involving a descent into atmospheres that may be stratified, the atmospheric envelope should be tested a distance of approximately four feet in the direction of travel and to each side. If a sampling probe is used, the . . . rate of progress should be slowed to accommodate the sampling speed and detector response [OSHA(f)].

These procedures represent a good first step toward the definition of SOPs and work instructions for sampling strategies for stratified atmospheres. However, as noted, consideration must be given to the use of the words "shall" or "must" in place of "should."

Another important step is to formally define an acceptable LEL meter reading. For example, OSHA defines the maximum acceptable level for a combustible gas meter reading in a confined space to be 10% LEL [OSHA(e)]. While some organizations define that as being 5 to 10% LEL, in the belief that a 10- to 20-fold safety factor is sufficient, others define the only acceptable reading as zero. An SOP of a major producer of petroleum-based chemicals states, "The combustible gas level MUST READ ZERO. . . ." (Personal Communication).

The meaning of "zero" in this case, is actually

Weakness in employee training frequently manifests itself in the failure to calibrate LEL meters. Anecdotal information demonstrates the widespread weakness of such training.

"<0.5% LEL." That is because the minimum readability of many combustible gas meters in the settings normally used during a hazard survey is 1% LEL. Since any reading above >0.5% LEL will be rounded up to 1.0% LEL, then a reading of <0.5% LEL will be "zero."

This kind of unequivocal requirement is necessary for hazard surveys. The reason is that the assumption of homogeneity of flammable gas and vapor concentration in or around any potentially hot worksite is a flawed one. The assumption that a 5 to 10% LEL reading provides a sufficient safety factor is, in most cases, an assumption that may be correct, yet almost always comes with no supporting data. In some cases, the vapor concentration could be rising, thus giving the evaluator a false sense of security relative to the safe concentration of the contaminant. Any reading greater than zero should be followed by an assessment to:

- determine the source of the flammable vapors;
- eliminate the source, if possible;
- ensure control of the source so that concentrations will not exceed (at most) 10% of the LEL at any location where it is possible that an ignition source may be present.

Continuous or Follow-Up Monitoring

Most organizations have a requirement for continuous or follow-up LEL monitoring under conditions where the process, sequence of work instructions or ambient conditions might reasonably be expected to change in a manner that might increase the concentration of flammable gas or vapor.

NFPA 51B states:

> 3-2. Before [hot work] is permitted, and at least once per day while the permit is in effect, the area shall be inspected by the person responsible . . . to ensure that it is a fire safe area [NFPA(a)].

The difficulty here, experienced in actual practice, is that the phrase "at least once per day" sets a lower bound on inspection frequency, but gives no objective metric by which a technician can make the decision to increase the frequency of hazard surveys or recommendations for continuous or follow-up monitoring. Many SOPs use wording such as: "If conditions change during the course of the permit period in a way that presents or could present additional hazards, then work will be terminated until the area or conditions are made safe and permit conditions are re-evaluated." Anecdotal evidence suggest this requirement may be overlooked. The reasons for this are:

- The criteria for significantly "changed conditions" are almost never detailed in SOPs or work instructions. These criteria should include factors such as changes in:
  - processes that may affect the composition, concentration, flow rate or volume, pressure and/or temperature of flammable liquids, vapors or gases;
  - processes adjacent to the process at which hot work is being performed;
  - ambient conditions such as temperature, wind direction and wind speed;
  - other factors, such as the presence of uncontrolled vehicular traffic and/or ignition sources.
- The requirement for extra time to be spent by the safety technician at a hot work area during multiple times in a day.
- The extra LEL monitoring equipment needed for continuous or follow-up monitoring.
- The objectionable financial consequences, both for employees and contractors, of follow-up monitoring results shutting down previously approved hot work.

Such criteria and work instructions must be provided with sufficient detail and be posited as a requirement under specified conditions, not as a suggestion.

