METALLURGICAL PROCESS PLANT SAFETY—
AN INTEGRATED APPROACH

Stephen R. Brown
CEO
Performance Associates International, Inc.
10195 N. Oracle Road, Suite 105
Tucson, Arizona 85704
U.S.A.

ABSTRACT

In many mine and plant operations, safety is looked upon as an extra layer of special attention placed above the operations management layer. In this approach, safety awareness and procedures are tacked onto the "normal" operations and maintenance procedures. Typical of this approach is to ensure that there is a "culture" of safety, and based on the "safety culture," employees' behavior must ensure conformance to applicable safety procedures, general safety awareness, and the elimination of unsafe practices. Of course, all of this is very important for a good safety program. But more is required for an excellent safety program.

Safety awareness must be built into the detailed operations and maintenance training on the equipment as well as on the process itself. For example, operators must know the physical, chemical, and thermodynamics of the process backward and forward, as well as controls, interlocks, alarms, and all of the operating procedures. Specific examples of process knowledge that affect safety include:

- When normal process reagent leaks are dangerous, and why.
- Reagent handling and mixing procedures.
- Suction effects of crushed ore in a bin during feeding of a reclaim feeder.
- Safety issues associated with pin-size leaks in hydraulic components.
- Pressure relief valve preventive maintenance.
- Causes and effects of water hammer.
- Furnace combustion systems and associated safety interlocks.
- Potential hazards associated with boiler steam drum level measurement.

We believe that the safety culture and awareness must be combined with thorough knowledge of process details—only accessible via a first-class training program combining safety and process.

THE FACTORS GOVERNING SAFETY

When assessing the potential for accidents in a metallurgical process plant, several factors become obvious. Methodologies must be implemented to enhance safe outcomes. In general, we believe that the obvious methodologies necessary for a safe working environment are as follows:

Eliminate the Unsafe Potential

Engineering solutions regarding physical plant infrastructure largely provide this safety buffer:

- Handrails and kick plates.
- Machine guards.
- Pressure relief valves.
- Backup sensors, such as boiler steam-drum level sensors.
- Combustion safety interlocks.
- Conveyor belt safety pull switches.
- Etc.

Mitigate Unsafe Potential

Unsafe potential can be mitigated with specific safety procedures for:

- Wearing appropriate personal protective equipment specified for the job.
- Mixing sodium cyanide, caustic soda, and water to be used for gold and silver processes.
- Cleaning spills around conveyor belts.
- Lifting heavy objects.
- Rigging and lifting large items with a crane.
- Safety gear to be used when working at heights.
- Safe driving in company areas.
- Evaluating the work area from a safety perspective prior to starting work.
- Etc.

Safety Awareness

A culture of safety awareness ensures that employees in the plant are continually on the lookout for potential safety hazards, such as walking under loads lifted by a crane or parking behind a large haul truck. This awareness ensures that employees aren't involved in any unsafe acts.

Are the aforementioned procedures, physical infrastructure, and safety awareness enough? They are important, but we don't think they are enough. Safety issue awareness must be attained via training on the process itself. Safety issues are inherent in the chemistry, physical changes, and thermodynamics associated with the feedstock as it proceeds through the process. This is why *Operations Hazard Analysis*—or *HAZOPs*—are conducted during plant design. The process itself contains hazards, and these must be eliminated or mitigated.

PROCESS TRAINING WITH SAFETY BUILT IN

Performance Associates has been developing metallurgical plant training programs and conducting on-site training instruction for over 30 years, originally using hard-copy manuals in binders and now via interactive computer-based e-learning. We have found that a process operator with deep process knowledge is likely to be a safe operator, and conversely, that one with superficial knowledge is not likely to be. The same logic applies to maintenance training on the equipment.

Performance Associates training covers the following major topics for each plant major circuit:

- Safe job procedures.
- Process design, including descriptions, principles of the major unit operations, and animated process flowsheets.
- Process control, including process variables, control loops, and automatic sequences.
- Safety and process interlocks.
- Alarm response procedures.
- Operating procedures, including:
  - Start-up and shutdown under various conditions.
  - Standard operating procedures for various operator tasks such as inspections, process optimization, etc.
  - Process troubleshooting.

