Training for the future

John Morgan, USA, and Alan Royer, Canada, PetroSkills | John M. Campbell, explain how carefully structured training can improve safety and cut costs at LNG plants.

Surging construction places a premium on trained staff in all LNG plant functions. Training technical and operations staff requires different course materials and delivery methods.

Efficient training requires defining the 'must-know' information for course materials. Equally important are instructors experienced in gas processing, LNG theory, its application, and also in equipment and plant operations.

An overview of on-the-job activities, eLearning, distance learning and blended-learning techniques for LNG form a conclusion explored in this article.

Table 1. Contrasting LNG engineer and operator training

Engineers	More abstract. Some mathematics and applied engineering principles. Often quite intense. Connect basic chemistry and physics to how an LNG plant works. Engineering principles of key equipment including off-sites and utilities. In most cases, learning is in the office or classroom
Operations	Generally specific to the plant down to equipment numbers and drawings, flowsheets, equipment data, etc. Practical demonstrations of scientific and engineering principles. Detailed 'operation' knowledge of individual equipment. Context of the operators' day-to-day duties. Stop short of valve-by-valve procedures. Combination of classroom learning with skill verification and evidence recording in the field

Table 2. Process technologies of gas plants and LNG units

Mainstream gas processing	LNG processes
Producing wells (offshore/onshore)	
Gas/oil/condensate gathering lines	
Field dehydration (glycol), etc.	
Inlet separation/slug catchers	
Condensate stabilisation	
Gas sweetening (amine, etc.)	
Gas dehydration – molecular sieve	
Mercury removal	
Propane refrigeration	Mixed or cascade refrigeration
Natural gas liquids (NGL) extraction	Cryogenic liquid expanders
LPG storage and shipping	LNG storage and BOG
Nitrogen rejection	LNG shipping*
*Shipping of liquefied gases has a long history in certain regions	

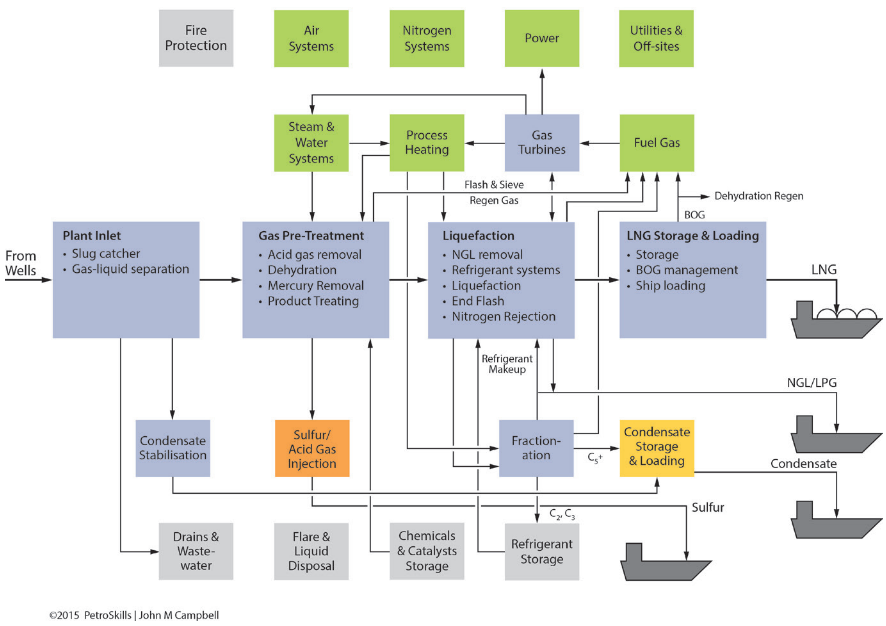

Figure 1. Main process units of an LNG plant.

LNG training: engineers and operations technicians

This article covers the training structure for gas production, baseload liquefaction and regasification terminals. Important characteristics of engineer and operations training are summarised in Table 1.

Engineering duties are usually medium to longer term. However, unit contact engineers often have urgent assignments. Engineering is discussed later in this article.

In contrast, operating technicians' work is usually more immediate. They operate in the middle of the LNG plant and handle its operation.

Gas processing and LNG plants

Figure 1 illustrates the main processing and utility blocks. Baseload LNG plants represent enormous project management, engineering, procurement and construction (EPC) challenges. Mostly, they are large gas processing plants in remote locations. They involve complex and specialised cryogenic liquefaction, product storage and shipping. Furthermore, they contain some of the largest compressors and other equipment in the oil and gas industry.

Processes clearly specific to LNG, as contrasted to the broad range of gas processing, include the following:

- The liquefaction block's processes handling mixed refrigerants (MR), and/or ethylene, methane cycles.
- LNG storage and boil-off gas (BOG).
- LNG loading and shipping.

The remaining blocks in Figure 1 largely draw upon traditional gas processing technology. This contrast is summarised in Table 2.

It is mainly with the liquefaction processes below, for example, -40°C (-40°F) that a clear and interesting specialisation appears. However, the complex liquefaction technologies are underpinned by the subcooling and economiser principles found in propane refrigeration systems.

