OPERATING MANUALS AS A TOOL IN OPERATOR TRAINING FOR METALLURGICAL PLANT START-UPS

by

Mr. Stephen R. Brown

Principal
Performance Associates International, Inc.

ABSTRACT

A number of relatively recent factors associated with the design of new metallurgical processing plants have made the effective training of operators a requirement for a successful start-up. Some of these factors include large capital investment in a minimum of processing lines, highly complex process control systems, and stringent regulations on plant effluent, to name a few. More than ever, operating mistakes during the start-up phase can lead to substantial delays in achieving design production, as well as problems with government authorities if permit limits are exceeded. The only way to assure your return on plant investment is to ensure new plant operators have the knowledge to properly run the plant from the outset. A comprehensive set of operating manuals specifically targeted for plant operators and foreman, written by experienced operating personnel, is the only effective way to provide the necessary information for start-up-related training.

WHAT OPERATORS NEED TO KNOW

Performance Associates has been in the business of assisting mining companies to start up new minerals-related processing plants for the past eleven years. During this time it has become apparent that certain, key information must be known by the operators and front line supervisors if the start-up is to be a success.

This key information consists of several key elements. First, it is essential that the operators have a conceptual understanding of the process and the principle of operation of each major unit operation in their area of responsibility. Conceptual knowledge allows for more effective reasoning when process upset conditions occur. Rather than attempting to provide a recipe covering any conceivable upset, the operator’s conceptual knowledge will allow him to draw the appropriate conclusions based on the situation at hand. In addition to understanding the process and its equipment, the following information is also vital.

To ensure each employee works safely, information on the correct methods for performing potentially hazardous jobs must be understood. Each new plant operation will contain potential hazards that must be understood by every employee. These hazards include working with various reagents, such as sodium cyanide, caustic, sulfuric acid, etc. They also include working around various types of moving equipment.

Each operator must also fully understand each control loop in his area of responsibility. This understanding includes the variable being controlled, the instruments and control strategy employed, how to recognize when control problems occur, the backup options available, and when it is appropriate to exercise those options. This understanding has become more difficult over the recent past since control strategies have become increasingly complex with the advent of more and more powerful process control software.

In addition to the control loops, all interlocks must be thoroughly understood, including how interlock logic is effected by various operating parameters, such as remote operation, local operation, maintenance operation, etc. We have seen a very significant increase in the complexity of plant interlocks just during the past two years.

Once the process and its critical variables are understood, along with the controls and interlocks, the operator must then learn the fault, cause, and remedy associated with each alarm. This learning can be a tall order since many of today's new plants have literally hundreds of programmed alarms in each plant area.

Each operator must also learn the correct steps to start up and shut down the plant under various conditions. These conditions normally include: start-up from complete shutdown, start-up from standby shutdown, start up from power failure, and start-up from emergency shutdown. Additionally, each operator must know how to manipulate the distributed control system (DCS) to determine what is happening in the process, to take control of a particular controller, to adjust set points, etc. Operators must also know how to effect control using any local control panels in the plant. These panels are typical for packaged boilers, samplers, and solution heaters. The new complexity of metallurgical plants make all of these procedures much more involved than they used to be.

Finally, each operator must learn other operating procedures deemed necessary. For example, these procedures include such tasks as checking cyanide concentration, checking carbon concentration, taking solution samples, measuring slurry density, conducting routine inspections, and ensuring the plant operates within permit requirements.

Operators having any limitations in the above described knowledge will cost the company during the start-up and subsequent initial operation — the more the knowledge gap, the more it will cost.

In plant start-up situations where very little of this knowledge has been transmitted to operators, the start-up can be little short of disastrous. In a typical start-up scenario, personnel react inappropriately to process upset conditions, causing further upsets. These upsets result in a new series of inappropriate reactions, sometimes including physical plant changes. Many times a never ending circle of operator reactions causing problems — causing different reactions — causing more and more serious problems, occurs. Once this cycle has started it can quickly get out of hand. Just getting back to the base plant condition can be virtually impossible.

To add to these problems, once the plant actually starts and problems develop, there is no time left to train the operators. The problems begin to multiply; since everyone is working extra hours to deal with the problems, there is no chance to catch up. Operators are left to absorb the necessary information by trial and error while dealing with the start-up problems. In some cases more complex plants never do successfully start up. Simpler plants may eventually operate at production capacities approaching design but only after long, arduous start-up periods.

