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Advanced Operator Training with Innovative Distillation Simulation

Accelerating Operator Performance with Innovative TOP-OP Training Program

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Abstract

Operator experience levels in the processing industries is reaching a near-crisis level due to downsizing, lessened resources and both helped and complicated by the acceleration of advanced computer control systems.

Due to the loss and impending loss of significant human resources, the average experience level has drastically decreased in recent years. Compounded by reduced staffing and budgets, this calls for innovative training methods to reduce the learning curve for process operators and ensure proper qualification.

This paper outlines these driving forces and provides a framework for accelerating operator training, focused on distillation operations.

Authors

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About ATR
ATR is a leading provider of integrated e-learning, performance support and compliance management solutions to the processing and power industries. Founded in 1990, ATR has provided solutions to 100s of Fortune 500 operating companies, including DuPont, BP-Amoco, Dow, Petronas, Shell, Akzo Nobel, Florida Power and Light, Valero, Tesoro, Alliant Tech Systems, Goodyear, B.F. Goodrich, ChevronPhillips, ConocoPhillips, ExxonMobil and many more. ATR was a core team member of the Abnormal Situation Management Consortium. ATR's premier procedure management software, Vanguard was a winner of Chemical Processing's prestigious Vaaler Award. After September 11th, ATR provided its e-learning and procedure solutions to the New York City Fire Department and helped raise over $1 million to provide computers and support in the massive rebuilding efforts.

Background

Today's operations have been significantly impacted by the quantum changes in employee demographics. The refining and petrochemical industries have had a relatively stable, but aging workforce.

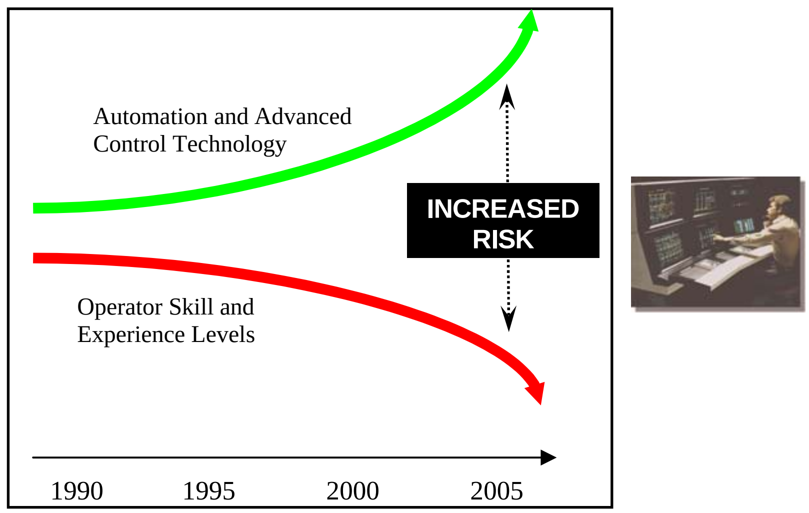
Downsizing programs and normal retirements are resulting in a more inexperienced workforce causing companies to promote much quicker to provide replacements. Overall driving forces that potentially affect operational performance include the following:

Driving Force	Description	Impact
Reduced staffing	Companies have substantially reduced the overall number of operating and support personnel, dictated by company profitability goals.	• Insufficient personnel to the job effectively • Delays in processing information • Potential "dropped balls" • "Not my job" syndrome
Increased regulations	Process safety management has had a significant impact on the health, safety and environmental methodologies used.	• Increased focus on health and safety considerations • Better procedures • Better safety practices
Reduced experience	Reduced staffing primarily has affected the more senior personnel.	• Reduced experience levels • Reduced leadership • Reduction in experiential-based training
Increased automation and advanced control	Distributed control systems and advanced control technologies have proliferated in the last 10 years. Computer control provides enormous incremental control capabilities.	• Optimized operational performance • Potential for "dumbing down" of operators based on reduced level of operation.

Analysis

Based on studies from the Abnormal Situation Management Consortium (in which the author's company was a core team member for six years), there was a significant and growing gap between the skill and experience of operating personnel (<u>decreasing</u>) versus the level of advanced control (<u>increasing</u>), as shown in Figure 1.

