Chemical Sciences Division

Fiscal Year 2014

Environmental Health and Safety

Self-Assessment Report

Safety of Compressed Gases:

Storage, Transport, Use, and Disposal

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Executive Summary

This Compressed Gas Self Assessment evaluated the procurement, delivery, storage, transport, use, and return of empty compressed gases cylinders throughout the LBNL Chemical Sciences Division as part of the divisional assessment and also evaluated how our program integrates with all of LBNL through our involvement in the Institutional Compressed Gas Assessment. As a result, we have made positive changes throughout the division to our compressed gas program. Assessment of division spaces was conducted by first reviewing the applicable LBNL policies regarding compressed gas storage, usage, and training. Next, interviews with selected CSD researchers, EHS, and ALS staff were conducted to identify problem areas for further focus. Lastly, safety inspections were conducted of the compressed gas storage and use areas, and all attempts were made to fix each issue that was identified. Deficiencies with the identification, demarcation, storage and transport of heavy cylinders were identified and rectified. And similarly, problems with improper storage of large and small cylinders were also fixed. The safe transport of large and small cylinders was addressed by obtaining new gas cylinder carts, and the storage racks with angled transitions were retired and replaced with flush-to-grade storage racks. The training program was also evaluated, and upgrades were made to the online training class as well as recommendations to be adopted during OJT. It is important to state that these solutions to the Chemical Sciences compressed gas program need to be maintained. As such, persons have volunteered to maintain each of the identified compressed gas storage areas, and regular laboratory inspections will continue.

Introduction

Environment, Health, and Safety (EHS) Self-Assessment is a process of continuously evaluating safety program effectiveness. The major goal of the EHS self-assessment process is monitoring the effectiveness of Divisional Integrated Safety Management (ISM). The self-assessment process provides feedback which results in improved work processes and safety programs. Each year, the LBNL Chemical Sciences Division (CSD) performs a formal self-assessment of their safety program performance. There were several issues associated with the compressed gas program in the Chemical Sciences Division that were in need of review.

This Compressed Gas Self Assessment evaluated the state of the LBNL CSD compressed gas program. We have made improvements to the way heavy cylinders are delivered, stored and transported. We have rectified shortcomings in the way small size cylinders are used, stored, and transported. Moreover, we have address risks at cylinders storage facilities, and also addressed deficiencies in various aspects of our training program.

In addition to the division portion of this self assessment, the Chemical Sciences Division was instrumental in the completion of an institutional compressed gas assessment. The full report is included in Appendix 3. The purpose of the assessment was to provide assurance that the program adequately manages the hazards associated with compressed gas use and that the program meets LBNL's regulatory obligations.

Assessment Methodology

There are two main parts to this division self assessment. The first part is the division wide assessment of our compressed gas storage, use, transport and training, and the second part is our participation in the institutional compressed gas assessment. Assessment of division spaces was conducted by first reviewing the applicable LBNL policies regarding compressed gas storage, usage, and training (please see Appendix 1 and 2). Next interviews with selected CSD researchers, EHS, and ALS staff were conducted to identify problem areas for further focus. Lastly, safety inspections were conducted of the compressed gas storage and use areas with recommendations given for corrective action. The institutional portion of this self assessment was addressed by CSD participation in the institutional investigation conducted in March of 2014(Appendix 3). This institutional assessment of the compressed gas safety program at LBNL was conducted by an assessment team comprised of three persons independent of LBNL and two LBNL employees. CSD safety coordinators as well as four area safety leads and work leaders were interviewed for the assessment, and in addition, the institutional assessment team toured and inspected CSD compressed gas storage and use locations. The findings of this assessment as well as corrective actions are summarized below.

Assessment Results

The following findings were collected as a result of interviews, and inspection of compressed gas storage and use areas. All attempts were made to fix each issue that was identified, and for the majority of the divisional findings this was accomplished.

Please see the Lawrence Berkeley National Laboratory Compressed Gas Safety Program Assessment Report March 2014, which is included in appendix 3, for the institutional results and recommendations.

Heavy Cylinders

The weight of a 6K cylinder is around 340 Lbs. This is approximately 2.6 times heavier than a typical K cylinder weighting around130 Lbs. There is very little visual difference between the 6K and a K cylinder, (Please see figure 1). Many cylinders have a one inch label that says K or 6K (figure 2), but some only have the PSI 1000 or 6000 stamped in the shoulder of the cylinder. The safety concern is that a researcher may start to maneuver a 6K when believing they were moving a K cylinder, be unprepared for the extra weight, and lose control of the cylinder risking injury.

Figure 1: size comparison of K and 6K cylinders.

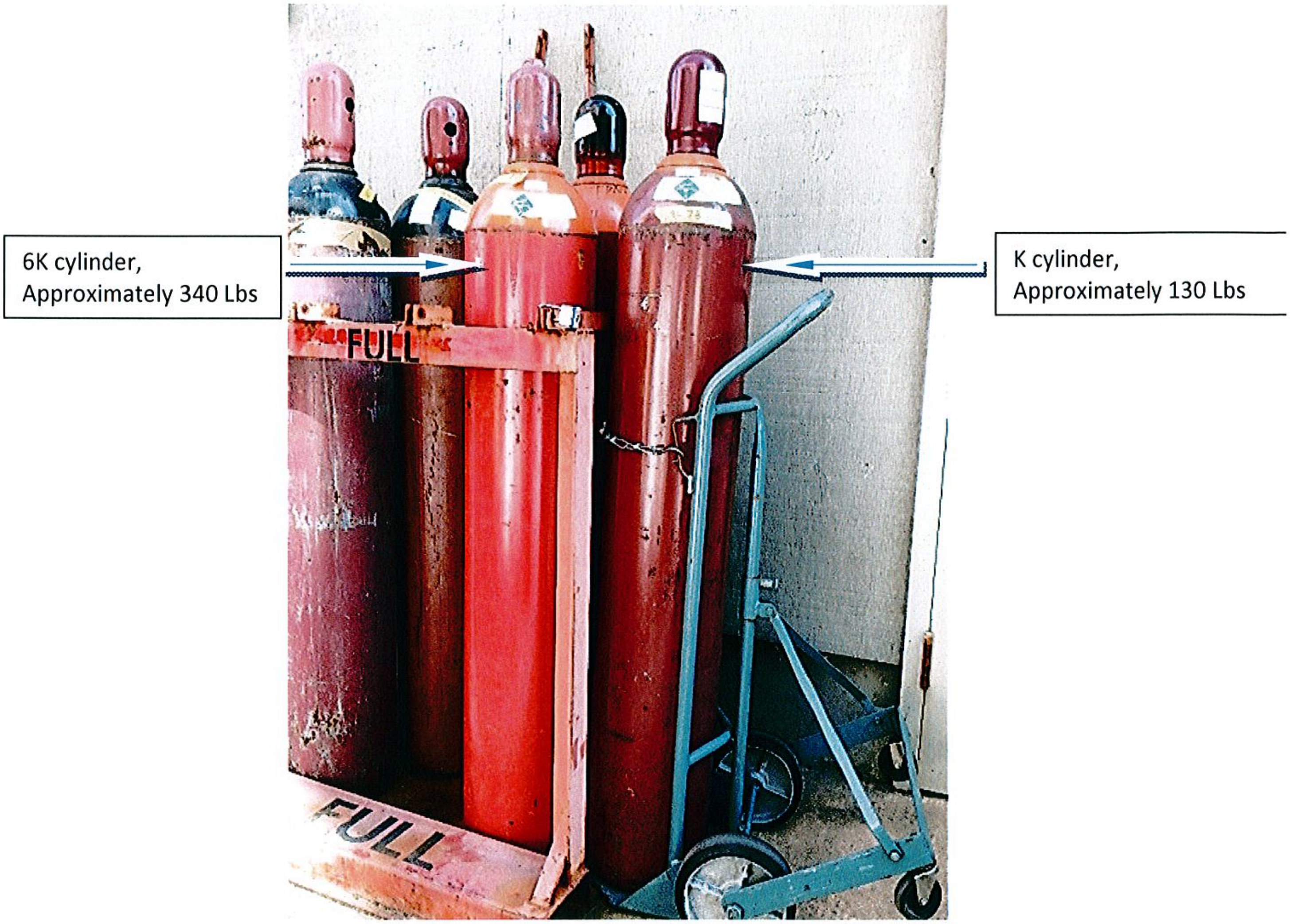


Figure 2: Difficult to distinguish between K and 6K cylinders.

