



**U. S. Chemical Safety and Hazard Investigation Board
RECOMMENDATION STATUS CHANGE
SUMMARY**

Report:	Airgas (Air Liquide) Nitrous Oxide Explosion
Recommendation Number(s):	2016-04-FL-R1
Date Issued:	March 17, 2017
Recipient:	Airgas, Inc.
New Status:	Closed - Exceeds Recommended Action
Date of Status Change:	September 7, 2019

Recommendation Text 2016-04-I-FL-R1:

Complete Post-Incident Actions and Process Safety Initiatives for Nitrous Oxide Operations

The goal of 2016-04-I-FL-R1 is to prevent all nitrous oxide explosions at its facilities, while preventing harm to workers and the public.

Following the August 28, 2016, incident, the company began a comprehensive initiative to review its nitrous oxide production facilities, trucking fleet, and cylinder-filling operations. The scope of the ongoing Air Liquide initiative is shown in Table 1.

Complete the development and implementation of the company's nitrous oxide business process safety initiative as shown in Table 1, consistent with the findings, conclusions, and recommendations contained in this report.

Table 1. Air Liquide Post-Incident Actions

<i>Topic</i>	<i>Current Status</i>
<i>Safety Management System</i>	<ul style="list-style-type: none"> • <i>Committed to applying a process safety management system for the nitrous oxide business;</i> • <i>Applying additional resources to existing facilities and rebuild of Cantonment; and</i> • <i>Will apply the hierarchy of controls throughout including hazard reviews, management of change, and corrective actions.</i>

<i>Topic</i>	<i>Current Status</i>
<i>Inherently Safer Design</i>	<ul style="list-style-type: none"> • <i>Gathering requirements and resources to conduct design review;</i> • <i>Developing plan to train key personnel;</i> • <i>Receiving proposals from inherently safer design safety experts;</i> • <i>Plan includes development of an ongoing inherently safety design component to be used in future hazard reviews; and</i> • <i>Commitment to implement inherently safer design where feasible (practicable).</i>
<i>Hazard Analysis</i>	<ul style="list-style-type: none"> • <i>Complete for Yazoo City and Maitland;</i> • <i>Increasing the basis for a nitrous oxide decomposition explosion consequence to a severity-level in the criticality matrix 4;</i> • <i>Will apply the hierarchy of controls;</i> • <i>Developing safeguard design and availability philosophy; and</i> • <i>Planning to transition to HAZOP and LOPA.¹</i>
<i>Apply Lessons from Previous Incidents</i>	<ul style="list-style-type: none"> • <i>Developing plan to use a corporate communication process; and</i> • <i>Will finalize after company investigation of Cantonment incident is complete.</i>
<i>Apply Industry Safety Standards</i>	<ul style="list-style-type: none"> • <i>Completed gap analysis of CGA G-8.3–2016;</i> • <i>Implementing plan to close gaps at Yazoo City and Maitland;</i> • <i>Developing plan to evaluate ISA-84;</i> • <i>Will incorporate ISA-84 approach in new HAZOP reviews;</i> • <i>Plan developed to train key personnel on safety instrumented systems; and</i> • <i>Adding industry safety standards to an existing program that monitors regulatory updates and changes.</i>
<i>Management of Change</i>	<ul style="list-style-type: none"> • <i>Implemented an MOC program to nitrous oxide plants (complete).</i>

¹ See [HAZOP, Hazard and Operability Study and LOPA, Layer of Protection Analysis](#), [159].

<i>Topic</i>	<i>Current Status</i>
<i>Contamination</i>	<ul style="list-style-type: none"> • <i>Developing engineering standard to address material of construction;</i> • <i>Currently testing contamination effect on nitrous oxide decomposition;</i> • <i>Testing program includes lubricants, refrigerants, metals, and metal oxides;</i> • <i>Plan to incorporate testing results into process safety information; and</i> • <i>Commitment to share summary of results with the Compressed Gas Association.</i>
<i>Process Safety Information (PSI)</i>	<ul style="list-style-type: none"> • <i>Plan developed to apply PSM/RMP program for process safety information to nitrous oxide business.</i>
<i>Technical Staffing</i>	<ul style="list-style-type: none"> • <i>Assigned an interim subject matter expert to provide additional technical support;</i> • <i>Developing plans and assignments for additional technical subject matter experts;</i> • <i>Obtained approval for additional technical staff resource to focus on process safety; and</i> • <i>Developing an audit tool to ensure long-term commitment to sufficient technical staffing.</i>
<i>Hourly Staffing</i>	<ul style="list-style-type: none"> • <i>Short term increases in current staffing levels to two operators per shift and will conduct safety review to determine long-term staffing levels and scheduling of tasks in order to improve safe operations; and</i> • <i>Updating training program for operators and drivers.</i>
<i>Audit Program</i>	<ul style="list-style-type: none"> • <i>Applying Air Liquide audit program; and</i> • <i>Developing a plan to review audit design.</i>
<i>Safety Interlock Testing</i>	<ul style="list-style-type: none"> • <i>Developing a plan to conduct a safety review of interlock testing all interlock testing procedures; and</i> • <i>Developing a plan to require a safety review of interlock testing procedures for new or modified safety interlocks.</i>