Tracking Denied Permits

An SOP must be in place to track denied permits. A history of HWPs for a given work site must be available before a new permit is issued. This SOP must include a provision that there is documentation that key persons see and read previous permits and permit denials. This is critical. The information associated with a prior permit denial can readily provide the person charged with issuing the permit key data needed to evaluate the permit request. Furthermore, analysis of the history of permit denials can be a powerful tool in determining trends in high LEL readings and other factors contributing to safe entry. Actual evidence, quoted anonymously after a fire, demonstrates this:

> - *Employee:* I have no knowledge nor any idea whether any other hot work permits had either been issued or denied for this particular job prior to the time I issued a permit. At that time there was no system of recordkeeping that would have enabled me to track whether or not hot work permits had been issued or denied for that particular work.
> - *Employee:* I have no knowledge of anyone (including myself) having made a request that there be access to information concerning denials to hot work permits.
> - *Supervisor:* There was no procedure in place before the fire for determining why there were high LEL readings associated with the denial of a hot work permit.
> - *Supervisor:* Prior to the fire there was no requirement for corrective action after a hot work permit had been denied but before another could be issued.
> - *Manager:* A permit refusal/discontinuation procedure has been developed which will ensure that when a hot work permit has been denied it will be communicated to other individuals who could be responsible for issuing a permit for the same job.
> - *Manager:* It wouldn't be important in my mind to know that there had been a previous denial of a hot work permit at the same site.

Communication Between Departments About the Content of Processes

Facilities covered by OSHA's PSM standard, and even those not covered, must know the content of storage tanks and process piping; such information must also be recorded and communicated to those responsible for the HWP program [OSHA(c)]. In the absence of such written records, communication is considered "not to have happened."

While it is unlikely that there is ever a question about the contents of process tanks containing single chemicals or known mixtures of chemicals in commercial preparations, this may become a safety issue in the case of tanks used for plant process wastes and for tanks in deactivated processes or process areas awaiting either dismantling or decontamination. In these cases, special care must be taken in recording and communicating the known or suspected contents of such tanks prior to the conduct of an HWP hazard survey.

Additionally, confined space entry rarely involves exclusively one department or operating function. In most cases, multiple departments are involved since the space will only be opened, available and accessible for a brief and finite period. Communication among these functions is critical to ensure not only an efficient work process but, more importantly, a safe one. Experience has shown that failure to clearly communicate work conditions and procedures in a timely manner among affected parties has resulted in inefficient and risky entries. Therefore, all prospective entrants must communicate frequently concerning the condition of the space and associated processes.

Documentation of Results (Recordkeeping)

Recordkeeping is different from, but a necessary complement to, the development and documentation of SOPs. Typical of such failures is the anonymous (paraphrased) testimony captured here:

- *Employee:* I haven't documented my most recent calibrations because our workload had increased dramatically.
- *Employee:* I have done the blocked flow test but do not recall whether or not I did it on the morning of the explosion.
- *Employee:* There was no recording of the routes and times I took during my survey, nor of the LEL meter readings I observed on the meter.

Management theory and practice requires that documentation be produced to prove that a specific action has been taken or instrument reading has been observed. Lack of documentation, and lack of a clear management commitment that documentation be maintained is a significant, serious issue that pervades most cases in which LEL meter misuse has been an issue in a fire or explosion. Without such documentation, which is the organization's responsibility, it is difficult to verify those responsibilities and actions that persons who were on site prior to the explosion or fire claim to have done and seen. Indeed, in modern management systems theory and practice, what has not been recorded has de-facto not been done.

ISA RP 12.13, Part II addresses user recordkeeping:

> 6.1 It is recommended that the user 1) assign an equipment identification (control) number to each instrument and 2) maintain complete records, including periodic performance, calibration and maintenance checks. [See Appendix 2, Instrument maintenance record for combustible gas detectors (typical)] [ISA(a)].

The weaknesses of this standard are that:

- it is not a source that is routinely used in the safety and industrial hygiene community (more likely used by instrument designers/manufacturers);
- it is written as a recommendation, not as a requirement;
- the work instructions for instrument maintenance default to the manufacturer's recommendations, which may or may not be adequate.