Figure 1
Increased Human-Technology Gap



This curve shows the increased risk potential as the gap between operator skill and experience levels drops as the advanced control technology curve increases. Studies show that overall, the advanced control systems are doing a good job and can help operate at a near-optimum level routinely. The problem arises when the control system is unable to compensate for operational conditions and requires human intervention. In many cases, especially with continuous operations, this lack of interaction produces a "dumbing down" affect on process operators. Nothing significant happens, no intervention is required, and no experience or practice is gained on a routine basis.

While the control systems have done an excellent job enabling operators to operate at When an alarm occurs, the operator can be flooded with the vast array of alarms and it can be an extremely difficult task for the operator to sort through this information overload and determine optimum recovery procedures, much less perform an effective root cause analysis.

Operator Distribution Analysis

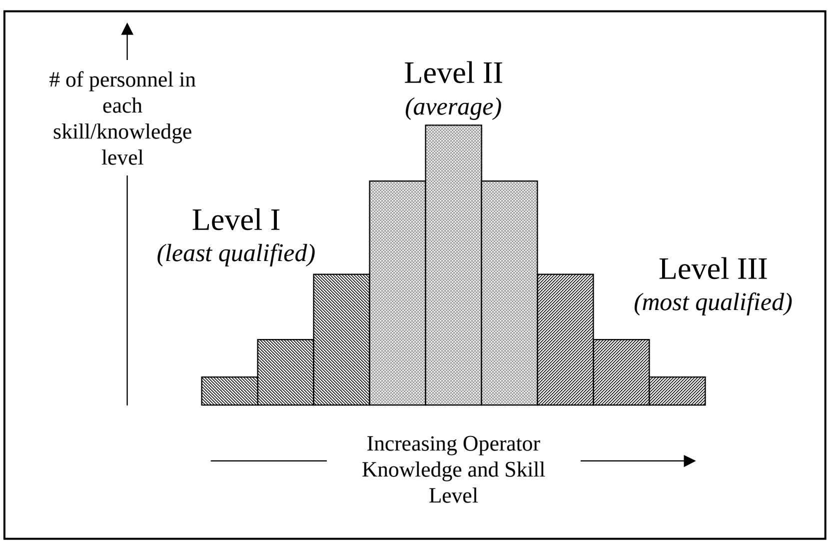
In any workforce there is a distribution of experience and skill. Figure 3 shows a typical "bell curve" distribution. This curve assumes a relatively stable workforce with an average experience level of between 5 and 10 years. The American Petroleum Institute (API) did a study several years ago with several oil and chemical companies and determined that the financial impact of having a Level II operator operating a facility versus a Level III operator approached $350,000 per year per operator.

Less experienced or knowledgeable operators are more apt to consume more fuel and resources, and less likely to optimize the process. Typically more supervisory time is required and there tends to be more downtime and out-of-specification products.

It is this author's experience that in spite of the very large economic driving forces associated with increasing the operator level, very few organizations spend a fraction to quantifiably define or train operators to the higher levels resulting in significant financial losses. One of the problems associated with advanced operator training is that few organizations have the appropriate systems or instructional methods to achieve the higher levels, typically requiring process-specific simulation and adequate instructional design methodologies or lesson plans.

In fact, different than nuclear or aerospace which routinely require advanced simulator training; the refining and chemical industry rarely justifies high-fidelity simulation or the training resources to use these tools effectively.

Figure 3
Operator Knowledge/Skill Distribution



Current employee demographics show a knowledge distribution quite different than the one shown in Figure 3. As the workforce has aged, the current curve is skewed drastically to the left, whereas there are many, more Level I operators on shift as many of the Level III operators have retired. In some cases, companies have Level II operators ineffectively training Level I operators creating a dangerous "incestuous" knowledge situation.

Operator Intervention Process

In order to better understand a typical troubleshooting process requiring an operator to intervene and resolve an operating upset condition, Figure 3 outlines a simple model used by the Abnormal Situation Management and Chemical Manufacturers Association.