Figure 3: posting for heavy cylinders

Cylinder demarcation and segregation is essential to mitigate the hazard of these heavy cylinders. For LBNL to accomplish the labeling of these cylinders, 6K cylinders needed to be intercepted when they arrive at LBNL. Kurt Ettinger, the compressed gas subject matter expert, worked with procurement personnel on a method of notifying EHS when 6K cylinders arrive anywhere at LBNL. Cylinder demarcation and segregation can then be accomplished. Kurt has designed, printed, and delivered a sign (pictured left) to hang on the neck of these heavy cylinders to all staff that have them, and delivers new signs whenever a new cylinder arrives. As the ALS uses the largest number of these heavy cylinders, Doug Taube has created a segregated area for these heavy cylinders for the ALS gas storage area, and he and the building 7 staff have been diligently recognizing these cylinders when they arrive and putting them into the special, locked gas rack.

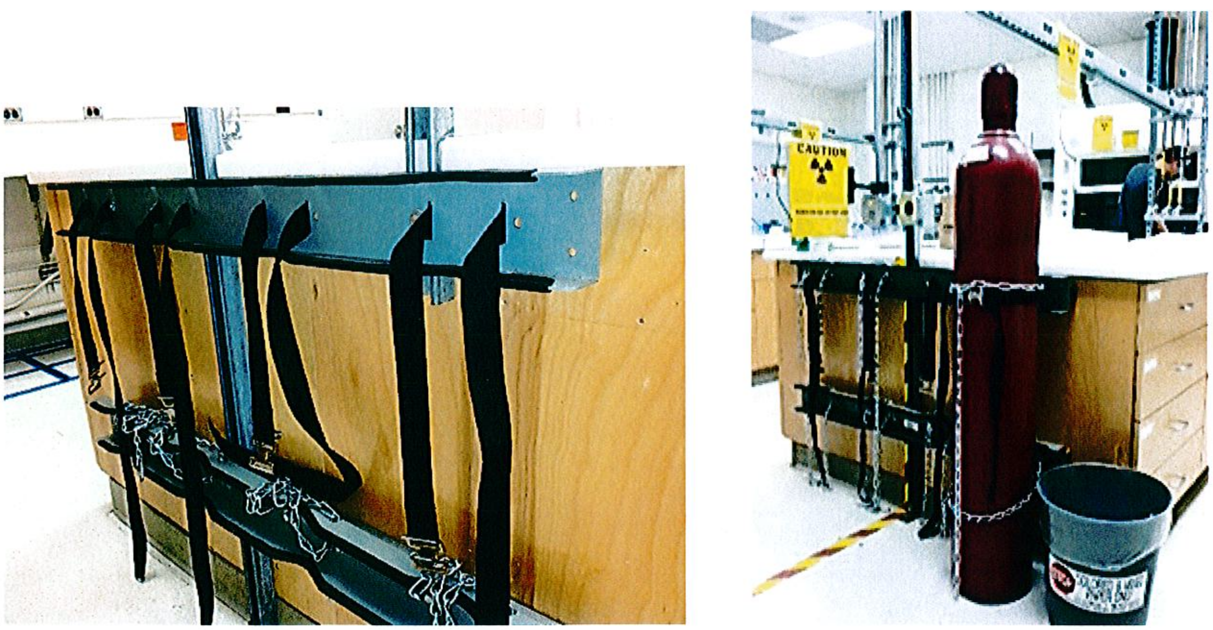
Cylinder Storage

Figure 4: Regulators were removed and protective valve caps were installed.

According to LBNL policy (Appendix 2), compressed gas cylinders should be stored with their regulators removed, with the protective valve caps attached, standing upright, in a location that is out of the rain and direct sunlight, and secured from falling with noncombustible straps or chains. Below are pictures of conditions that were identified and remedied during the course of this Division Self Assessment.

The first example is of several cylinders being stored with their regulators attached (figure 4). These cylinders had their regulators removed and the protective caps were installed. However, in the past, a special variance has been given by EHS for cylinder storage with regulators attached for very expensive gases, as regulator removal loses some gas.

Figure 5: Cylinder storage racks originally installed with nylon straps and one set of chains. We installed second set of chains.



In one of the CSDs new labs being remodeled, the cylinder storage racks were installed with nylon straps and one set of chains (figure 5). We installed second set of chains on the top rung for added support.

The angled transition on the compressed gas cylinder rack shown in figure 6, caused a researcher to lose control of a cylinder that then fell to the ground causing an injury to the researcher. All of this type of cylinder rack were removed from Building 6 and 7 storage area and replaced by the new rack pictured below that is level to the ground.

Figure 6: Changes to compressed gas cylinder storage.

Angled transition can cause tank to fall

New cylinder racks flush to grade.

Figure 7: Cylinder racks at building 58 have a very steep angled transition.

The compressed gas cylinder racks at building 58 have a very steep angled transition (figure 7). A safety concern has been written for this condition and corrective actions are in process. Bids for the repair are being collected from local paving companies and I have every confidence that it will be fixed in due course.

Small Cylinders

Small cylinders can pose their own set of hazards. Because they are small, these cylinders may not fit in the storage racks typically designed for standard large cylinders. These cylinders do not fit in most carts for transport. Therefore many people lift and carry them and thus risking musculoskeletal injury. Additionally, these cylinders may not be properly secured when in use.

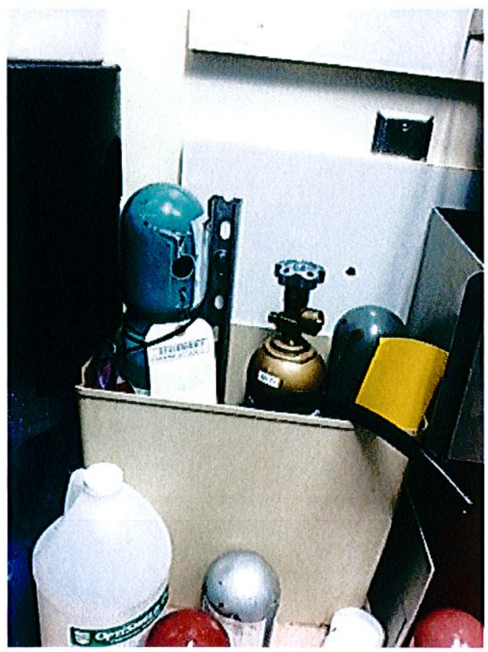
The pictures below (figure 8) show a variety of small cylinder storage solutions that were less than ideal. These were identified through the course of this division self assessment and all have been addressed. I do want to stress here that these pictures were isolated cases and in no way represent a wide spread problem.

Figure 8: Most standard cylinder racks do not accommodate small cylinders.

No support chains on two cylinders.

All cylinders chained to cylinder rack.

Small base trashcan not braced to wall.



Now bolted to wall, will not fall over.

Chain support on cylinder neck, no protective valve cap.

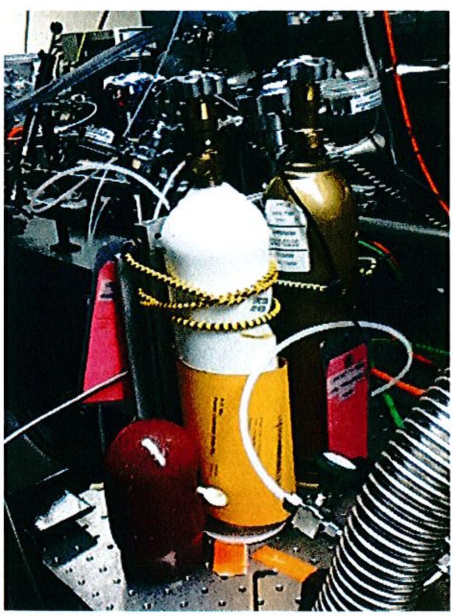
Cylinders shoved into corner and not effectively secured.

Better solutions for small cylinder storage are shown in figure 9. As can be seen here, there are a wide variety of acceptable ways that one may store these small cylinders. The main criterion to keep in mind are the same as for large cylinders; caps should be on if it has a cap (many small cylinders do not), stored upright, keep out of the rain and sun, secured from falling and rolling in an earthquake. As with large cylinders, straps must be made from non-combustible materials such as chains, but cylinders under 3 foot tall only require one support chain and not two (please see policy in Appendix 2).