Each of these topics is embedded with critical safety concerns that the operator must fully understand. Consider the following hypothetical scenarios.

Scenario No. 1: Autoclave Control Room Operator

An autoclave operator on night shift notices that the autoclave pressure is higher than the set point and gradually increasing. The high-pressure alarm has not yet activated. If the high-high alarm activates, the steam and oxygen to the autoclave will be automatically shut off via an interlock. The operator looks at the pressure controller for an indication of why the pressure is high.

This scenario is clearly a process operations issue, but it is also a safety issue, as we're dealing with very high pressures and temperatures. If the operator can resolve the problem before oxygen and steam are stopped and possibly the safety relief valves pop, an operations shutdown may be avoided and potential safety issues may also be avoided. The knowledge, skill, and training of the operator are now paramount.

The operator observes that the autoclave pressure controller output is low and therefore not correctly adjusting the pressure control valve to a more open position to vent excess pressure to the venturi scrubber. The operator switches the pressure controller to manual and manually adjusts the control valve to vent additional pressure to the scrubber. The pressure comes into the correct range. The operator contacts his supervisor and the instrument department to correct the problem.

How important is training in this scenario? Would this training normally be considered safety training? No, it wouldn't. But of course it is safety training, as well as operations training.

Scenario No. 2: Reagents Control Room Operator

A reagents operator is alerted to a high-high temperature alarm in a lime slaking circuit. Based on his or her knowledge of the associated control loop, the operator checks the flow rate of raw water to the slaker lime feed and water mixer, along with the associated temperature controller output. The high-high temperature indicates that insufficient water is being pumped into the slaker. The operator also checks to ensure that the emergency water valve has opened via an interlock when the high-high temperature alarm activated. This valve allows for additional high-pressure water to enter the slaker. The temperature controller seems to be appropriately trying to open the raw water temperature control valve. The operator still doesn't know what the problem is. The operator dispatches a field operator to check for proper water flow. Meanwhile, the operator ensures that the emergency water is flowing into the slaker and controlling the temperature. The operator then shuts down the circuit to further investigate the water and temperature control issue.

Again, how important is training in this scenario? The operator is thoroughly familiar with the temperature control methodology as well as the interlock to the emergency high-pressure water valve. Is this also a safety issue? Of course it is; high temperature slaked lime is a very dangerous and corrosive chemical.

Scenario No. 3: Acid Wash Control Room Operator

A simple acid wash circuit in Africa provides for pumping acid up through the acid wash column and from there directly to a barren solution tank. The associated carbon adsorption circuit consists of six carbon columns into which pregnant solution is pumped from a heap leach circuit. Barren solution exiting the final carbon column gravity flows to the same barren solution tank.

In this scenario, the operator notes that owing to a maintenance issue with pregnant solution pumps, flow through the adsorption circuit is interrupted, temporarily interrupting flow of barren solution to the barren solution tank. However, the acid wash pump is pumping acid into the acid wash column to wash a full column of carbon. The spent acid is still being sent to the barren solution tank.

The operator, as a result of training, knows that it is essential for the adsorption circuit to be operating if the acid wash circuit is operating. Without the high flow rate of barren solution from the adsorption circuit, a dangerously low pH may form in the barren solution tank owing to the flow of spent acid to the tank. The operator immediately stops the operating acid wash pump and the resulting flow of spent acid to the barren solution tank.

In each of the three scenarios described above, the operator is faced with operational issues as well as safety issues. However, these safety issues are not obvious in the same way as machine guards or conveyor safety pull cords are. Safety is an integral part of the process design. To the degree that operators are comprehensively trained on the process chemistry, design, control methodologies, and procedures, operators are also trained on the inherent associated safety issues.