This is certainly not to diminish the technology, sophistication and complexity of LNG liquefaction, storage and shipping, but rather to put them in perspective within the overall LNG plant facilities.

The new and fast growing mini and micro LNG plants extend training needs to an increasing number of plants with minimum staffing levels. These all require the basic gas processing to be correct. They also introduce a different set of skills related to LNG truck, coastal shipping, and barge cargo loading. The rapid growth in LNG-fuelled ships requires further training in LNG bunkering skills, such as hose handling, etc.

What to teach: instructional design

An alliance of companies has established common course content for many oil and gas activities. For example, in drilling, the required competencies are defined and mapped into a competency management system.

Likewise, in oil and gas facilities, such as LNG plants, there are established courses and learning programmes to train small or large groups. Figure 2 shows a simplified training and development sequence for operations technicians on a greenfield project. Versions of this sequence can address existing plants that require a structured training and development programme.

In Figure 2, the various job roles and positions matching the organisation chart are identified in Box 1.

Box 2a represents the major effort to define the necessary skills for each position. Initially, these can be high-level summaries for each skill/position, but at some point, an agreed-upon detailed skills list will be needed. The clockwise series of arrows around Box 2a signifies the iterative nature of discussions leading to an agreement on required skills. These skills need documenting. Competency maps (CMAPS) are an established format for such documentation and will be discussed later.

Box 2b, coupled with an instructional design function, defines the required training programme to deliver the required skills and competencies for LNG plant staff.

The activities in Boxes 3 and 4 culminate in identifying critical skill gaps in employees. These activities serve to both refine training materials and also form the basis for employee individual development plans (IDPs) (Box 5).

The 'ongoing activity' note accompanying Box 5 is a reminder that training and development is an ongoing individual activity long after start-up. The IDP is a roadmap for the employee's future career growth.

Box 6 covers the actual training programme delivery. The training programme needs careful scheduling to dovetail with LNG plant start-up.

The important skill verification and documentation in Box 7 should reside in a company's learning management function. This systematic approach documents the team's preparedness to begin complex operations.

Returning, for a moment, to Box 2a and the documenting (mapping) of the skills – such maps already exist within the CMAPS of the 34 companies constituting the PetroSkills training alliance. In this alliance, a system of curriculum advisors, discipline managers and subject matter experts create CMAPS that meet their needs and satisfy their standards. In turn, training materials are based on these competencies.

Owner-managed training

This training is best done as a direct owner-led activity. This allows the management structure established during the training phase to flow into start-up and operations, producing continuity and confidence. Why would an owner want to avoid and neglect the rapport developed between trainers and operations just when most needed during the stress of start-up and initial operation?

With direct owner-led training, the operations supervision and management are already familiar with the personalities, strengths and limitations of all operating technicians and maintenance team members at start-up.

A detailed training programme for operations technicians should include separation, absorber, adsorber, and refrigeration theory from the perspective of hydrocarbons, both chemically and physically. Laboratory settings would also be included where hands-on experience in a controlled environment would test the theory and enforce key learnings.

This is followed by hands-on training on plant equipment for skill verification and documentation. This training is specific to each individual piece of equipment for which the operations

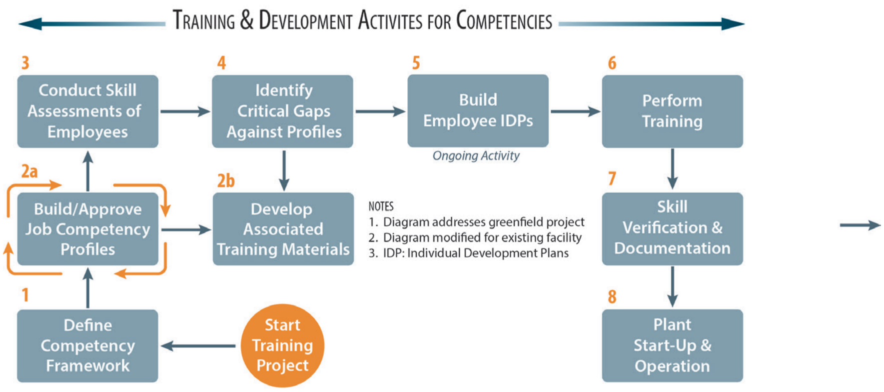

Figure 2. Training and development sequence.