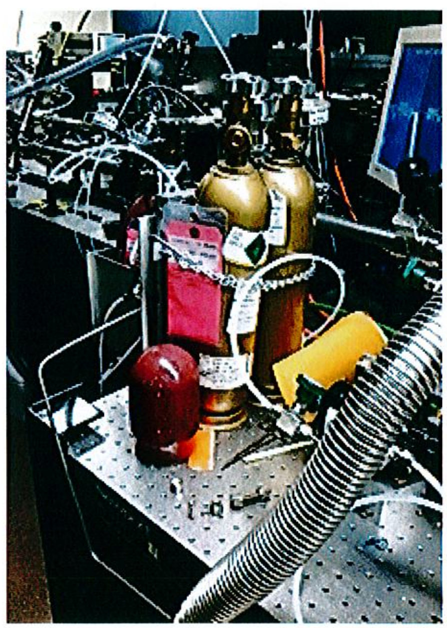
Figure 9: Small gas cylinder storage options.

When cylinders are in use, the same set of basic criterion for securing the cylinder apply. Below are a series of pictures depicting cylinders in use and secured in acceptable ways (figure 10).

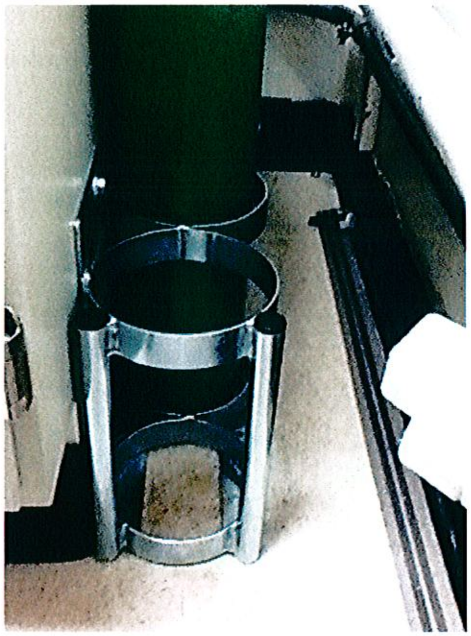
Figure 10: Small gas cylinder securing while in use.



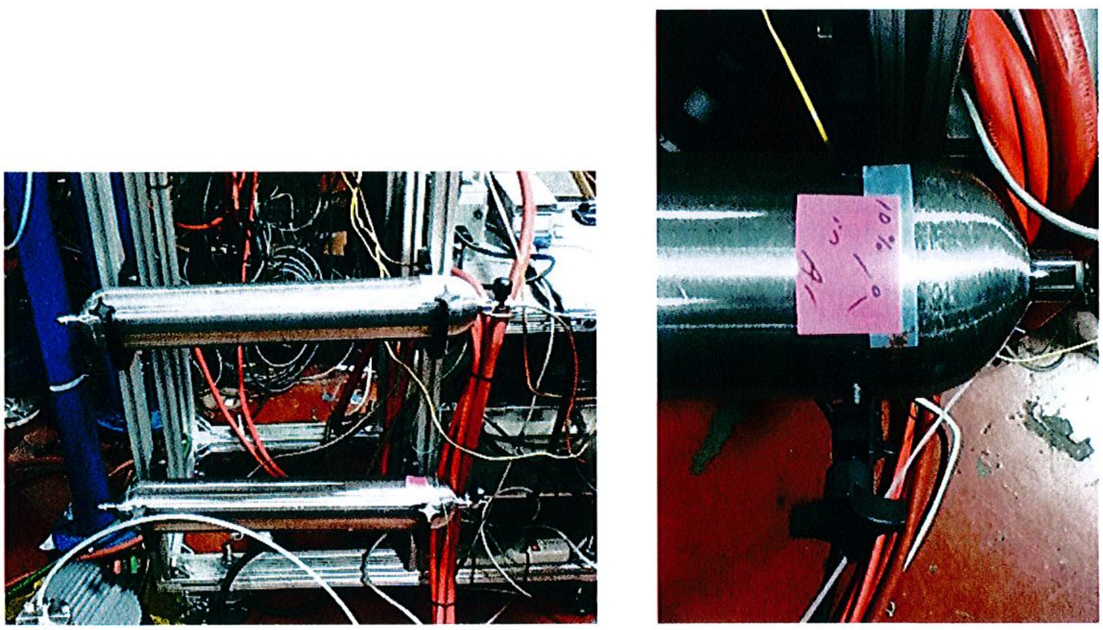
Although secure, do not use combustible straps.



Use chains, metal straps, or metal supports.



Great solution for cylinders that are in tight space and need replaced often.

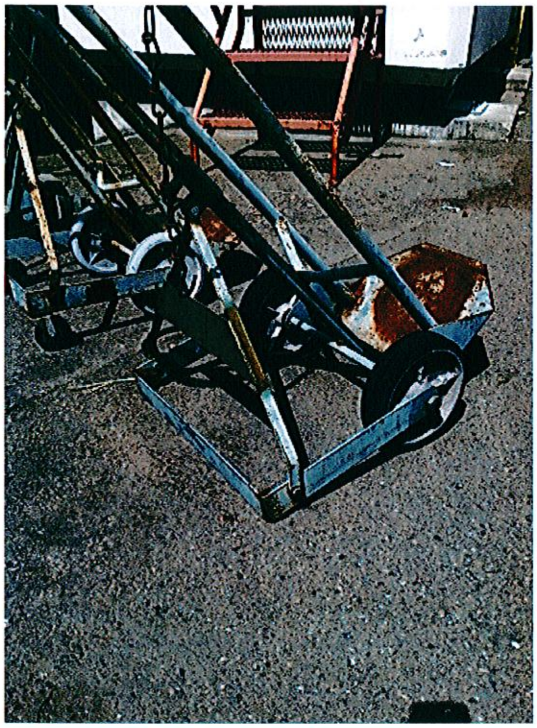


Custom engineered metal mount for cylinders. Cylinders are held at both ends securely.

Cylinder carts

Over the course of this Self Assessment, three problems were identified with the cylinder transport carts used within Chemical Sciences Division areas. First, many of the carts are old and in need of repair (figure 11). The cart pictured is missing its rear casters. This is an obvious problem, but the remainder of the cart and the carts adjacent to this cart show signs of long term wear. These old carts, even if they appear to still be in working order, do not look as if they are sturdy enough to handle the extra weight of a heavy 6K cylinder. Second, more than one type of cart, including the most common type of cart at LBNL has a fatal flaw that if not properly secured, the cart will fold and the cart and cylinder will fall to the ground (see related picture sequence in figure 12). As these carts age, it is an ever increasing possibility that one will be damaged, not noticed by a user, and fold while in use. Moreover, these carts are designed to fold up for storage when not in use, but most of the time these carts are stored unfolded and locked in place. Many of the users of these carts do not realize that the carts can fold, and do not check that the locking mechanism is securely in place before they use the cart. If a cart were to collapse, the cylinder would fall in the direction of the researcher.

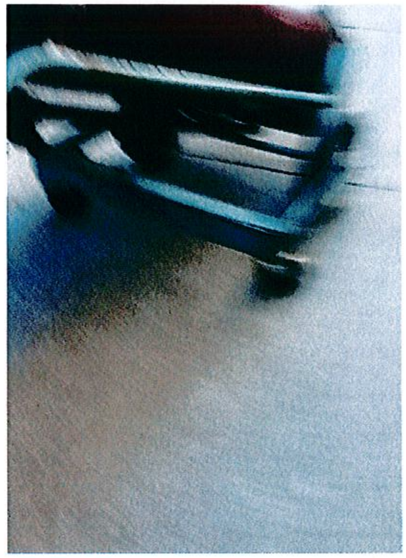
Figure 11: Old style gas cylinder carts in need of repair.



Rear casters are missing

Figure 12: folding carts can potentially fold while in use.

Latch that keeps the cart from folding.



With the latch disengaged, the cart folds.

And the cylinder and cart come crashing to the ground.