Generally operators of plants started under these conditions all have their own pet methods for controlling the operation. We have observed many plants where critical variables are controlled with entirely different home-grown strategies on each shift. In some cases even the target values are different.

AN ALTERNATIVE APPROACH

Introduction

Few people would dispute the necessity of transmitting literally thousands of pieces of information about the new plant to the operator. In fact, there is really only one way to actually do it. We have found that writing a series of custom plant operating manuals, specifically designed for an education level of the average high school graduate, is the correct approach. These manuals are then used in a formal classroom training program, complete with graphic support, work books, and tests. The training must occur prior to mechanical completion. Ideally, the trained operators complete the class work and then assist with the final stages of preoperational testing. Only then are they ready to introduce feed and perform their normal operating functions.

The operating manuals that we have used over the years for this purpose have evolved based on our direct experience. We have found that the following contents work well, both for training, and as a continuing reference.

Operating Manuals Contents

<u>Introduction</u>: This section describes the purpose of the manuals and identifies those volumes in the set. It also illustrates the scope of the particular manual volume.

<u>Use of the Manual</u>: This section describes how pages are numbered and how to find information. It is important that the manual contents are well organized and it is easy for an operator to find the information he needs.

<u>Safe Job Procedures</u>: This section provides formal written procedures, including any special equipment required, to be followed by the operator when performing potentially hazardous job functions.

<u>Process Design</u>: This section provides a written description, complete with necessary schematic diagrams and illustrations, describing the process. It also includes brief principles of operation for all of the major process unit operations. For example, unit operations such as vacuum pumps, dryers, filters, etc. are described. It is essential that the operator is provided with the necessary information so he or she can describe the key operating principles. This section also provides an equipment list and color flowsheets. These flowsheets are simplified, having had the material balance information removed. Each process flow stream is produced with a different distinctive color.

<u>Process Control</u>: This section provides a table identifying each critical process variable, such as temperatures, flows, pressures, densities, etc. It also summarizes their target values, methods of control and their impact on the process. Following the process variable table, each control loop is described using text, a simple block diagram, and a simple loop diagram extracted from the piping and instrument diagram (P&ID). Each method of control such as automatic remote set point, automatic local set point, and manual are discussed, as applicable.

Interlocks: This section provides tables identifying all interlocks and permissives for each motor and affected instrument, along with cause-and-effect diagrams. The diagrams cover the same information as the tables and are used to complement the tables. The interlock tables and diagrams are organized by logical process system.

Alarms: This section illustrates each alarm in the process sorted by tag number. It is in a tabular format and includes the affected equipment, the fault, the potential causes, and the steps to take to remedy the alarm.

Operating Procedures: This section is divided into three sections: Start-Up, Shutdown, and Operator Tasks.

START-UP describes the detailed procedures necessary to start up the plant from a complete shutdown, from a standby shutdown, from a power failure, and from an emergency shutdown.

SHUTDOWN describes the procedures necessary for a complete shutdown, a standby shutdown, and an emergency shutdown. It also describes the effect of a power failure and any specific procedures the operator should perform.

OPERATOR TASKS describe additional procedures required to operate the plant. These procedures always include preoperational inspections necessary to set up the plant for start-up. They also include procedures necessary for the operator to perform his job function. They may also include any steps the operator must take to manually control key process variables. Typical operator tasks for various job functions are:

- Manual boiler blowdown.
- Measuring pH.
- Preparing a batch of flocculant.
- Preparing strip solution.
- Shift inspection.

An operator task procedure is important whenever consistency is critical.

Instrument List: This section provides a complete list of each instrument along with its service.

Operating Manuals Development

Writing each manual is a tedious and involved process. The following source material is needed:

- Flow diagrams.
- Piping and instrument diagrams.
- Equipment operating and maintenance instructions.
- Interlock logic diagrams.
- Motor control schematics.
- Design criteria.
- Equipment list.
- Instrument list.

This material is used to develop each of the sections previously described. Manual writers must be experienced in plant operation and should be good writers; this is often a difficult combination.

Typically, several months must be dedicated to the manual writing process. In many cases, engineering changes are still occurring as the manuals are being prepared; this adds to the complexity.