<i>Topic</i>	<i>Current Status</i>
<i>Run-Dry Safety Interlock</i>	<ul style="list-style-type: none"> • <i>Completed review of run-dry protection systems;</i> • <i>Conducting full engineering assessment to document technical specifications and finalize engineering solution;</i> • <i>Installing redundant systems with independent instrumentation on all nitrous oxide pumps; and</i> • <i>Improvements at other sites for the ground pumps that at similar to pumps at Cantonment (complete).</i>
<i>Transfer Pumps</i>	<ul style="list-style-type: none"> • <i>Conducting engineering review;</i> • <i>Developing a plan to ensure pump systems meet NPSH guidelines;</i> • <i>Maintaining additional level in some tanks as an interim safety measure;</i> • <i>Developing a plan to have a standard pump and pump design;</i> • <i>Evaluating additional instrumentation through hazard analysis and ISA-84 process; and</i> • <i>Developing a plan for comprehensive electrical grounding and bonding systems.</i>
<i>Flame Arrestors</i>	<ul style="list-style-type: none"> • <i>Conducted literature review;</i> • <i>Developed preliminary prototype designs;</i> • <i>Developing plan for a comprehensive testing program;</i> • <i>Planning to develop engineering standard, specifications, and written preventive maintenance plan;</i> • <i>Planning to add to critical equipment list;</i> • <i>Planning to develop specific audit tool for periodic evaluation; and</i> • <i>Commitment to share summary of testing results and engineering specification with the Compressed Gas Association.</i>

<i>Topic</i>	<i>Current Status</i>
<i>Operations</i>	<ul style="list-style-type: none"> • <i>Reviewing pressure relief valve discharge locations;</i> • <i>Reviewing relief valve design;</i> • <i>Reviewing preventive and predictive maintenance; and</i> • <i>Developing a plan for engineering modifications to reduce employee exposure to nitrous oxide.</i>
<i>Electrical Grounding</i>	<ul style="list-style-type: none"> • <i>Developing a program to ensure electrical continuity for tanks and trailers.</i>

Board Status Change Decision:

A. Rationale for Recommendation

On August 28, 2016, a nitrous oxide trailer truck exploded at the Airgas, Inc. (Airgas) manufacturing facility in Cantonment, Florida. The explosion killed the only Airgas employee present and heavily damaged the facility, permanently halting nitrous oxide manufacturing at Cantonment. The U.S. Chemical Safety and Hazard Investigation Board (CSB) determined that the most probable immediate cause of the incident was, during the initial loading of a trailer truck, a pump heated nitrous oxide above its safe operating limits. Exceeding these critical safety limits appears to have started a nitrous oxide decomposition reaction that propagated from the pump into the trailer truck, causing the explosion.

The CSB investigation found that Airgas lacked a safety management system (SMS) to identify, evaluate, and control nitrous oxide process safety hazards, which led to the explosion. Although not required by Federal regulations, good practice recommends developing and implementing a robust SMS to manage the hazards relating to manufacturing, transferring, and shipping nitrous oxide. Consequently, the CSB issued a recommendation to Airgas to address this gap.

B. Response to the Recommendation

Airgas provided the CSB with sufficient information to document that the work required to fulfill the recommendation has been completed and meets the intent of the CSB’s comprehensive and multi-layered recommendation contained in Table 1. In addition to the overall commitment and aggressive implementation schedule demonstrated by Airgas, in several areas the company has surpassed the objectives envisioned by the Board when it issued this recommendation, as seen in the following areas:

- Safety Management Systems
- Hazard Analysis
- Apply Lessons from Previous Incidents
- Apply Industry Standards

- Technical Staffing
- Audit Program
- Safety Interlock Testing
- Run-Dry Safety Interlock
- Operations

This recommendation as outlined in Table 1 has 17 total components, with each component containing numerous subparts required for completion. Airgas exceeded the CSB's expectations with respect to nine of the components, and met all others. More than mathematical computation, however, a careful assessment of the the amount, nature, and quality of the work undertaken by Airgas, including the company's ongoing commitment to work broadly within the compressed gas industry, suggest an intent to promote safety in a manner above and beyond the requirements of the recommendation.

C. Board Analysis and Decision

The action on the recommendation taken by Airgas meets and surpasses the objectives envisioned by the Board, in a manner that enhances the extent of reduction of future risk. Moreover, the speed with which the company accomplished this comprehensive effort is also noteworthy. As such, the Board voted to change the status of the recommendation to “**Closed-Exceeds Recommended Action.**”