Lastly, most carts present at LBNL are not designed for small cylinders (figure 13). There is no support behind the cylinder when the cylinder is inclined for transport, and the chains are only at the top of the cart and therefore the cylinder is completely unsecured. It is for this reason that many researchers lift these cylinders and carry them from place to place. If this is done, the researchers are at greater risk to musculoskeletal injury, dropping the cylinder on their lower extremities, and also breaking off the valve of the cylinder. Remember that many small cylinders do not come with the ability to affix a valve cap. For this and other reasons the Chemical Sciences Division has purchased seven new compressed gas cylinder carts, (figure 13, left hand cart), and retired all of the broken or damaged cylinder carts in our division areas. These new carts are of heavy construction so they can easily handle the heavy 6K cylinders, do not fold, have back support for smaller cylinders, and have chains top and bottom for securing large and small cylinders.

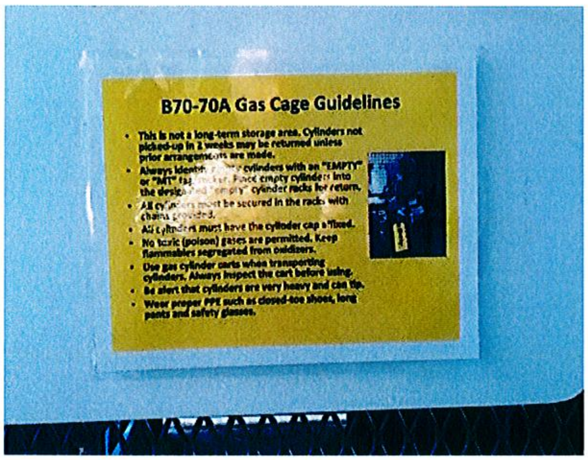
Figure 13: New fully welded gas cart versus old style folding cart.

New cylinder cart on left, and old style folding cart on right.

Gas Storage Area Management

Most compressed gas storage areas do not have a clearly designated person or group that is responsible for the management of the area. These storage areas are associated with a building or even multiple buildings but are not part of the building, and therefore the task of managing these areas does not conveniently fall within the duties of Facilities personnel. Moreover, there are multiple division stakeholders within each building therefore the task of managing these areas does not conveniently fall within the duties of any one division. The result has been that these areas can be neglected. The neglect of these areas manifest itself in the form of debris building up in the corners, mistakenly ordered gas cylinders not being returned to the manufacturers, empty cylinders not being returned, collections of disposable cylinders not being dismantled for recycling, inventory not entered into the Chemical Management System, and even very old cylinders that are past their hydrostatic test date. We have identified buildings 70-70A, 2, and 6-7 storage areas as not being properly managed, and have addressed these areas (figure 14). Building 70-70A gas storage area was cleaned up by Ron Scholtz, EETD Safety Manager, and is now being managed by Susan Synarski, B70 Building Manager. Building 2 compressed gas storage area was cleaned up by Doug Taube, ALS Chemical Safety Specialist, and Martin Neitzel, CSD Safety Coordinator and is now being managed by Martin Neitzel. The building 6-7 storage area was cleaned up by Doug Taube, and is now being managed by Derrick Crofoot, ALS Materials Specialist, and Doug Taube. The neglect of these areas has been addressed and continued maintenance of these areas is progressing well.

Figure 14: Clean gas storage areas with posted rules and instructions.



New guidelines for users posted.

Instructions for cryogen station posted.

Storage areas are now in good shape.

The following is a document prepared by Ron Scholtz, EETD Safety Manager, which is now being widely used for the return of compressed gas cylinders.

Empty Gas Cylinder Return Procedures

The following summarizes the different requirements for returning empty and unwanted compressed gas cylinders. Compressed gas cylinders should always be handled as if they were "full" and must be transported in compliance with applicable Department of Transportation (DOT) hazardous materials requirements. This includes proper labels and cylinder caps. Always clearly identify "empty" cylinders with an affixed "EMPTY", "MT" or "RETURN" tag.

Vendor	Contact	Procedure
Aeris	See contact information for Matheson Gas	See procedure for Matheson Gas
Air Liquide	Shelley Taniguchi Shelley-taniguchi@airliquide.com (800) 323-2212	Air Liquide does not make regular deliveries or pick-ups from LBNL. Call Customer Service to make special arrangements. Identify the number of cylinders, types of gases, and cylinder ID number engraved on the cylinder collar.
Air Products	See contact information for Airgas	See procedure for Airgas
Airco	See contact information for Airgas	See procedure for Airgas
Airgas	Log into E-Buy and click on the "Progressive (Airgas)" merchant link: https://ebuy.lbl.gov Customer Service (800) 336-4004 Neil O'Donnell Progressive Industries	Airgas makes infrequent deliveries and pick-ups from LBNL. Gas cylinder returns need to be requested through the Progressive (Airgas) E-Buy website. Once on the Progressive E-Buy page, there is a "return request" button on the right side. If needed, call Customer Service if the request is not being processed.

	nodennell@progressivepii.com (773) 763-9565	
LBNL- Owned	LBNL Procurement Laura Sanders lsanders@lbl.gov (510) 486-4592	Cylinders are identified with a "LBNL" stencil on the cylinder body. They normally have Airgas labels affixed. Procurement will make arrangements for pick-up and scrapping.
Linde	Theresa Birk Theresa.birk@linde.com (908) 329-9779	Complete and submit a Linde return form. Linde does not pick-up empties directly. They will send Yellow Freight to pick-up. Yellow Freight only knows to go to the B69 shipping dock, so call LBNL Transportation (X4388) and arrange to have the cylinders moved there first.
Matheson	Montgomeryville, PN Customer Service Info@mathesongas.com (877) 844-7192 Edward Coughlin- Customer Service Manager	Matheson does not make regular deliveries or pick-ups to LBNL. Identify the number of cylinders, types of gases, and cylinder ID number engraved on the cylinder collar. There is a $60 minimum charge for cylinder pick-up with additional charges depending on the number of cylinders.
Praxair	Mercedes Pacheco Customer Service Mercedes_Pacheco@praxair.com Office: (800) 660-2066 Steve Scagliotti Steve_scagliotti@praxair.com (925) 431-2297	Praxair makes regular deliveries and pick-ups of gas cylinders at LBNL. Place any "empty" cylinders in the designated empty cylinder rack and they should be picked up automatically within a few days. If cylinders are not getting picked-up as needed, let Customer Service know.
Scott Specialty Gas	See contact information for Air	See procedure for Air Liquide

	Liquide	
Scott-Marrin	Lori Thomas- Sales lori@scottmarrin.com (951) 653-6780	Scott-Marrin does not pick-up empties from LBNL. They need to be shipped directly back through LBNL Transportation (X4388). Transportation will pick-up the cylinders with account number and MSDS. Also see the Scott-Marrin cylinder return guidelines.
Spectra Gas	See contact information for Linde	See procedure for Linde

Lecture Bottle (LB) Size Cylinders

Gas cylinder suppliers no longer take back lecture bottle (LB) sized gas cylinders. These are now considered as "single use" containers and the contents must be disposed as hazardous waste through the LBNL Waste Management Group. Submit a completed Hazardous Waste Disposal Requisition. Pick-up and disposal is available about every 6 months.

Cylinders with Unknown Contents

Contact the LBNL Waste Management Group for assistance. The cylinder contents will need to be sampled and analyzed before disposal requirements can be determined.

Cylinders with Out of Business Vendors

Contact the LBNL Waste Management Group for assistance. The cylinder will need to be properly disposed.

Cylinders with Missing Caps or Labels

Contact the vendor directly and notify them that you need a cap or label for one of their cylinders when picking up. There may be a charge for replacement depending on the vendor, but many vendors have these items on their trucks and are willing to help.

Training

Through interviews held with members of the Chemical Sciences Division it was determined that most on-the-job (OJT) training does not consider the handling of 6K cylinders or small cylinders, and that neither did the compressed gas training program, EHS0171.

We recommend OJT include a discussion of 6K cylinders which should at a minimum address the recognition of heavy cylinders, and the technique for safely manipulating and transporting them. We should stress that effective OJT should incorporate a demonstration from a qualified and experienced gas cylinder handler and satisfactory demonstration of safe gas cylinder handling from the trainee.