Once the manuals are completed, we suggest preparing an accompanying training module for each manual volume. The training module optimizes use of each of the manuals in a formal classroom instruction setting.

Training Module Contents

Learning objectives and module outline: This section provides a list of the objectives that the trainee should be able to accomplish once the training is over. The module outline provides the instructor with an outline of the manual and a suggested training time for each section.

Overhead transparencies: All graphics in the operating manual are made into overhead transparencies for use during classroom instruction.

Workbook: The workbook is a learning device comprising a series of fill-in-the-blank-type questions which the trainee answers while referring to the operating manual. It is used to reinforce learning after the material is covered in a traditional lecture. The instructor is provided with an answer sheet.

Knowledge assessment test: The knowledge assessment test is a validation device designed to determine how much of the material was learned by the trainee. It comprises multiple choice and true-false questions and is given after the module's classroom instruction is completed. Results can be used to determine if remedial training is required; it can also be used to determine where individual operators are ultimately placed in the operation.

Qualification checklist: The qualification checklist is designed to validate that the trainee can apply the theory learned in the classroom on the job. It is completed by the trainees' immediate supervisor during the intial stages of operation. It can be used in combination with a probationary period during which the operator proves he can accomplish the job functions required.

Once the modules have been completed, the next step is to conduct classroom training.

Classroom Training

It is important to use credible personnel with previous experience in plant operations for training instruction. Ideally, the personnel who have prepared the manuals and modules should carry out the classroom instruction. In many cases we use our personnel to conduct train-the-trainer classroom sessions for the client's trainers, then they in turn train their plant operators. We have found this approach very successful.

The formal training consists of three components:

- Classroom lecture.
- Trainee completion of workbooks.
- Site visits to observe the plant equipment.

We have found that the lecture, workbook, and site visits work best when they are distributed throughout the training day. Too much time in the classroom can dull the learning process.

During the classroom phase it is important to get the trainees involved. Trainee participation results in better retention and makes for a more interesting experience. Near the end of each module, simulation drills can be held. These drills require that the group is split into teams. Each team then attempts to determine the cause of hypothetical process upsets postulated by other teams or by the instructor. The simulation drills require knowledge of the full breadth of information contained in each manual.

Once the formal classroom training sessions are completed, additional time can be spent in the field tracing pipelines, identifying every control valve and instrumentation element, and generally marking up P&IDs as instruments, equipment, and pipelines are identified.

The final phase of training is trainee participation in preoperational testing prior to introduction of feed. Operators, having completed training, are extremely knowledgeable about the new plant. They make ideal personnel to walk the plant and prepare punch lists of discrepancies.

When functional testing of completed plant systems occurs, operators can also participate in that testing. Ideally, the new operators can use the distributed control system or local PLC controls to operate the equipment necessary under the direction of appropriately qualified engineering personnel. As problems are identified during the testing phase, the new operators and supervisors can participate in problem solving teams investigating the problems.

We have found that there is no substitute for highly trained operating personnel during the testing and start-up phase of any new plant. The training program described above will provide those highly trained operators and supervisors. We know of no other satisfactory method for ensuring that your personnel are ready to operate the new plant.

NEW TRAINING TECHNOLOGIES

Recently, advances in interactive, multimedia software for personal computers have provided other options for employee training. This software, known generally as authoring software, allows for linking audio, text, full-motion-video, and interactive animations to create an integrated training product, including trainee work books and tests.

We believe that computer based training provides many advantages. It provides an ideal method for providing refresher training and for training new employees after start-up since trainees can interact with the computer as schedules permit. With computer-based training, it is not necessary to get all the operators in a classroom with an instructor.

SUMMARY AND CONCLUSIONS

There are literally thousands of specifics that must be learned by each operator involved in a new plant. In addition to facts concerning the new plant, operators must also learn principles and theory associated with the new equipment, controls, and methods. No matter how carefully the plant has been designed, or how good the new equipment works, the start-up will not be a success until the operator has completed this learning.

There are only two ways for operators to learn the material necessary. They can learn it in a controlled classroom environment as has been discussed in this paper. Alternatively, they can learn it as they are attempting to operate the plant by trial and error. The cost of the former approach, while certainly not inexpensive, is very low compared to the lost production and damage usually associated with the latter approach.