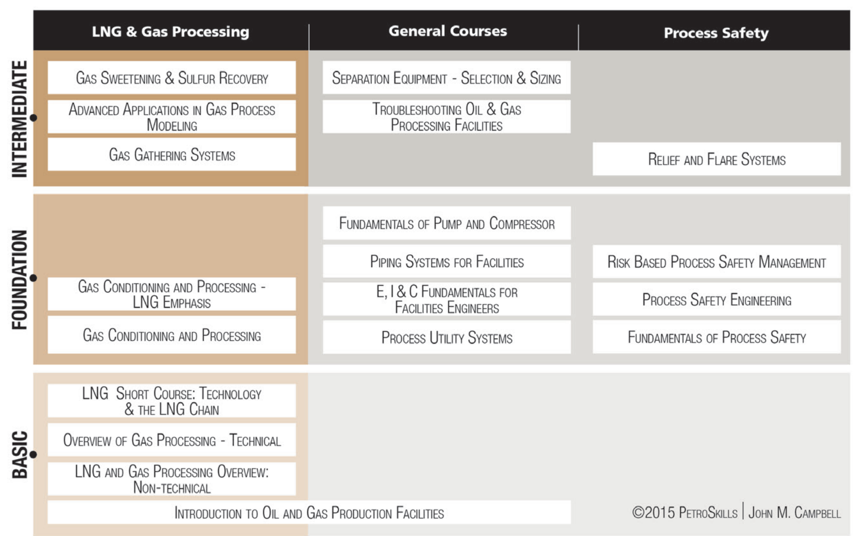

Figure 3. Example engineering course progression.

technician is responsible. This would need to be integrated with both health, safety and environment (HSE) and vendor-training initiatives. In several ways, the pre-commissioning and start-up phases represent the 'final' stages of structured training. Additional external start-up support personnel are invaluable at this point.

LNG plant availability and reliability are directly related to an operator's ability to understand and manage the various technologies involved. After commissioning and start-up, more specialised training is needed to support the management of change (MOC) techniques required for de-bottlenecking and correction of any design issues. This training could cover multiple areas, such as risk analysis, Hazard and Operability Studies (HAZOP), or Hazard Identification Studies (HAZID).

Additional insights: engineering training

Some aspects of graduate engineering training are indicated in Table 1, but there needs to be a structure and sequence of courses. Figure 3 shows an example structure, with an engineering course progression that addresses the following:

- Entering professional qualifications.
- Anticipated duties in an LNG plant.

The progression in Figure 3 ranges from basic to foundation onto intermediate levels. In addition, there will be important training from process licensors and equipment vendors, which need sequencing in a logical flow. For example, the 'fundamentals of pump and compressor' course in Figure 3 is required before the major compressor vendor's training along with compressor controls.

Value of field trips during engineer training

For engineers, a field trip into the LNG plant consolidates the 'book-learning.' A full day-long field trip might involve 3 x 1 hr structured exercises, each with immediate follow-up by a 1 hr assimilation of observations and learning points.

The exercises could include details on the following: pump seal-flush plans; key exchangers' TEMA designation and why they were chosen; pressure safety valve (PSV) configurations; main cryogenic exchanger controls; propane compressor anti-surge system; brazed aluminium exchanger cool-down; and quantifying leaks into propane loop. Training is not just delivering knowledge. It must also build confidence to apply that knowledge. Exercises and practice help build that confidence.

Blended learning: looking to the future

As an example, a course may have ~80% core material that all participants need to understand. Furthermore, this ~80% core lends itself to modularised materials in clear, easily digested pieces. The final ~20% capstone of instruction consolidates the ~80% core knowledge. In addition to this, consider that attendees will learn that core ~80% at different rates. Skillfully packaging this core material into self-paced modules allows the participants to learn at their own speed. These self-paced modules can be studied online until understood.

By contrast, in a standard face-to-face (F2F) classroom setting, slower learners might struggle to keep up.

Along with the core material, the remaining and vital ~20% is needed to knit the learning modules together. This ~20% is often an F2F classroom activity. It can be a mix of open discussions, key learning point sessions, and case studies. These consolidate, apply and illuminate the core materials. Case studies serve to validate the core knowledge and build attendees' confidence to apply the core knowledge in their duties.

Blended learning techniques can include several delivery methods, including the following: instructor-led training; videos; field trips; individual excercises; eLearning; on-the-job activities; webinars; group exercises; reference reading; and asynchronous distance learning. A key advantage of blended learning is that it is less disruptive to work schedules. A blend of online core modules coupled with syndicates, case studies, etc., requires much less F2F classroom time. Note that it does require the supervisor to allocate work time for those ~80% core modules. The supervisor must observe that time requirement for blended learning to succeed.

Conclusion

When building (for instance) an LNG complex worth US$10 billion, how much should be budgeted for training the team that will operate and maintain the facility?

Training is an investment in human capital. Carefully structured training directly improves safety. The training investment provides returns in HSE, plant availability, and the ultimate profitability of the enterprise. **LNG**

Process safety engineering[1]

The LNG industry enjoys a commendable safety history. Many safety-related aspects are involved, such as: MOC, occupational health, safety cases, human factors, etc. Process safety engineering is one such key activity during both design and operation. Important process safety engineering topics include the following:

- HAZLOP/Layers Of Protection Analysis (LOPA).
- Inherently safe design.
- Historical Incident Database (HID).
- Fire protection.
- Leakage and dispersion.
- Combustion equipment and plant layout.
- Process control.
- Process Hazard Analysis (PHA).
- PSV, flare and drains.
- Safety Instrumented Systems (SIS).
- Risk Assessment Matrix (RAM).
- Corrosion and materials of construction.

Note

Ron Hinn, Curtis Cain, Gerard Hageman, John Sheffield and Jan Blum of PetroSkills, contributed to this article.

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