When we started this Division Self Assessment, the LBNL Pressure and Compressed Gas Safety Training (EHS0171) did not consider the handling of 6K cylinders, or transporting gas cylinders. This has been rectified. The EHS division has created a short video to give information about compressed gas cylinders. This video demonstrates and gives suggestions on how to safely move gas cylinders. This video also stresses that it is not a substitute for proper on the job training (OJT), and that proper OJT from a qualified and experienced gas cylinder handler must also be obtained. The training video is at the URL, http://www.lbl.gov/ehs/training/webcourses/EHS0171/, and also included in the link below.

However, LBNL Pressure and Compressed Gas Safety Training (EHS0171) does not currently address the hazards or storage concerns of small compressed gas cylinders. To address these concerns in the Chemical Sciences Division, we strongly recommend that this topic be included in future OJT. In addition, we recommend that EHS171 be updated to include safe handling of small cylinders.

Institutional Compressed Gas Assessment

Three persons independent of LBNL, (Mike McDaniel SLAC Compressed Gases Primary Program Manager, and Bob McCallum and Kyle Turner from McCallum Turner) partnered with two LBNL employees (Andrew Peterson, EHS Assurance Manager, and Bill Wells, Safety Compliance Program Manager) to assess the compressed gas safety program at LBNL. The Chemical Sciences Division was instrumental in the completion of this institutional compressed gas assessment. The safety coordinators as well as four area safety leads and work leaders were interviewed for the assessment. In addition, the institutional assessment team toured and inspected CSD compressed gas storage and use locations. The purpose of the assessment was to provide assurance that the program adequately manages the hazards associated with compressed gas use and that the program meets LBNL's regulatory obligations.

The assessment team found that the users and support staff are engaged and proactive in managing compressed gases. Lab resources supporting the program received positive feedback, and compressed gas use at the Lab is well managed for the most part. The risk of an injury or accident seems low, the assessment found. The team however did observe two notable deficiencies, three noteworthy practices and 24 opportunities for improvement. The full report is included in Appendix 3.

The two notable deficiencies that hinder the full success of the gas safety program are communication and efficiency.

- Communication: This was noted due to the following;
    - unclear or undefined ownership, roles and responsibilities and work processes, such as with the undefined ownership of the compressed gas storage areas.
    - inadequate communication between "overlapping" process owners in storage areas.
    - poor communication from gas vendors following deliveries.
    - and seemingly inaccurate or outdated information in Chapter 13 and EHS-0171.
- Efficiency: Due to process for return of "old" compressed gas cylinders to former vendors which is inefficient and contributes to incident risk.

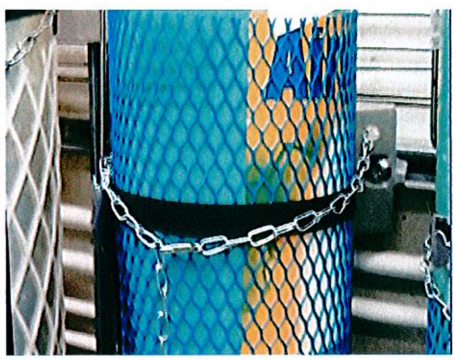
Conclusion

Environment, Health, and Safety Self-Assessment is a process of continuously evaluating safety program effectiveness. This Compressed Gas Self Assessment evaluated the procurement, delivery, storage, transport, use, and return of empty compressed gases cylinders throughout the Chemical Sciences Division as part of the divisional assessment and also evaluated how our program integrates with all of LBNL through the institutional assessment. Deficiencies with the identification, demarcation, storage and transport of heavy cylinders were identified and rectified. And similarly, problems with improper storage and transport of large and small cylinders were also fixed. The safe transport of large and small cylinders was addressed by obtaining new gas

Appendix 1:

From LBNL EHS0171 Pressure and Compressed Gas Safety Training.

Common cylinder restraints found at LBNL are shown below. Open racks (shown on the left) with double chains top and bottom are common. An issue with this type of storage is that when the racks get full, often the lower chain is lost against the wall and cannot be accessed because the cylinders are too close. A preferable method is to hook the chains on rails below the top rail so that they don't fall against the wall. Top and bottom chains are required to prevent the cylinder moving during an earthquake



The center photograph shows a cylinder restraint that uses both a web sling and a chain. As long as the sling is pulled up tight so the cylinder cannot move, a single restraint at mid-cylinder height is adequate. If the web sling is not used then top and bottom restraints are required.

On the right is a cylinder restraint system designed at LBNL. It uses a metal channel with a finger-joint front panel. A single holder about mid-cylinder height works well, these have been designed so that the cylinder will not kick out of the restraint. This type restraint is designed for a full-size cylinder and does not work well with shorter or smaller diameter cylinders.

Cylinder restraints must be non-combustible in order to not fail in a fire situation. Chain, bars, or sheet metal are good restraint material. Fabric webbing, rope, plastic cable ties, and any other material that will be damaged in a fire are not acceptable unless they also have a non-combustible backup as shown in the center photograph.

Cylinder restraints that clamp to a table or work surface are not acceptable. All cylinder restraint devices must be secured to a sturdy, structural element. All attachment to building walls must be installed by LBNL Facilities Division.

cylinder carts, and the storage racks with angled transitions were retired and replaced with flush-to-grade storage racks. The training program was also evaluated and upgrades were made to the online training class as well as recommendations to be adopted during OJT. It is important to state that these solutions to the Chemical Sciences compressed gas program need to be maintained. As such, persons have volunteered to maintain each of the identified compressed gas storage areas, and regular laboratory inspectional will continue.

Appendix 2: From Pub 3000

- **Training**

a) Personnel who operate or work on compressed gas and pressure systems must complete the Berkeley Lab *Pressure Safety* training course(EHS0171). Additional requirements apply to personnel who design or assemble pressure systems. (See *Pressure Safety and Cryogenics*.)

b) Personnel who handle or use hazardous gases must complete the *Chemical Hygiene and Safety Course* (EHS0348). They must also receive specific training on the hazard and safety procedures for each hazardous gas-use operation, including a review of any AHD. This training is the responsibility of the supervisor.

- **Gas Cylinder Storage and Use Locations**

a) **Exits and Lighting.** Storage and use of gas cylinders in exit corridors are prohibited. Hazardous gases must be located away from exit routes and doors, unless located in gas cabinets. Adequate natural or artificial lighting must be provided.

b) **Area Signs.** Entrances to all areas where hazardous gases are used or stored must be posted with visible and durable gas-hazard-identification signs. Hazardous-gas exterior storage and use areas must have signs that prohibit smoking within 8 m (25 ft).

c) **Exterior Locations.** Exterior storage and use areas must be covered with a noncombustible canopy. These areas must be protected from vehicle damage. Cylinders must not be placed on unpaved ground or on surfaces where water can accumulate.

d) **Combustible Materials Separation.** Cylinder storage and use locations must be kept clear of all weeds, grass, brush, and trash, as well as any other combustible materials, for a minimum distance of 5 m (15 ft) from all cylinders. Exception: An approved noncombustible barrier, cabinet, or hood may be used instead. (See the *Hazardous Materials Separation* section, below).

e) **Hazardous Materials Separation.** Hazardous gases must be separated from incompatible hazardous materials by distance, barriers, cabinets, or lab hoods, as noted in Table 13.1, below. See Appendix B for hazard categories of specific health hazard gases. When a gas is classified in more than one category, all compatibilities must be considered and the most stringent separation used. Nonhazardous gases (e.g., inerts) may be stored in any hazard category. When gas cylinders must be separated into hazard categories, each category area will be posted with a hazard-category sign.

f)

Table 13.1 Gas Cylinder Separation by Hazard

Gas Hazard Category	Nonflammable	Corrosive	Oxidizing	Flammable	Pyrophoric
Toxic	—a	—	6 m (20 ft)b	6 m (20 ft)b	6 m (20 ft)b
Pyrophoric	—	—	6 m (20 ft)b	6 m (20 ft)b	
Flammable	—	—	6 m (20 ft)b		
Oxidizing	—	—			
Corrosive	—				

Footnotes:
a A dash (—) indicates that cylinders with these hazard ratings may be stored adjacent to each other.
b Exception 1: Containers of hazardous solids or liquids with a capacity less than 2.3 kg (5 lb) or 1.9 L (0.5 gal) when stored in quantities not exceeding exempt amounts specified in Article 80 of the UFC.
Exception 2: Distances can be reduced without limit when hazardous materials are: (1) separated by a one-half-hour-rated noncombustible barrier (e.g., 2.5 mm or 12 gauge steel) that extends not less than 50 cm (18 in) above and to the sides of the gas cylinder; or (2) stored in separate approved hazardous materials storage cabinets, gas cabinets, or lab hoods.

f) **Safety Shower and Eyewash.** An approved safety shower and eyewash must be maintained within 30 m (100 ft) or 10 seconds (whichever is less) of locations where corrosive, eye-irritating, or skin/eye-toxic gases are stored or used.