Figure 3
Operator Intervention Process

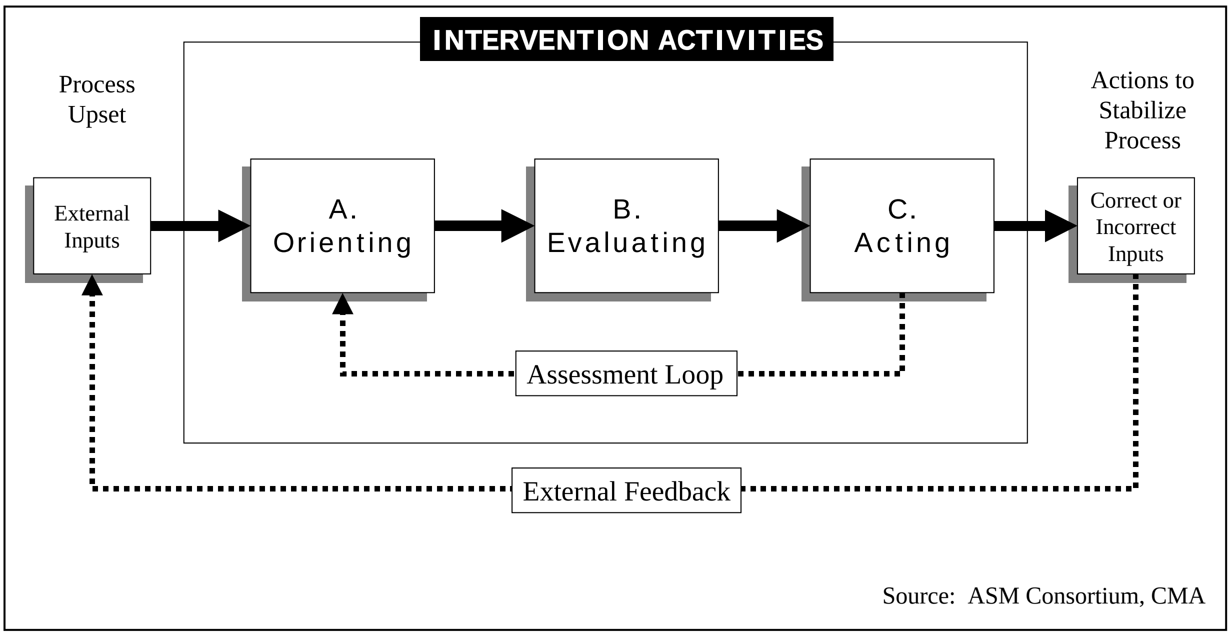


Table A describes some of the activities and learning considerations required at each step. An effective training program requires attention paid to each step and operations requires adequate staffing to ensure that all necessary steps are effectively covered. In some organizations, there may be only one Level III operator who must control operations with a team staffed with Level I operators.

Table A
Operator Intervention Process Description

Action	Description	Learning Considerations
External Inputs	These are the signals, instructions or alarms available to the operator.	• Knowledge of design or standard operating conditions • Knowledge of control system and/or other notification methods • Interaction with control system to retrieve information
Orienting	Includes operators sensing, perception and initial observations associated with detecting an incident.	• Understand process information and alarms • Understand trends and process • Ability to focus on critical information • Ability to process significant amount of information and avoid information overload • Operator vigilance; avoiding "target fixation" • Effective communication
Evaluating	Step in which operator processes information, analyzes. Diagnosing current upset condition and predict impact. Evaluate potential impact of recovery plan. Selecting appropriate recovery plan. Obtaining appropriate additional information.	• Requires strong diagnostic or cognitive skills • Strong understanding of process and control system • Sort through unorganized and massive amount of information to perform root cause analysis • Knowledge of procedures and impact analysis • Ability to diagnose and react with incomplete information • Work well under pressure • Requires experience and discipline
Acting	Coordinating with other members of operation's team. Conduct a sequence of activities to resolve upset and/or mitigate consequences.	• Knowledge of process and control system • Knowledge of plant operating procedures • Flexibility to work beyond limited procedures that don't cover all conditions • Ability to delegate and manage tasks to meet operational goals
Correct/Incorrect Inputs	Operator actions that affect the process that may or may not correct upset condition	• Understanding of control system • Effective communication • Effective procedures
Assessment Loop	Assessing whether actions taken have positive or negative impact on operations or mitigate consequences. Review	• Ability to quickly assess situation and make determinations whether actions are correcting situation • Analytical skills • Communication skills • Follow-up to ensure operational goals are

	and analyze data. Determine if system response corresponds with plan.	met

When setting up operator training programs, it is necessary to explore the training, experience and quantified performance and skill level to determine gaps and be able to take corrective action. All elements of this process are critical to the success of the "mission." First the operator must "wake-up" and get involved in the process. He/she then collects data, makes an assessment and determines the correct series of actions to resolve the immediate problem.

He/she then takes the corrective action, determines whether process situation has been stabilized and then bring the unit back to normal operations. Each delay or incorrect action can complicate or elongate the corrective time line; potentially resulting in a worsened situation and complicate recovery.