A source that can reasonably be expected to be available to the safety and industrial hygiene community is the *Manual of Recommended Practice for Combustible Gas Indicators and Portable Direct-Reading Hydrocarbon Detectors* (Chelton). This manual provides useful SOPs and some work instructions. In the case of recordkeeping, the use of guidance "should" statements and requirement "shall" or "must" statements is not clearly delineated. For example, while six "must" requirements are provided for recordkeeping, they are given in the context of this introductory statement: "Recordkeeping should include the following characteristics" which, in itself, diminishes the compulsory nature of the six requirements that follow.

In another paragraph, the true statement is made that "good practice and legal liability functions demand impeccable recordkeeping." In the case of good practice and LEL sampling, crisp, clean records are essential. In many cases, data from these analyses may serve to advance the scientific body of knowledge in this arena and ultimately save lives. Only with thorough, complete and accurate recordkeeping will these data be of any benefit in this regard.

Similarly, from a compliance and legal (risk) perspective, impeccable records are absolutely essential in establishing a defense that can weather the scrutiny of any motivated inspector or attorney. There is no substitute for accurate recordkeeping in such compliance and legal matters. Recordkeeping issues are perennially among the most commonly cited OSHA standards.

Auditing of HWP Procedures & Results

Self-auditing of SH&E programs is a common practice in all industries, and especially in industries that use hazardous chemicals. This is almost always performed by or under the auspices of a corporate office; under ideal circumstances, it may follow the guidance of documents such as *Industrial Hygiene Auditing: A Manual of Practice* (Leibowitz). In a root-cause analysis of fires and explosions, the lack of such an audit program may play as great, if not a

The information associated with a prior permit denial can readily provide the person charged with issuing the permit key data that is needed to evaluate the permit request.

greater role, than that played by having undetected vapors and ignition sources. In a management system sense, the vapors and ignition sources are the "effects" or "physical root causes," not the "actual root causes." Lack of an audit SOP may be one of the root causes of many fires and explosions.

API 750, Management of Process Hazards is, in many ways, a complementary companion to OSHA's PSM regulation, and is concerned with the issue of auditing:

> 12.2 . . . The findings of the audit should be provided to the management personnel responsible for the facility . . . [who] should establish a system to determine and document the appropriate response to the findings and to ensure satisfactory resolution . . . [API(a)].

Audits may take many forms or be conducted by any of several entities. In essence, however, the audit must determine whether what is stated to be done is indeed done. Although superficially this concept appears to be straightforward, time has shown that well-conceived and implemented audits are the exception, not the rule. Audits must be swift and thorough. Auditors must be aggressive and independent of the function they are auditing, yet objective, creditable and experienced.

Auditing of hot work programs is critical due to the implications of hot work incidents—since deaths do occur. However, experience has shown that the act of auditing the HWP process is not as frequent and refined as other audits. Thus, thorough audits must be performed with regularity and clarity, and must include the use of LEL meters.

Continuous Improvement of SOPs

Continuous improvement of SOPs may seem to be a redundant requirement, but it is not. Organizations cannot develop SOPs, then have no mechanism to ensure that those procedures are reviewed, then improved or discarded as necessary. Such a requirement is central to the success of management system standards in use globally (ACC; BSI). This approach is at the heart of the concept of continuous improvement, and is a primary adjunct of the audit and management review processes (ACC; BSI).

Requirements for the development of SOPs may include specifications for:

• **Frequency of SOP review.** At a minimum, critical SOPs must be reviewed annually. In addition, they should be reviewed and either corrected or standardized whenever an audit result indicates that an SOP or the performance derived from it is not in conformance with a government regulation or corporate or voluntary standard. In addition, the frequency of illnesses, injuries, unplanned incidents and near-hits should, ultimately, govern the frequency of SOP review.

• **Education, credentials, experience and authority level of persons conducting periodic SOP reviews and correction.** Management systems for occupational safety and health do not specify the education, credentials, etc., for persons conducting the reviews of SOPs, nor should they (BSI). What is central to the success of an organization's management system is that the organization itself have a documented method for deciding the criteria for such responsible persons—and that the determination of required qualifications be performed according to the organization's procedures and policies. This may sound like a "procedure to set up a procedure to review procedures." Strange as it sounds, that is exactly correct. The alternative would be that some external body, such as OSHA, ASSE or AIHA, specifies criteria for the qualifications for such responsible persons. This has not been done by any entity for those persons in charge of periodic review of hot work permit SOPs.