- **Gas Cylinders**

a) **Cylinder Transportation**

1. Use only standard DOT cylinders for transporting compressed gas.
2. Personnel trained to use compressed gases may use standard cylinder carts to transport cylinders within buildings and between adjoining buildings. Carts are preferred, but cylinders weighing 11 kg (25 lb) or less may be hand-carried. Valve-protection caps and plugs must be in place during movement of cylinders. Lecture bottles and other cylinders without protective caps must be transported in standard shipping crates or an equivalent container.

Go here to watch the Safe Handling of Gas Cylinders video for more detailed information.

(Please note that Adobe Flash Player is required to watch this video. Google Chrome includes Adobe Flash Player built-in. Other browsers [e.g., Firefox, Safari, Internet Explorer] will need Flash to be installed.

3. Gas cylinders must be transported between non-adjoining buildings by a person properly trained, licensed, and equipped to transport gas cylinders. Proper transportation is provided by Berkeley Lab Facilities Transportation or by approved Berkeley Lab gas supply subcontractors.

b) **Cylinder Position.** Gas cylinders must be stored in a "valve end up" upright position, including conditions where the cylinder is inclined as much as 45 degrees from the vertical. Exceptions include cylinders designed for use in a horizontal position and cylinders with nonliquefied compressed gas that have a water volume less than 5 L (0.18 cf or 1.3 gal).

c) **Cylinder Securing.** Gas cylinders must be secured to prevent falling due to accidental contact, vibration, or earthquake. Cylinders must be secured in one of the following ways:

1. By a noncombustible, two-point restraint system (e.g., chains) that secures the cylinder at the top and bottom one-third portions. Exception: Cylinders less than 1 m (3 ft) tall require only one restraining point.
2. By a noncombustible rack, framework, cabinet, approved strapping device, secured cylinder cart, or other assembly that prevents the cylinder from falling.

d) **Cylinder Valves, Caps, and Plugs**

1. Gas cylinders designed to have valve-protection caps and valve-outlet caps and plugs must have these devices in place. Exception: when the cylinder is in use, connected for use, or being serviced.
2. Gas cylinder valves must have a handwheel, spindle key, or other approved control handle on the valve stem while the cylinder is in use. Cylinder valves should be opened slowly. Cylinder valves seat in both the closed and open position and are likely to leak unless left in the fully open or fully closed position.

e) **Unauthorized Cylinder Modification or Use.** All labels, markings, and tags provided on the gas cylinder by the manufacturer must be maintained in good condition. Gas cylinder parts must not be modified, tampered with, obstructed, removed, repaired, or painted by the gas user.

f) **Empty Cylinders.** Gas cylinders should be left with residual pressure (i.e., typically 200 kPa or 30 psi) to prevent contamination of cylinder contents. Cylinders considered to be empty should be handled with the same precautions as cylinders filled with gas because so-called "empty" cylinders still contain residual gas and pressure. Empty gas cylinders must be labeled "Empty."

g) **Cylinder Changing.** Two people must be present during hazardous-gas purge and cylinder-change procedures. Reconnected gas fittings must be checked for leaks using a leak-detection fluid or other approved method.

h) **Cylinder Temperature Control.** Gas cylinders should be stored in the shade and must not be exposed to temperatures exceeding 50°C (125°F).

Appendix 3:

Lawrence Berkeley National Laboratory Compressed Gas Safety Program Assessment Report March 2014

Lawrence Berkeley National Laboratory
Compressed Gas Safety Program
Assessment Report
March 2014

Andrew Peterson	Date
Bill Wells	Date
Mike McDaniel	Date
Kyle Turner	Date
Bob McCallum	Date

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Lawrence Berkeley National Lab
Compressed Gas Safety Program Assessment
March 2014

Introduction

On March 3-5, 2014, the gas safety program was assessed by an independent team to ensure the program is adequately addressing risks associated with compressed gas use, meets compliance requirements and meets the needs of gas users at LBNL. This assessment is occurring in collaboration with seven Divisions who are assessing compressed gas safety as one of their Division Self-Assessments.

This assessment primarily focused on LBNL's institutional gas safety program as documented in PUB-3000, Chapter 13, Gas Safety, but it was expanded to assess the "life-cycle" from cradle to grave of compressed gases at the Lab. As part of this assessment, the assessment team identified and prioritized a list of opportunities for improvement to improve gas safety at LBNL.

Executive Summary

Three persons independent of LBNL (Mike McDaniel, SLAC, Bob McCallum, McCallum Turner and Kyle Turner, McCallum Turner) partnered with two LBNL employees (Andrew Peterson and Bill Wells) to assess the compressed gas safety program at LBNL. This assessment relied heavily on staff interviews and included lab and site walkthroughs and document reviews. The purpose of the assessment was to provide assurance that the program adequately manages the hazards associated with compressed gas use (controls) and that the program meets LBNL's regulatory obligations (compliance). The assessment team incorporated lines of inquiry into the assessment to assess other important performance measures (communication, efficiency, culture, trends and feedback/improvements).

In general, users and support staff are engaged and proactive in managing compressed gases. Lab resources supporting the program received positive feedback, and compressed gas use at the Lab is well managed for the most part. The risk of an injury or accident seems low. The team however did observe notable deficiencies that hinder the full success of the gas safety program and have identified several opportunities for improvement.

In total, there were two findings, 13 observations, three noteworthy practices and 24 opportunities for improvement.

Compressed Gas Life-Cycle at LBNL

Ownership of processes governing the procurement, installation, use and disposal of compressed gases at LBNL is de-centralized. Different stakeholders own different parts of this process. The compressed gas subject matter expert (CG SME) owns the compressed gas safety program itself. Other stakeholders own distinct functions within the program, such as Procurement (gas purchasing, restricted items), Facilities Transportation (cylinder transport), Regulator Shop (regulator selection and testing), Facilities trade workers (system installation), Salvage (metal recycling) and Waste Management (hazardous materials disposal). Other stakeholders such as the ventilation SME, the pressure safety SME, the Chemical Management System SME, the Roof Access SME, and Protective Services own separate programs or processes that overlap or interface with the compressed gas safety program. Finally, there are the gas vendors, the gas users and Division support staff. Each of these groups plays some role in the life-cycle of compressed gas at the Lab.

Staff who need to use compressed gases ("users") reported the overall program was working well, and they are able to procure, install and use the gases they need to perform work. Division staff supporting these activities who need to interface with the different process owners expressed more safety concerns and reported more challenges managing compressed gases, particularly, the disposal and returns of cylinders. The CG SME however received widespread praise from users and support staff during the assessment for his responsiveness and support.

Observations

- In some cases ownership, roles and responsibilities for stakeholders in the overall process have not been well defined or well communicated; process stakeholders are not necessarily communicating or cognizant of one another or their respective roles; and defined processes or procedures do not exist for each step of the life-cycle of compressed gases at the Lab. This has led to confusion about who owns or is responsible for what part of the program and whom to turn to for assistance.

Opportunities for Improvement/Recommendations

- Map the current "as is" state of the program and define ownership, roles and responsibilities for each discrete function within the program and for each program interface where other program overlap with gas safety. Include process stakeholders in this effort.
- Incorporate ownership, roles and responsibilities (including responsibilities for assurance for all life-cycle stages) in PUB-3000, Chapter 13, Gas Safety. Consider reorganizing Chapter 13 around the life-cycle of compressed gases at LBNL.
- Centralize information about compressed gases. Consider a single online location where users and support staff can find relevant information on how to procure, receive, install, use, store, transport, return and dispose of compressed gases.

Gas Safety Program

PUB-3000, Chapter 13, Gas Safety documents LBNL's gas safety program. The program is primarily limited to requirements for storage and use of compressed gases. It contains general requirements for all compressed gases and specific requirements for pyrophoric gases, flammable gases and health hazard gases.

