Safety matters

Ted Cudal and Ruben Rodriguez, Nikkiso Cryo Inc., USA, examine how to implement a safety and environmental management system to reduce risks in cryogenic pump testing.

LNG facilities are built with state-of-the-art equipment and safety controls. The industry's highest priority has always been safety and security, which is reflected in its impressive safety record. In Japan, the LNG safety record provides a good indication of the industry's overall safety performance. According to the University of Houston's Law Center Institute for Energy, Law & Enterprise, LNG carriers supplying Japan have not had any significant incidents or safety problems in port or while at sea. On average, an LNG ship safely enters Tokyo Harbour every 20 hours.

LNG is typically not stored under pressure and it is not explosive in its liquid form. Although a large amount of energy is stored in LNG, it cannot be released rapidly enough if leaked into the open environment to cause the overpressures associated with an explosion. LNG vapours (methane) mixed with air are not explosive in an unconfined environment, although if an ignition source is present and the gas and air mixture is within combustible limits, a fire can ensue.

Testing submerged pumps in LNG and LPG requires special permits and requirements to meet US federal and state regulations for safety, liquid handing and storage, as well as highly trained staff to ensure personnel working in and around the test stand are as safe as possible.

As the growth of the LNG industry continues, Nikkiso Cryo Inc. (NCI) has seen an increase in cryogenic pump testing at its test facility in North Las Vegas, Nevada, US, which was built in 1996. A summary of the number of pump test hours and liquids consumed over the past five years is shown in Table 1.

The major difference between LNG liquefaction and regasification production plants, and cryogenic testing facilities, is that the former tend to operate continuously, without shutting down their processes, and under normal conditions, piping and equipment are connected and not open to the atmosphere. The testing of cryogenic pumps includes a number of set-up, disassembly and starting and stopping cycles. Each pump requires assembly, installation, purging and cool down in the test liquid, performance testing, removal and disassembly, every time a test is performed.

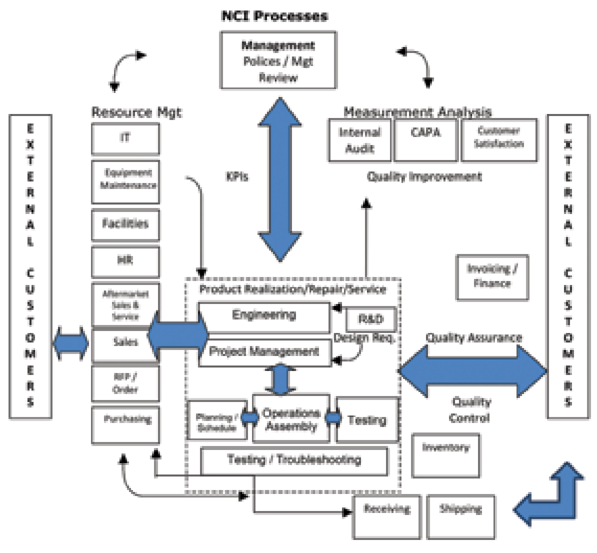

Figure 1. NCI's Management System Processes.

Cryogenic pump testing facility

The NCI cryogenic pump testing facility is utilised to provide performance and mechanical tests for submerged motor cryogenic pumps for engineering purposes for development, engineering tests for production and Factory Acceptance Tests (FAT) for customers. Currently, the facility is designed to test LNG and LPG pumps. These pumps range from high head, low flow units that provide up to 2500 psig (172 barg) outlet pressure at 140 gal./min. (32 m^3/hr) to low head, high flow units that provide 50 psig (3.4 barg) outlet pressure or more, and up to 15 000 gal./min. (3407 m^3/hr).

In general, prior to testing, a pump is installed in one of two test vessels: C-302 or C-304. Once a pump is installed and sealed, the test stand is purged and made inert with warm gaseous nitrogen, and then pre-cooled with cold gaseous from the liquid nitrogen system stored in C-200, C-201, C-202, and C-203. The LNG or LPG used for the pump testing is stored in two ASME storage tanks: C-100 and C-101. Once the test stand is cooled, some of the LNG or LPG stored in these two tanks is pushed with pressure to the test stand in preparation for a test. As this LNG or LPG is pushed to the test stand, it cools down the piping, vessels and equipment at the test stand. Some of the LNG or LPG will flash to vapour during the cooling process. This LNG or LPG will normally be recovered by the vent condenser, E-401, and returned to the recirculation vessel, E-300. In the event of a major process upset or failure of E-401, the LNG or LPG vapour is vented to the flare stack, FL-100. For the case of the LNG process fluid in the facility, FL-100 would not be in service and would serve as a vent stack. LPG that is not recovered will be burned off at the flare.

Maintaining the LNG or LPG temperature during testing is accomplished using E-301, a test loop chiller/exchanger using liquid nitrogen to chill the test fluid, as well as circulation pumps, P-300 and P-301, circulating the liquid through E-301 and back into E-300.