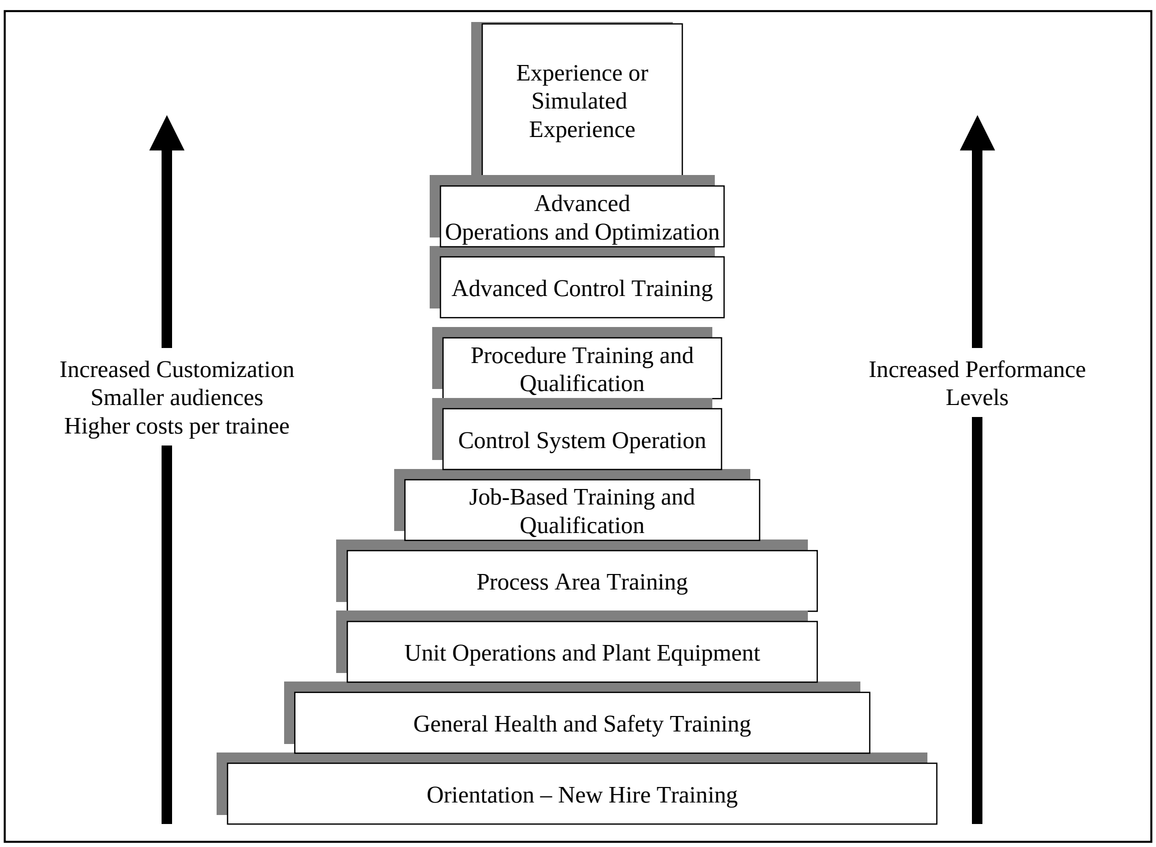
Limitations of Current Training Programs

Many training programs operate under significant limitations. Understaffed and with relatively little strong instructional design experience, many plants provide "adequate" training and trust that on-the-job training or as-needed training will be sufficient. The change in employee demographics and increasing turnover has put enormous pressure just to provide basic level training which includes general health and safety, as well as unit operations and basic equipment training.

Coupled with initiatives to meet OSHA health and safety or process safety management regulations, there is often an emphasis on getting these done by site training departments and therefore insufficient attention paid to advanced operator skills.

Figure 4 shows the standard components of an operator-training program.

Figure 4
Standard Operator Training Program



Most companies do well in the lower three learning components. Some of this can be purchased off-the-shelf and is readily available through a wide variety of resources. The lower two areas constitutes only about 15% of the necessary training required to produce effective Level III operators, and while necessary, it doesn't impact operational knowledge to any significant degree. As companies provide more and more of the mid- and upper-levels of training, there is significant movement to produce stronger Level III candidates with the resultant economic benefits.