Observations

- Chapter 13 contains requirements that do not match current work practices. For example,

  - Work Process D4 lists specific requirements for Facilities Transportation for receipt and delivery of health hazard gases. According to Facilities Transportation, the process for compressed gas delivery changed about 10 years ago, and compressed gases are no longer routinely handled by Receiving staff.
  - Under Roles and Responsibilities, the Facilities Department Technical Services is required to screen gas purchase requests and ensure that requests requiring pre-purchase approval are approved by EHS Field Support. Facilities has not performed this role for years.
  - Work Process A4(c) requires exterior storage and use areas to be covered. Most exterior storage locations did not have covers, and this programmatic requirement is not a regulatory or consensus standard requirement.
  - Work Process A5(a)iii restricts vehicle transport to Facilities Transportation or Lab vendors while staff are actually allowed to transport cylinders under the Department of Transportation's Materials of Trade exception.
- Chapter 13 does not document the "visual inspection" process required in OSHA 1910.101(a), and it is not clear how LBNL satisfies this requirement. Furthermore, Compressed Gas Association (CGA) Pamphlet C-6 and C-8 (incorporated by reference by OSHA), which detail acceptable visual inspection processes for compressed gas cylinders are not readily available.
- Several gases listed in Chapter 13, Appendix B, including sulfur dioxide, hydrogen bromide and methyl chloride are listed as NFPA Health Hazard 2, but the Chemical Management System (CMS) lists these as NFPA Health Hazard 3 substances. This may be significant as Activity Hazard Documents (AHDs) are triggered by NFPA Health Hazard 3 gases.

Opportunities for Improvement/Recommendations

- Identify a small team of stakeholders to review Chapter 13 against current regulatory requirements and practices and bring the chapter up-to-date. Evaluate Chapter 13 requirements that exceed regulatory requirements, and remove those that are unnecessary for a safe working environment. Ensure the program addresses regulatory requirements.
- Work with SMEs owning programs that overlap/interface with the compressed gas program to ensure roles, responsibilities, requirements and expectations at program interfaces are accurately reflected in the individual programs.

Gas Procurement

Most gases are ordered through LBNL's eBuy system. This well-known process used by gas users and Division support staff has worked well. It is the first opportunity to ensure proper work planning and control. LBNL uses UNSPSC (United Nations Standard Products and Service Codes) to "tag" health hazard and reactive gases in the eBuy system. Orders of these gases require approval from the CG SME before the purchase is processed. Procurement is also an opportunity to address potential fire code limits prior to arrival onsite. This is performed to some extent by the CG SME who is a reviewer on purchases of all flammable gases.

Division Safety Coordinators and support staff are not approvers or reviewers within the eBuy system. Several individuals interviewed stated that they occasionally first learn of a new health hazard or reactive gas when they discover it inside a lab. The reviewer function in eBuy could be used for this purpose; however, Procurement personnel interviewed indicate that the e-Buy software is difficult to modify to include additional reviewers (and approvers).

Observations

- When division safety coordinators and users are unaware of expected and/or actual deliveries of compressed gas, efficient management of local storage area and associated fire code storage limits is compromised. Prior knowledge of orders would allow support staff to ensure adequate work planning has occurred and appropriate controls are in place.

Opportunities for Improvement/Recommendations

- Query Division Safety Coordinators and key support staff and determine if prior notification of gas purchases is desirable. If desirable, determine if the personnel included on the ordering process for gas cylinders can be expanded to include Division Safety Coordinators or support staff or explore other opportunities to include those individuals in a notification process when these gases are ordered.

Gas Delivery/Receipt

Compressed gas is usually provided by either Praxair or Airgas. These vendors deliver the requested cylinders to designated storages areas around the Lab and to offsite facilities typically at the building location of the requesting users. Special delivery instructions cannot be added within the eBuy system, and it is expected that Lab personnel coordinate deliveries with the vendors whereas the vendors are expected to inform designated Lab personnel of their arrivals. Users indicated however, that they are not usually notified when cylinders are delivered.

Both the Praxair and Airgas contracts have provisions for expedited delivery within 24 hours of order for an increased fee, which is used by some locations to minimize the inventory of gases they store onsite. Several personnel interviewed are using this provision. Others interviewed were unaware of this contract option.

Occasionally, some Lab personnel order specialty gases that are not available through either Praxair or Airgas. Purchasing and delivery arrangements for specialty gases (e.g., gases used in semiconductor manufacturing, refrigerants) are made directly by researchers or supervisors with the vendors. In such cases, the vendor organization may use a third party transporter, which can include conveyance via an 18-wheel truck. If this occurs, the delivery must be made to Building 69 where Facilities Shipping and Receiving personnel transfer the specialty gas to the user. Shipping and Receiving personnel have the required commercial driver's licenses and training.

Observations

- Lack of delivery notification impacts the Lab's ability to efficiently manage local storage areas and associated fire code storage limits.
- Personnel's lack of familiarity with expedited delivery provisions could impact their ability to effectively minimize the onsite inventory of compressed gases.

Opportunities for Improvement/Recommendations

- Increase the compressed gas user's awareness to the Praxair and Airgas contract provisions allowing for expedited delivery.
- Explore options with Praxair and Airgas to notify LBNL staff when cylinders are delivered (e.g., an email notification upon delivery).

Work Planning and Authorization

Use of a compressed gas at an LBNL location is reviewed through the processes outlined in Section 13.7 "Required Work Processes" in PUB-3000, Chapter 13 Gas Safety. Specific work processes requirements (A: General Requirements, B: Flammable Gas, C: Pyrophoric Gases, D: Health Hazard Gases) are invoked as a function of the inherent properties of the individual gas to be introduced to a work location. These different work process requirements address such aspects of work planning as gas quantity and location control, proper gas storage and segregation, placarding, gas flow controls, pressure safety, oxygen deficiency hazards, ventilation, and gas detection. For all classes of compressed gas, "Work Process E: Training" is also required as part of the work planning and authorization.

An AHD must be developed and approved for all hazard gas uses that could cause significant injury or property damage at LBNL or offsite. PUB-3000, Chapter 6, Safe Work Authorizations and Chapter 13 provide details for when an AHD is required. The AHD outlines potential hazards and documents appropriate controls for a compressed gas in the expected location of use. The Principal Investigator (PI)/Supervisor is responsible for developing the AHD and the Division Safety Coordinator and EHS Industrial Hygiene Group staff review the AHDs.

In labs with health hazard gases that the assessment teams visited and asked the question, the researchers stated that an AHD had been considered and/or performed for operations with hazard gases. Existence of the AHD was confirmed in these cases (e.g., AHD 2028 and 3501). In one instance, carbon monoxide was used on a bench top and an AHD was not in place. Documentation of the assessment and decision to allow this use without an AHD was verified via email correspondences between the CG SME and the user.

When a health hazard or reactive gas is ordered, the CG SME is notified and ensures an AHD is in place or that the process to establish a new AHD is underway before the gas order is approved. This process is an excellent control to ensure use of health hazard and reactive gases are properly reviewed and authorized.

Per Chapter 13, depending on the hazards and the pressure rating of the compressed gas system, a Safety Note may be required to record engineering calculations or tests on specific equipment, as well as to specify operational requirements.

Findings

- Work Process C3(b) requires pyrophorics at any pressure to have a Safety Note and Work Process D4(c) requires all gas flow systems at any pressure that handle NFPA Health Hazard Classes 2, 3 and 4 to have a Safety Note. Active AHDs with "compressed gas – pyrophoric, reactive, health hazard, flammable, oxidizer" hazards were reviewed for Safety Notes. Five AHDs were reviewed (AHD 2028, 2046, 2062, 2069 and 3259), and none had Safety Notes.

Opportunities for Improvement/Recommendations

- LBNL should determine if Safety Notes are truly required for use of compressed gases when not associated with pressure safety issues. If so, implement this requirement. If not, remove this requirement from the program.
- In interviews with the division support staff, it was suggested that researchers do not always know when an AHD is required prior to delivery. Therefore, LBNL should consider enhancing communication with researchers to assure understanding of these requirements.

Training

Compressed gas safety training is provided as part of EHS-0171, *Pressure Safety*. The following specific items related to compressed gas storage and management are covered: (1) compressed gas cylinder restraints, (2) compressed gas cylinder handling, (3) compressed gas cylinder disposal, (4) mixing gases with cylinders, and (5) regulators. All LBNL staff and affiliates whose work might involve use of compressed gases are required to take this class. There is no retraining period associated with EHS-0171. Following a cylinder drop event in 2012 that resulted in personnel injury, LBNL augmented the previous training material to include a video on safely transporting gas cylinders and published a lessons learned.

