OPERATOR TRAINING simulators (OTSs) have been around the chemical industry for decades and now represent mature technology. However, because of global trends and competitive pressures, the need to improve the skills, knowledge and behavior of operations staff never has been greater. Five factors are driving more and more chemical makers to invest in these tools:

1. Retirement of veteran operators;
2. The impact of human error;
3. The quest for faster startups;
4. Improved OTS effectiveness; and
5. A refocus on training objectives.

So, let’s look at each of these factors and what’s required to successfully address them.

RETIREMENT OF VETERAN OPERATORS
Process operator performance is important during the commissioning, operations and extension phases of a plant’s lifecycle. However, many chemical manufacturers worldwide expect most of their experienced operators to retire before 2020. So, the companies risk losing a lot of knowledge and know-how unless they take steps to capture it.

Mentoring certainly is valuable but poses a risk of passing on bad, as well as good, habits. Also, the lessons learned this way don’t necessarily reflect best practices.

Using a training simulator program to capture the skills of veteran operators before they retire solves some of the problem of building the expertise of new and less-seasoned operators. One chemical industry insider comments that with “industry simulation technology, we have been able to increase the overall knowledge base of current operators and provide broader scenario training to future employees. We have had about 40% of our operators go through the testing so far and have received nothing but positive comments. Some want to go through the training as often as possible instead of the regular 18-month training cycle.”

Critical to success: The best way to capture experienced operators’ knowledge is to use a documented approach to OTS design and deployment. One technique is to facilitate a series of workshops with a cross-functional team representing operations, engineering and training. The workshop leader writes a statement that communicates the workshop’s aim, e.g., “Identify, define and document the top 20 learning outcomes from the OTS and specify the OTS requirements necessary to deliver the learning outcomes.” A learning outcome might be, for example: “Trainee is able to demonstrate basic process understanding.” Part of this process should involve identifying the training and measurement mechanism — for instance, if,
after an exercise, the trainee can identify a key piece of process equipment and describe its function in relation to the overall plant purpose, then the learning objective has been achieved.

The first workshop should define program components. Further workshops then should pinpoint program materials within the framework of a workbook, i.e., a document that describes the training exercises or lessons that will be delivered to the intended trainee pool. Each workshop should take the form of a series of facilitated interviews between the workbook designer and subject matter experts (SMEs), who typically are experienced operators, process engineers and training professionals. The SMEs should work with the designer during the workshop to specify the detailed content of the training exercises based on their specific knowledge and experiences.

The desired outcome from this process is that the OTS is scoped based on the collective knowledge and experience of the people close to day-to-day plant operations and the workbook that’s generated incorporates best practices (Figure 1).

THE IMPACT OF HUMAN ERROR

Research from the Abnormal Situation Management Consortium indicates U.S. chemical plants lose more than $20 billion annually from abnormal situations, with $8 billion due to human error and insufficient knowledge. Engineering measures, such as control and safety systems, are necessary to reduce risk but aren’t sufficient protection. Simulator-based training can help manage that risk. A structured approach accelerates learning and helps maintain abilities through refresher training. A typical program includes:

Basic training for new operators —
• Process/control familiarization, 1 week;
• Initial startup and shutdown, 1 week;
• Incident avoidance, 1 week, 10 lessons; and
• Incident recovery, 1 week, 10 lessons;
Annual refresher training between turnarounds —
• Incident avoidance, 1 week, 10 lessons; and
• Incident recovery, 1 week, 10 lessons.

The exercise content is produced through the facilitated workshops. One format that’s proven successful divides each lesson into three sessions:
1. Learning. The trainee reads appropriate background material, and also may need to answer a series of questions relating to the reading material.
2. Application. The trainee uses the OTS to gain practical experience of the process, and will be guided through the appropriate procedures.
3. Assessment. The trainee reviews what has been learned in the learning and application sessions. The instructor then has the trainee perform various activities and answer questions, and discusses the whole lesson.

Critical to success: A common misconception is that an OTS is a form of video game, not a serious business tool.

Some psychological concepts used in gaming can motivate and stimulate use of an OTS — particularly by younger trainees familiar with modern interactive teaching methods. These proven concepts include:
• Reward. “You have demonstrated the necessary knowledge, behavior and skills to progress from trainee to panel operator.”
• Status. “You now are ready to be challenged by more-complex training scenarios.”
• Achievement. “You successfully managed a complete plant shutdown with no unexpected trips.”
• Self-expression. “You can contribute to the design of new exercises.”
• Competition. “You are progressing to a higher level of attainment.”
• Altruism. “You can share your expert knowledge with others.”