Overall limitations of operator training programs include:

- Ineffective higher-level training and evaluation methods
- Limited training resources
- Poor understanding of basic unit operations and control
- Poor instructional design methods and lesson plans
- Knowledge-based versus performance-based
- Too much over-the-shoulder, "do as I do" training
- Instructors poorly trained or "incestuous" learning
- Too many conflicting priorities and disruptions
- Ineffective use (or non-existence) of advanced simulation tools
- No "What-if" and "Troubleshooting" drills and practice operating scenarios
- "All or nothing" syndrome – "everything (including simulators) has to be identical to our process or we can't use it."

Advanced Operator Training using Distillation Simulation

The innovative TOP-OP program offered for process operators provides advanced operator training with a holistic approach to train operators. Conventional training is limited and typically forgoes important building blocks and advanced scenario-based training. TOP-OP provides a vehicle to teach and practice important operational concepts and reinforce critical diagnostic and communication methods.

This paper will only touch on a small segment of the TOP-OP program. Figure 5 shows the primary training components provided in this innovative approach.

The recommended class size is about 8 personnel with one operational instructor. Each student would have access to a PC for hands-on simulator training as well as interacting with both what-if and troubleshooting exercises. Operators learn to "think outside the box" and remain flexible in their approach to solving problems. They learn to understand the need for understanding basic unit operations and essential principles of process dynamics. The more they understand how the systems work, the less likely they are to operate by the "seat of their pants." Collaborative team exercises are designed to be competitive in nature and subject to group analysis to recommend corrective measures for improving performance or communication.

Figure 5
Components of TOP-OP
Training Program

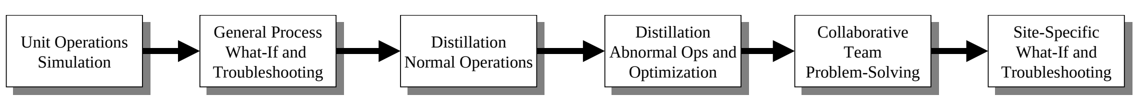


Table B
TOP-OP Training Description

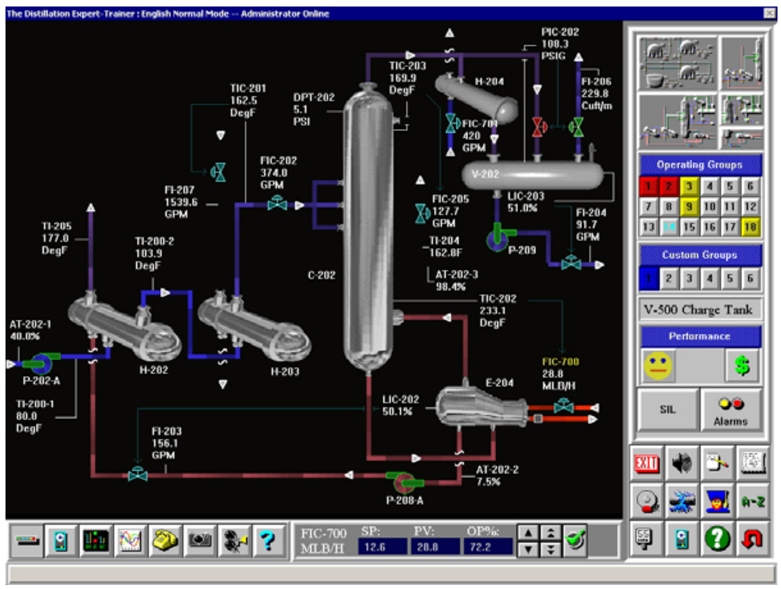
A.	**Unit Operations Overview,** **What-If and Troubleshooting Drills**	Operators get familiar with unit operations and basic principles associated with control and operation. Go through series of progressive what-if drills to reinforce cause-effect relationships, then proceed to Troubleshooting drills providing operators with trends and operational information whereby they have to analyze the data and determine root cause.
B.	**Unit Operations Simulation Scenarios**	Provide overview of basic unit operations ranging from exchangers to pump and valve operations to flash drums, compressors and heaters. Operators perform routine and non-routine tasks on individual modules then work their way to more comprehensive integrated modules. They learn to read and understand the process through the use of trend displays, process economics and operational goals, as well as start-ups and shutdowns.
C.	**Distillation – Normal Operations**	Overview of standard operations; gaining familiarity with standard process and control system. Go through standard startup and shutdown activities. Monitor process and make incremental measurable changes.
D.	**Distillation What-If and Troubleshooting Drills**	Provides what-if and troubleshooting scenarios focused on simulated process to reinforce operational cause and effect and accelerate to troubleshooting exercises. Use simulator to reinforce these scenarios.
E.	**Distillation – Abnormal Operations**	Provide a variety of progressive drills and operating scenarios to enhance procedural and diagnostic abilities. A wide variety of upset conditions ranging from equipment and control problems to feedstock swings and changing operational requirements. Operators learn to choose operational recovery plans and stabilize the process.
F.	**Collaborative Team Solving – Operational Exercises**	These exercises are designed to promote "best-practice" collaboration with the focus on team-building and communication. Teams are monitored to determine effective organization and distribution of duties in solving a variety of operational problems.
G.	**Site-Specific What-If and Troubleshooting Scenarios**	These exercises are designed to produce and practice process specific scenarios and should be required prior to additional advanced simulator training.