Once the system is filled and cooled down, it is ready for operation. An electric generator is used to provide power to the pump being tested, with power cables connected to the submerged motor through a glass seal type penetration. This is the same set-up as the systems used for the pumps in operation at customer sites. When the system is ready for test loop operation, the generator is placed online, the

Table 1. NCI cryogenic pump test: liquids and hours

	2011	2012	2013	2014	2015 (May)
Total LNG used (gal.)	66 244	592 417	439 000	334 498	81 522
Total LPG used (gal.)	58 833	29 683	0	13 275	31 500
Total length of testing (hr)	379	509	562	527	283

Table 2. NCI's OSHA reportable injury rates (2010 – 2014)

Year	Number of recordable injuries	Average number of employees	Number of total hours worked	Injury rate
2014	0	76	147 043	0
2013	1	62	120 151	1.66
2012	4	46	89 903	8.89
2011	3	36	66 090	9.07
2010	1	27	50 721	3.94

circulation pumps are stopped, and the valves are aligned for test operation. When the test pump is started, the pump draws its suction from C-300. The discharge of the test pump is reduced in pressure by a control valve on the discharge. The reduced pressure stream is ratio controlled between a return to C-300 and a flow through E-301 to control the temperature in the test fluid and remove the heat added from the test pump operation. E-301 is sized to remove all heat added into the system. The temperature control on C-300 will increase or decrease the flow of nitrogen into the chiller in order to remove heat from the liquid flow. The pressure control on C-300 is provided to add nitrogen if the C-300 pressure falls too low, and to vent pressure should the pressure rise too high in the system. Both pressure and temperature controls work independently to keep the system at the desired set points.

Most system reliefs and vents discharge into C-300. It is used as the vent drum as well as the recirculation vessel for the test stand. A small purge gas flow is used to keep the vent header oxygen-free. Once the pump testing is completed, the LNG/LPG liquid is returned to the storage tanks C-100 and C-101. The test loop is then purged with warm nitrogen gas to remove any remaining liquid or vapour and to inert and warm up the system.

The testing is monitored in the data acquisition (DAQ) room. Pump performance is systematically verified based on the model and customer requirements. The data acquisition system monitors more than 250 parameters, and can record testing (if required) for 24 hr/d, 365 days a year. Real-time and buffered data are usually witnessed by the customer or a third party.

Environmental and safety performance

NCI's continued growth has increasingly put pressure on the organisation to track and maintain an injury free workplace, while continually maintaining environmental and safety regulations. Environmental Health and Safety (EHS) management systems are one way of managing the vast array of compliance requirements. The traditional means of tracking EHS compliance can be overwhelming, and as production increases, without the proper controls, incidents could potentially cause injuries to employees.

Over the past five years, NCI has made a concerted effort to reduce injuries by documenting Standard Operating Procedures and Work Instructions (see Table 2). A majority of the programmes have centred on complying with the State of Nevada's Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) and the

Nevada Division of Environmental Protection (NDEP) Chemical Accident Prevention Program (CAPP) regulations. These two programmes are very similar (see Table 3). Other OSHA and environmental training requirements were managed internally by NCI departments that handle training and compliance responsibilities (i.e. facilities engineer, operations, maintenance). The PSM and CAPP programmes ensure that the health, safety and welfare of residents and workers are protected from any potential hazard while using cryogenic liquids. In addition, NCI implemented 33 written programmes to comply with environmental and safety regulations.

Integrating environmental and safety management systems

NCI has been registered to the ISO 9001 Quality Management System (QMS) since 2002, and the overall quality processes are identified in Figure 1.

With the QMS processes outlined, the implementation of both an Environmental Management System (EMS) and Occupational Health and Safety Management System (OHSMS), or ISO 14001 and OHSAS 18001, respectively, could be developed.

Environmental aspects and hazard identification, risk and controls

From the QMS processes, the organisation can identify environmental aspects, as well as hazards, risks and controls. At NCI, a matrix was created based on the process areas, to which legal and other requirements were linked. If a permit was required, it was embedded in the file. For environmental aspects, significant characteristics were ranked and scored with objectives and targets development to prevent pollution and provide improvements. For safety, a similar matrix was developed. The main difference between the two is that for the safety matrix, any risk to injury identified on the list must be controlled. NCI developed Job Hazard Analysis (JHA) for major activities and systematically determined areas within pump assembly and testing where risks to injuries could occur.

Environmental and safety programmes are managed through the environmental aspects list and hazard risk list. Applicable permits, NCI programmes and JHAs are linked within the list for easy reference. This allows an organisation to declare that it is 100% compliant with regulatory requirements, and with ISO objectives to reduce pollution and prevent injuries. These goals can be quantified and reported to management, which is required by ISO within the management review process.

Figure 2. Nikkiso Cryo cyrogenic pump test facility.

Figure 3. Nikkiso Cryo's data acquisition centre.

Conclusion

NCI uses an integrated management system to improve quality, safety and environmental performance in a process and systems approach. This has allowed the company to improve productivity, prevent pollution and increase safety performance. **LNG**

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Table 3. Common elements for both PSM and CAPP

PSM elements	CAPP elements
Employee involvement	Facility and substance information
Process safety information	Process safety information
Process hazard analysis	Process hazard analysis
Operating procedures	Standard operating procedures
Training	Training programme
Contractors	Mechanical integrity
Pre-startup safety review	Management of change
Mechanical integrity	Pre-startup safety review
Hot work permit	Verification of compliance audits
Management of change	Incident investigation
Incident investigation	Employee participation
Emergency planning and response	Contractor programme
Compliance audits	Emergency action plan
Trade secret	Emergency response plan