• **Documentation of the review and correction process.** In addition to documenting HWP audit implementation and results, the actual review of audit results by senior management and the implementation of corrective and preventive actions must be documented.

• **Tracking and replacement of obsolete SOPs at all work areas and job classifications.** All critical SOPs and work instructions must be encoded with version number and release date at a minimum. A procedure must be implemented for removing obsolete SOPs.

In a facility with no formal procedure to develop new SOPs and to document the development and use of old or new SOPs, it is likely that no SOPs will be developed until a disaster occurs, a customer expresses dissatisfaction or a specific OSHA standard requires it. Setting of formal requirements for SOP development and documentation must be the responsibility and authority of executive and senior-level plant management and/or corporate specialists.

As noted, API 750 is, in many ways, complementary to OSHA's PSM regulation. The issue of SOPs is central to this standard: "5.1 . . . Written operating procedures . . . should be provided for any facility subject to this recommended practice. . . [API(a)]" The comprehensive list found in this standard makes it clear that API believes that good SOPs are central to successful application of the standard. (Note, however, that the word "should" must be replaced with "shall.")

SOPs are related to and centrally important to the safe conduct of an HWP program. These procedures include a contractor safety program, confined space entry program, lockout/tagout program, hazard communication program and safe work permit program. It is essential that SOPs about the interrelationship of these programs—and of the employees to whom these programs are assigned—be written and communicated.

Recommendations

Based on this discussion of the reasons for and criteria applicable to hazard surveys for the issuance of HWPs, it is imperative that the government establish appropriate regulations; that professional societies establish professional standards; or that industry/trade associations establish codes of practice that require the following:

1) A professional standard specifying requirements ("shall" or "must" statements) and guidance ("should" statements) should be considered to replace the multitude of such documents in which requirements and guidance are not clearly delineated or in which requirements are erroneously listed as guidance.

2) Calibration and performance checks for LEL instruments must be made mandatory regardless of the language contained in manufacturer's instruction manuals.

3) A clear and inclusive set of work instructions must be developed for sampling strategies used during hazard evaluations that use LEL meters before issuance of HWPs.

4) Specifications for conditions that require follow-up monitoring, and the nature of that monitoring, must be established.

5) A formal auditing program must be established to ensure ongoing viability of hot work programs at all organizations performing such work.

Conclusion

Currently available guidance is inadequate to ensure that organizations understand and implement the requirements for successful LEL monitoring during hazard surveys for issuance of HWPs. Deficiencies exist in the wording, level of detail and scope of documents currently available. These deficiencies are in training and instrument use, calibration of instruments, sampling strategy, continuous or follow-up monitoring, tracking of denied permits, communication between departments related to the content of flammable materials in processes, documentation of results, auditing of HWP procedures and results, and the review and continuous improvement of standard operating procedures. These deficiencies must be corrected. ■

Organizations cannot develop SOPs, then have no mechanism in place to ensure that those procedures are reviewed, then improved or discarded as necessary.

References

Acer, K.S. and S.R. Bayer. "OSHA Revamps Rules for Monitoring Confined Spaces." *Pollution Engineering.* Oct. 1990: 41-44.

American Chemistry Council (ACC). Responsible Care 14001: Technical Specification. Arlington, VA: ACC, 2001.

National Fire Protection Assn. (NFPA)(a). ANSI/NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes. Quincy, MA: NFPA, 1994.

NFPA(b). ANSI/NFPA 306, Standard for the Control of Gas Hazards on Vessels. Quincy, MA: NFPA, 1997.

American Petroleum Institute (API)(a). API 750, Management of Process Hazards. Washington, DC: API, Jan. 1990.

API(b). API 2009, Safe Welding, Cutting and Other Hot Work Practices in Refineries, Gas Plants and Petrochemical Plants. 6th ed. Washington, DC: API, Sept. 1995

Blank, M. "Prevent Hot Work Fires Through Management." *Occupational Hazards.* July 1999: 40-42.