Training Scenarios for TOP-OP Training

The TOP-OP program uses an interactive high-fidelity distillation simulation. An overview of the process is shown in Figure 6. Also included are some tank farm operations for feed and product storage.

After receiving instruction on the user-friendly simulator that generally takes about 1 hour, operators go through a series of basic overview exercises to gain familiarity with the operation and the interactive controls.

Figure 6
Distillation Simulator



In a standard TOP-OP 3 day course, conducted by an experienced operation's specialist, the trainees alternate between interactive discussions, problem-solving exercise, computer-based-training and simulation practice and test scenarios.

Table C provides a list of typical upset conditions that can be created in addition to the standard operating procedures. The simulator allows the instructor to set up an automated time-line which can include a series of these upsets.

Table C
Types of Upset Scenarios

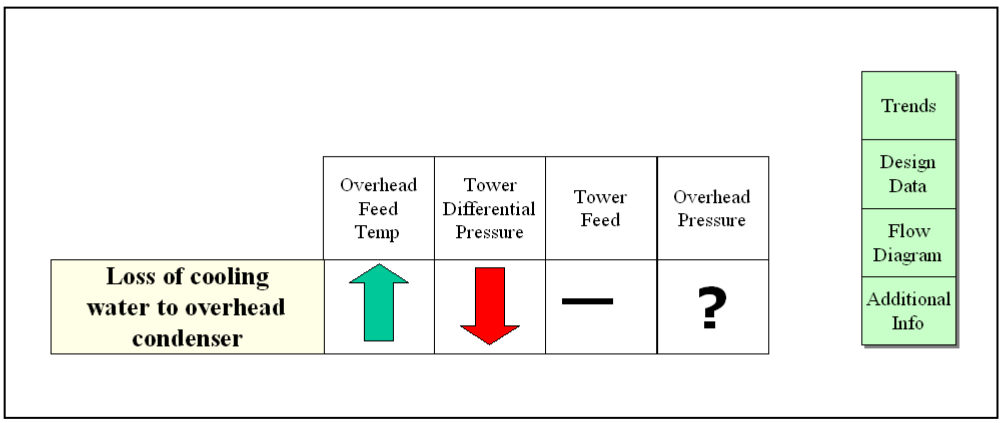
Controller – Instrumentation Errors	• Level controllers • Pressure controllers • Temperature controllers • Flow controllers	• Valve sticks • Loss of instrument air • Rupture diaphragm • Transmitter failure • Plugged orifice taps • Calibration offset • Tuning deviations
Equipment Failures	• Condenser • Hot Oil Exchanger • Pre-Heater Exchanger • Reboiler	• Fouling • Loss of Steam
Indicator Failures	• All indicators	• Transmitter failures • Calibration offset
Pump Failures	• Feed pump • Overhead pump • Bottoms pump	• Pump trips • Toggles • Failure • Impeller damage
Tower	•	• Fouled trays

The TOP-OP program puts operators through several operating scenarios in a progressive learning environment and uses group, team and individual exercises.

What-If Exercises

A series of computer-based **What-If?** exercises is created to ensure operators are familiar with the overall process and relationship between process variables, as shown in Figure 8. A condition is established and the operator must decide whether other variables experience an increase, decrease or no change. Alternatively they may not have sufficient data to make a determination, so in some cases an "I don't know" is an acceptable answer.