MAKING USE OF THE HAZOP IN PROCESS TRAINING

Following completion of process training in a plant area, the training experience can be enhanced primarily from a safety perspective by using the HAZOP that was developed for the plant during the design stage. If the plant has been in operation for an extended time and the HAZOP is not available, a HAZOP-type approach can be used by the instructor working in concert with the trainees. It is essential that the primary process and operational training be completed prior to embarking on this phase. Primary training for each plant area will need to cover the following:

- Safe work procedures.
- Process description and characteristics of the unit operations.
- Process control, including process variable target ranges, control loops, and sequences.
- Process and safety interlocks.
- Alarm response procedures.
- Operating procedures:
  - Start-up procedures for various conditions.
  - Shutdown procedures for various conditions.
  - Standard operating procedures for various operator tasks.
  - Process troubleshooting.

Refer to Performance Associates' white paper titled*: Preparation of Effective Computer-Based Operator Training (CBT) Programs for Metallurgical Plants* for more information on this training.

The computer-based training system will need to be used for reference in that it displays flowsheets, control loops, and interlock and alarm diagrams. However, a set of P&IDs is also necessary for reference. Ideally, PDFs of the P&IDs are accessible from the computer-based training dropdown menu.

Using the HAZOP approach, the plant process being covered is divided into areas and systems in the same way that Performance Associates divides the plant for the computer-based training. For example, an area might be primary grinding. A system in that area might be pebble recycle conveying and crushing. Each system is composed of unit operations, e.g., crusher and its lube system, recycle conveyor, etc. The design/process intent for each unit operation can be evaluated.

The *design intent* is a description of how the process is expected to behave at the unit operation; this is qualitatively described as an activity (e.g., transport product, precipitate solids) and/or quantitatively (e.g., change in temperature, flow rate, pressure, composition, size distribution, etc.). A design intent, or *parameter,* is selected for discussion and a series of *guide words* is applied to the parameter. A guide word is a short word used to create an imagined deviation from the design/process intent. Examples of guide words include:

- No.
- More.
- Less.
- Part of.
- Reverse.
- Too high.
- Too low.

Examples of process parameters are temperature, pressure, flow rate, etc. A deviation is a way that the process conditions may deviate from the design/process intent.

Guide Word + Process Parameter —> Deviation

For each of the imagined deviations, a potential *cause* or *causes* can be assessed by the trainees and the *consequences* evaluated. A cause is the reason why a deviation could occur. Several causes may be identified for a single deviation. A consequence is the result of a deviation, should it occur. Dividing the class into two or more teams competing with each other on potential deviations and consequences can make the class more interesting.

Safeguards are facilities that help to reduce the occurrence frequency of the deviation or to mitigate its consequences. In general, there are five types of safeguards that the trainees can evaluate based on potential effectiveness, frequency of the deviation occurring, etc.:

- Identify the deviation, e.g., alarms, detectors, or human operator detection.
- Compensate for the deviation, e.g., an automatic control system or interlock.
- Prevent the deviation from occurring, e.g., an inert gas blanket.
- Prevent further escalation of the deviation, e.g., an interlock trip.
- Relieve the process from the hazardous deviation, e.g., a pressure relief valve or rupture disk.

The HAZOP training approach implemented following intense process and operational training for a plant area also adds interest to the training, as the trainees become involved in looking for potential hazards and causes. Symptoms that could indicate a safety-related deviation could also be discussed. What could the operator observe that might indicate the initial stages of a proposed process (and safety) deviation?

CONCLUSION

The main point of this white paper is to establish that safety awareness, management, and training is not a "management layer" placed over the operations layer. Safety is an integral part of the process and operation. *Detailed process knowledge is detailed safety knowledge.* Safety training is not complete unless it is integrated with the process and operations training.

Occasionally, we hear senior operations management say that they (management) have plenty of experience with metallurgical plants, so comprehensive training isn't required. The issue is not whether senior management has "plenty of experience," it's transmitting those skills and knowledge to new, less experienced operators—those operators on whom the success of the operation will hinge. It's those operators who need the skills and knowledge to effectively, *and safely* operate the plant.