However, these aspects only work in a business context if the individuals involved perceive the underlying system as relevant. This has two key implications. Firstly for the OTS design, involving the user community for workbook generation ensures users become stakeholders rather than just training services consumers. Secondly, organizations must keep the simulator a close match to the actual plant. Once the actual plant deviates from the simulator, trainees challenge the OTS’s relevance and the training value quickly erodes. A simulator-maintenance best practice is to have a mechanism that allows OTS stakeholders to review all plant modifications to determine if an update is needed. Updates then can be executed annually. A common trap to avoid here is considering that modifications are minor and can be explained to the trainee either during or before the session. While experienced operators may be able to cope with significant differences, new trainees may not be able to put even small ones into context — significantly decreasing training.

![Workbook Generation Diagram](image-url)
effectiveness. Senior managers should seek regular feedback from stakeholders on the OTS’s ongoing relevance.

THE QUEST FOR FASTER STARTUPS
For 30 years, the primary driver for investing in an OTS was to prepare operators for the startup of a new unit. This remains one of the primary drivers today. The economics are compelling: the loss of revenue due to delayed production and the gain in revenue due to early production both can be massive [1]. Figure 2, which includes data from a Finnish chemical company covering startups without an OTS (1997 and 2002) and with an OTS (2007), shows how the training paid off in a faster startup. Engineers involved with these projects commented: “We developed successful and consistent training programs to keep our employees up-to-date on the plant — something they demanded once they experienced the real-world scenarios. Our operators were excited about the process and took an active role in learning to help make this plant as profitable as possible.”

With training came smoother, quicker startup. There are other examples; a UK-based chemicals manufacturer reported similar benefits, including saving eight days during initial startup followed by a day saved during additional startups following turnarounds [2].

Critical to success: Plant startup is usually an infrequent activity. Many years could pass between the initial startup and the next turnaround. Simulators enable practicing and perfecting startup and other infrequent procedures. From the point of view of procedural training, accurate and consistent execution of unit procedures is fundamental to safe and reliable operation. The training coursework should include and reference the latest versions of any relevant procedures. If the simulator hasn’t been updated, the instructor must note this within the training session. Particular attention should be placed on training for procedures or activities that aren’t part of the standard operator duties, and relevant documents within the workbook materials should be referenced. Validating a trainee’s ability to identify when a standard procedure should be deployed, where to find the procedural information, and compliance to the procedure are key benefits of using an OTS.

IMPROVED OTS EFFECTIVENESS
The chemical industry has used OTSs for about 30 years, so plenty of systems are deployed. Discussions with companies that have installed simulators have identified key areas for improving OTS effectiveness. The feedback typically doesn’t focus on the quality of the underlying process models or the fidelity of the control and logic emulations. Instead, key inputs received by Honeywell during customer interviews mainly center on using the simulator to address weaknesses in current training methods. Four particular shortcomings cited are:

1. Limited on-the-job performance measurement —
   • Measurement often doesn’t happen or only is considered after an incident has occurred.
   • Performance measures tend to be informal, subjective and biased, and don’t relate to specific competencies.
2. Inadequate feedback to operators on performance relative to competencies —
   • Competency-related on-the-job feedback rarely is given.
   • Feedback during training often lacks structure and isn’t grounded in specific competencies.
3. Limited value of evaluations during training —
   • Results are based on process outcomes without a clear relationship to specific competencies.
4. Lack of focus on a comprehensive set of competencies —
   • At least 50% of the customers interviewed weren’t using a competency model for training.

It’s possible to address each of these issues in the training environment. However, doing so requires incorporating the OTS within a structured framework.

Critical to success: A company must consider a variety of

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**Figure 2.** Finnish company’s use of OTS before 2007 startup resulted in much better performance than in two previous startups.

**Table 1.** Such a map should include both behavioral indicators and training activities.
### SIMULATOR PROGRAM MANAGEMENT

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<th>BEST PRACTICE</th>
<th>DESCRIPTION</th>
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| **Single Owner and Point of Responsibility** | One person is given responsibility for:  
- Scheduling training sessions;  
- Maintaining records of simulator use;  
- Ensuring the simulator matches the current plant;  
- Making sure the training materials are up-to-date with the plant and relevant to the plant training needs; and  
- Planning simulator maintenance. |
| **Track Key Performance Indicators (KPIs)** | Preparation of management reports on KPIs:  
- Total hours of training;  
- Hours of simulator training per trainee; and  
- Simulator availability. |