FIGURE 8
What-IF Scenario



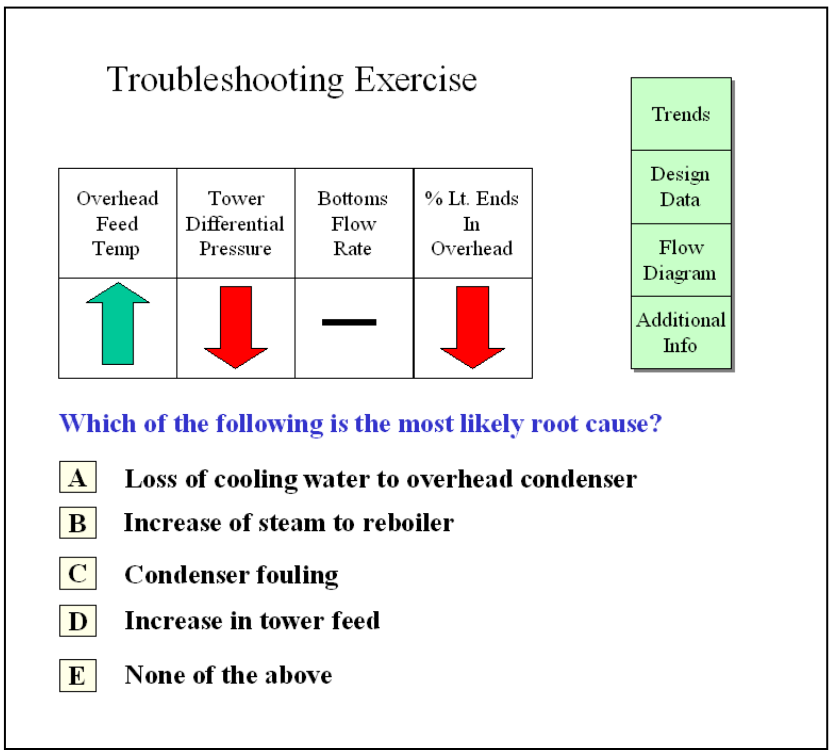
Troubleshooting Exercises

After the operators have a good understanding of the cause- and effect relationships associated with the associated process, they would go through a series of computer-based troubleshooting exercises, as shown in Figure 9.

These exercises are structured to provide the operator with specific information about the current condition of the process, including changes in variables, trends and current operating and control conditions.

With this information they are expected to perform a root cause analysis and determine the most likely cause from several potential conditions. This series of exercises taps into the cognitive understanding and diagnostic abilities.

Figure 9
Troubleshooting Exercise



Additional Scenarios for TOP-OP Training

1. Performs plant status check and ensures proper turnover. Reviews process conditions, alarms, trends and setpoints

2. Checks and verifies status of critical operating variables

3. Looks for “out-of-control” valve positions

4. Examines trends for process variables

5. Monitors process economics and optimization data

6. Communicates with other team members any safety issues, plant maintenance concerns, unusual plant conditions or process needs

7. Enters log data and reports problems, concerns or abnormalities

8. Performs standard operating procedures with checklist verification/completion

9. Develops operating plan containing alternative course of action, priorities, consequences of deviation and roles and responsibilities based on a potential problem

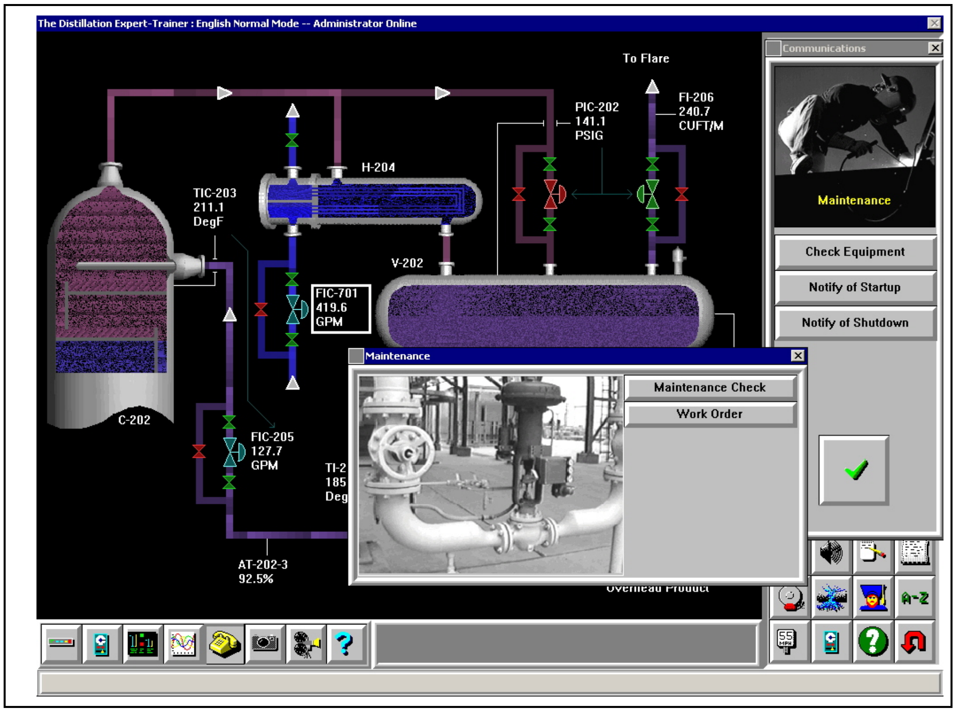
10. Makes specified process changes to bring process from one operating state to another while remaining within equipment limits