British Standards Institute (BSI). Occupational Health and Safety Management Systems 18002: Guidelines for the Implementation of OHSAS 18001. London: BSI, 2000.

Chelton, C.F., ed. *Manual of Recommended Practice for Combustible Gas Indicators and Portable Direct-Reading Hydrocarbon Detectors.* 2nd ed. Fairfax, VA: AIHA, 1993.

DiNardi, S.R. *The Occupational Environment: Its Evaluation and Control.* Fairfax, VA: AIHA, 1999.

Environmental Protection Agency (EPA). EPA 550-R-98-001. EPA Chemical Accident Investigation Report. Washington, DC: EPA, Office of Solid Waste and Emergency Response, 1996.

Huss, G. "Proper Use of Calibration and Bump Check/Field Gas." *Industrial Hygiene News.* May 1999: 49.

Industrial Safety Equipment Assn. (ISEA). "Statement on Verification of Calibration for Direct Reading Portable Gas Monitors Used in Confined Spaces." Arlington, VA: ISEA, Nov. 18, 1996.

ISA(a). ISA RP 12.13: Part II—Installation, Operation, and Maintenance of Combustible Gas Detection Instruments. Research Triangle Park, NC: ISA, 1987.

ISA(b). ISA RP 12.13: Part I—Performance Requirements, Combustible Gas Detectors. Research Triangle Park, NC: ISA, 1995.

Leibowitz, A. *Industrial Hygiene Auditing: A Manual for Practice.* Fairfax, VA: AIHA Publications, 1999.

Mulhausen, J.R. and J. Damiano. *A Strategy for Assessing and Managing Occupational Exposures.* Fairfax, VA: AIHA Press, 1998.

Muthukrishnan, S. "Use of Calibration Gas and Equipment Can Save Lives." *Industrial Hygiene News.* May 2000: 27-28.

NSF International. *Codex Alimentarius: Basic Texts on Food Hygiene.* 2nd ed. Ann Arbor, MI: NSF International (for WHO's Food and Agricultural Organization), 2001.

OSHA(a). 29 CFR 1910.106, Flammable and Combustible Liquids. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(b). CFR 1910.109, Process Safety Management of Highly Hazardous Chemicals: Explosives and Blasting Agents, Final Rule. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(c). 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(d). 29 CFR 1910.119. Appendix C: Process Safety Management of Highly Hazardous Chemicals—Compliance Guidelines and Enforcement Procedures. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(e). 29 CFR 1910.146, Permit-Required Confined Spaces. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(f). 29 CFR 1910.146. Appendix B: Procedures for Atmospheric Testing, Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(g). 29 CFR 1910.252, General Requirements: Subpart Q—Welding, Cutting and Brazing. Washington, DC: U.S. Dept. of Labor, OSHA, 1998.

OSHA(h). 29 CFR 1910.307, Hazardous (Classified) Locations. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(i). "OSHA Hazard Information Bulletin: The Use of Combination Oxygen and Combustible Gas Detectors." Bulletin 19909118. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(j). OSHA Inspection 122163967: Citation and Notification of Penalty. Oct. 17, 1995 to March 21, 1996. Citation Issued April 15, 1996. Washington, DC: U.S. Dept. of Labor, OSHA.

OSHA(k). . "Combustible Gas Meters." TED 1-0.15A *Technical Manual.* Section II, Chapter 3, Section G.3.h. Washington, DC: U.S. Dept. of Labor, OSHA, Jan. 20, 1999.

Perkins, J.L. *Modern Industrial Hygiene.* Vol. I. New York: Van Nostrand Reinhold, 1997. 636-637.

Personal Communication. Unnamed company plant safety manual. To S. Levine, July 3, 2000.

Plog, B., et al. *Fundamentals of Industrial Hygiene.* 4th ed. Itasca, IL: National Safety Council, 1997. 512-514.

Reason, J. *Human Error.* Cambridge, UK: Cambridge Press, 2002.

Your Feedback

Did you find this article interesting and useful? Circle the corresponding number on the reader service card.

RSC#	Feedback
31	Yes
32	Somewhat
33	No