### TRAINING COURSEWORK

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<th>BEST PRACTICE</th>
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<td><strong>Structured Coursework</strong></td>
<td>The coursework developed for the simulator is embedded within and complementary to the organization’s overall training strategy and goals. Coursework is designed to build competency progressively from an understanding of basic principles of operation through procedure execution to qualitative and quantitative process-interaction understanding.</td>
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<tr>
<td><strong>Relevant Training Scenarios</strong></td>
<td>The training material pertains to the operational goals of the unit. For example, if the unit is scheduled to take on new hires, then the training material is configured to develop skills of new operators as well as provide refresher training for experienced ones.</td>
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<tr>
<td><strong>Procedural Training</strong></td>
<td>Awareness and compliance with standard procedures is reinforced through training exercises.</td>
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<tr>
<td><strong>Train for Infrequent Activities</strong></td>
<td>Attention is paid to potential high-risk areas of infrequent operations.</td>
</tr>
<tr>
<td><strong>Train for Planned Abnormal Operation</strong></td>
<td>Training is planned to prepare staff for periodic activities like unit turnaround or shutdown.</td>
</tr>
<tr>
<td><strong>Promote Teamwork by Joint Training</strong></td>
<td>The simulator is used to spur teamwork between and among shifts. Combining inside and outside operator training allows people in both functions to gain greater understanding of the requirements and constraints of the other.</td>
</tr>
<tr>
<td><strong>Shift Handover Training</strong></td>
<td>A shift change could lead to operational problems if incomplete or inaccurate handover between shifts occurs.</td>
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### TRAINING DELIVERY

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<tr>
<td><strong>Instructor-Led Training and Self-Training</strong></td>
<td>Instructor-led training can address new or unfamiliar subjects. Self-training is more flexible and can be scheduled more easily around other commitments. Experience shows a combination of both forms of training results in the greatest overall benefit.</td>
</tr>
<tr>
<td><strong>Instructor Qualification</strong></td>
<td>All instructors are aware of the OTS’s scope and functionality, including any simplifications present in the model. Instructors receive formal training in the use of the OTS software. Other people are available to assist if the instructor isn’t an expert on the particular process unit.</td>
</tr>
<tr>
<td><strong>Tracking and Logging of Individual Performance</strong></td>
<td>To enable the training coordinator to evaluate the tool’s overall effectiveness, all training sessions should be logged and recorded.</td>
</tr>
<tr>
<td><strong>Operator Assessment</strong></td>
<td>Formal operator assessment tools that provide a clear feedback of operator performance are used.</td>
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Table 2. Success in training demands attention to the simulator management program, training coursework and training delivery.
factors, such as:

- Mapping performance measures to core operator competencies;
- Focusing on soft skills and related competencies, e.g., behaviors;
- Defining a methodology to be used during training;
- Developing a work process to provide operators with feedback on their performance during training; and
- Establishing a relationship between the measures and competencies that underlie effective performance.

Including these success factors within a structured program is a scalable task and depends upon the facilities available within the given organization. At the basic level, this involves creating a simple training plan that details the skills, competencies and behaviors and maps them to behavioral indicators and training exercises. Table 1 illustrates an example competency: “Respond to abnormal situations.” It is mapped to five behavioral indicators and three training activities. Each activity has an associated assessment score that contributes to the total score the trainee achieves for the exercise, which, in turn, determines the trainee’s level of proficiency in the associated competency.

Keeping a record of each trainee’s progress, along with completed copies of the trainee workbook is a good idea. Most major OTS solutions offer electronic reporting facilities that instructors and training managers can use to monitor trainee progress. Maintaining a session checklist for each exercise is a simple, practical tool for providing consistent training and trainee feedback. At the most sophisticated level, the training is deployed within an enterprise-wide learning management system. Such systems are becoming increasingly common, and many support integration with OTS software so that results and progress can be held in a central repository.

A REFOCUS ON TRAINING OBJECTIVES

Applying dynamic process simulation to the problem of operator training has been a significant achievement. Advances in modelling technology and the increasing power of computers enable accurate simulation of almost any unit operation and largely end any size restrictions on model scope. However, all this technology is only a means to an end. What’s really important is having trained, competent operators who can run processes safely, efficiently and profitably in an environmentally conscious and sustainable way. To achieve these goals, it’s critical to place operator requirements at the heart of any project. This is how OTS was specified 30 years ago because computing power was so limited that each piece of the model had to deliver training value. The model was built to satisfy a clearly defined training need.

Critical to success: Consider the training objectives first and then decide the scope and fidelity of the process and control modelling needed to achieve those objectives. Table 2 covers some best-practice areas.

AN IMPORTANT TOOL

An OTS should satisfy both the operators’ and company’s needs. Keeping in mind the five factors we’ve covered will set up the project for success. Sustaining OTS benefits is best achieved by understanding the core competencies required and how these can map to training activities and performance feedback mechanisms.

MARTIN ROSS is Bracknell, U.K.-based global product manager for UniSim Solutions for Honeywell Process Solutions. E-mail him at martin.ross@honeywell.com.

REFERENCES