11. Move from a manual control design state to advanced control

12. Demonstrate proficiency in responding to alarms in a logical priority order

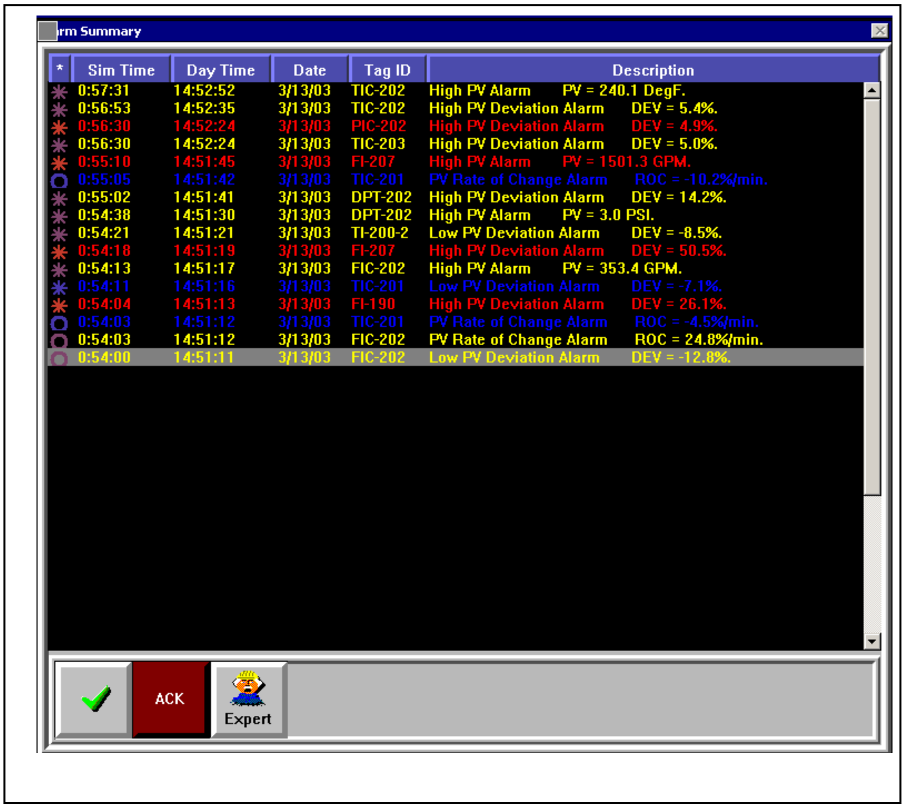
13. Demonstrate proficiency in dealing with multiple upset conditions and be able to focus on operational goals and bring unit back to design conditions

Figure 10
Maintenance Interaction with Simulator



Exercises can be set up to establish communication protocols and ensure effective communication with other team members. System tracks all operator actions for later review and analysis.

Figure 11
Alarm Summary



Exercises established to ensure operators can effectively to various alarm conditions and demonstrate proficiency in responding in a logical, prioritized way.

Summary

Today's operations requires innovative training methods to accelerate learning and to ensure that operators are effectively training and qualified in the critical skills required to do their job. The TOP-OP methodology provides a strong basis for bridging the gap between fundamental knowledge and skills and process-specific operational skills.

While companies typically do a good job in providing fundamental and basic health and safety knowledge; there is frequently a gap in ensuring that operators have the basic "block and tackle" skills that apply to any process in any industry. It is essential that operators understand process logic, relationships and have the necessary troubleshooting skills. The TOP-OP program helps ensure that operators have these important skills and provide a strong basis for moving operators directionally from a Level I to Level III skill.