Most LBNL scientific organizations reviewed during this assessment provide new personnel some level of on-the-job training (OJT) including some hands-on instruction regarding cylinder transfer from the storage area to the work area, connection of the cylinder to the distribution system at the laboratory work area, and return of the cylinder to the storage location when empty. The Work Lead typically provides this OJT.

Non-LBNL users do not transfer cylinders to and from the storage areas (cages) in some facilities. In these facilities, operations or support personnel transport cylinders themselves and provide instructions to non-LBNL users how to connect cylinders to the distribution system and assure the free flow of gas through the line. Facilities personnel involved in managing gas cylinders have extensive prior industrial experience and OJT is not considered necessary for them; such training would be provided to new Facilities employees should they not be familiar with applicable gas safety work practices.

Most personnel interviewed indicated that they had taken EHS-0171. They believed that the training did provide value; however, they could not always distinguish whether the source of their knowledge of compressed gas cylinder safety was from EHS-0171 or subsequent OJT instruction. Several interviewees recommended splitting EHS-0171 into two or more courses, e.g., separating pressure from compressed gas, separating detailed regulator information from compressed gas information, and providing more practical information for compress gas use at LBNL.

When asked about updated training information, a number of personnel were aware of the training update and had viewed the video; some others were unaware of the revision. Knowledge of the lessons learned material was similarly inconsistent.

Observations

- EHS-0171 contained information that seemed to conflict with requirements in Chapter 13 and other work practices at the Lab. These included:
    - EHS-0171 states that pyrophorics cannot be stored with any other hazard class, but Chapter 13 states that pyrophorics and corrosives can be stored together.
    - EHS-0171 allows a single restraint at mid-height is a web sling is used, but Chapter 13 only allows this for cylinders less than 3 feet.
    - EHS-0171 restricts vehicle transportation of cylinders to Facilities and Waste Management as does Chapter 13, but other LBNL policies allow users to transport cylinders in some situations.
    - EHS-0171 instructs users to leave LBNL-owned cylinders in storage racks for vendors to pick up which is not how these cylinders are processed.
- EHS-0171 also instructs users to bleed off gases in single use cylinders prior to disposal, but this activity may require additional instruction to perform this task safely, particularly if the cylinder contains hazardous gases.

Opportunities for Improvement/Recommendations

- Update EHS-0171 to remove or correct inaccurate or outdated information after Chapter 13 is revised.
- Evaluate the benefits of separating the course into two or more courses (e.g., pressure safety, compressed gas safety and regulator safety).
- Evaluate the benefits of tailoring the compressed gas portion of EHS-0171 to the job-specific needs of scientific organizations and providing more practical information. Determine if such tailoring would reduce the level of OJT currently provided.
- Determine if additional communication methods are needed to provide assurance that the Lab personnel are aware of training updates and lessons learned.

System Set Up, Storage and Inventory

Once compressed gas cylinders are received, they are transported to locations where they will be used. Facilities staff will typically install any piping that is required to connect the cylinder to a research apparatus. The Regulator Shop may also be engaged to assist with proper regulator selection. This service is not well known. The Regulator Shop was disbanded several years ago and is currently being reconstituted with a more limited commitment of resources. In the absence of assistance from the Regulator Shop, users have been purchasing their own regulators or selecting them from a supply of regulators they have on hand within the lab [which does not conform to Chapter 14, Work Process A6(d)].

When not in active use in a lab, gas cylinders are primarily stored at outdoor locations near building loading/delivery docks or other outdoor areas accessible by vendors and users. Many of these outdoor locations serve multiple users from multiple research organizations. Indoor storage is provided in some location, such as at JCAP (Joint Center for Artificial Photosynthesis) and for the refrigerant bottles used by Facilities maintenance personnel in the basement of Building 76. As noted above, cylinders are typically delivered directly to these locations and picked up by users when needed. There is the potential for build-up of cylinders if users place orders well in advance of actual need or if they are not notified of cylinder deliveries.

With few exceptions (see Findings below), use and storage of compressed gases were generally found to be in accordance with the Gas Safety Program, with proper separation between cylinders of different gas types, barriers, and identified return areas. Deficiencies observed included inadequate restraints [Chapter 13, Work Process A5(c)], pipe labeling [Chapter 13, Work Process A6(c)], and area signage [Chapter 13, Work Process A4(e)].

Access to some storage areas may pose potential difficulty for personnel in delivery and removal of cylinders. Issues included sloped storage areas, unpaved areas that must be traversed for some cylinder handling operations, limited access, slippery surfaces, and lips or short steps between delivery, use, and/or storage locations. In one situation, a safety concern and corrective action was submitted (CATS# 9590) and is pending approval with Facilities. Although these conditions do not affect conformance with gas safety requirements, they were viewed as presenting possible ergonometric or slip/trip hazards for personnel performing cylinder handling.

The LBNL-wide inventory of gas cylinder contents is accomplished through the Chemical Management System (CMS). Evidence of CMS use was observed in most locations. Some staff however verbally indicated that compressed gases were not regularly entered into CMS. CMS is limited to entering indoor locations which cause users to mark gases stored outdoors as stored indoors. This contributes to inaccurate data in CMS. It also may artificially suggest quantity limit thresholds are exceeded which triggers a sequence of events all of which unnecessarily consumes staff's time.

Findings

- Management of compressed gases across multiple divisions did not meet Chapter 13 requirements in several areas, including:
    - Several cylinders had either no restraints, a single restraint on cylinders taller than 3 feet, or combustible straps as restraints violating Chapter 13, Work Process A5(c).

  - Several pipes in multiple divisions were not labeled every 20 feet or as required by Chapter 13, Work Process A6(c).
  - Hazard category signs were not posted in all locations as required by Chapter 13, Work Process A4(e).
  - Outdoor storage areas in most locations assessed were not covered with a non-combustible canopy violating Chapter 13, Work Process A4(c).

Observations

- Responsibility for maintaining inventory for cylinders stored in multi-user locations is not clearly defined. Oversight of the configuration and inventory for many such storage locations has been taken on an ad hoc basis by some DSCs and building managers. In these locations, management of compressed gases was reported to improve significantly.
- Several concerns were raised during interviews, and the assessment team did not have sufficient time to validate the concerns.
  - Staff suggested that appropriate gas detection may not be provided in every lab where it would be appropriate.
  - Staff suggested gas cabinets in many cases do not have self-latching doors.
  - Staff suggested not all toxic gases are controlled with automatic gas shut offs.
  - Staff suggested roof access is not necessarily controlled by lock and key in all cases when toxic gases may be present on the roof.

Noteworthy Practices

- Ad hoc assumption of responsibility for management of storage areas by DSCs and building managers has provided material improvement in gas storage compliance. Practices adopted in these ad hoc efforts can be a model for more formal codification of how gas storage areas should be managed (see Opportunity for Improvement below).
- Staff interviewed in several locations (JBEI, JCAP and B62) emphasized their efforts to reduce the inventory of cylinders stored and used through engineering (e.g., installation of house systems and purchases of hydrogen generators) and administrative controls (e.g., just-in-time delivery of gases) as a way to reduce risk in their areas.

Opportunities for Improvement/Recommendations

- Modify CMS to allow designation of outdoor storage locations.
- Review assessment findings and determine which related to required regulatory controls and which related LBNL (i.e., non-regulatory) requirements. For deficiencies pertaining to regulatory controls, widely communicate the Lab's expectations for these controls. For deficiencies pertaining to LBNL requirements, decide if the controls are necessary for safety. If so, widely communicate the Lab's expectations for these controls. If not, remove these requirements from the program.

- Reinforce communication to users and to Facilities system installers about applicable program requirements related to cylinder restraining, labeling and signage requirements.
- Assess the value of the Regulator Shop in the management of compressed gases at the Lab and determine its appropriate role at LBNL. Organize the Regulator Shop at a level commensurate with the ideal role it should play in the compress gas program.
- Augment the Gas Safety Program to specifically delineate responsibility/ownership for management of gas storage locations, including those that serve multiple users and divisions.
- Evaluate outdoor gas cylinder storage locations to identify conditions that pose potential hazards in handling cylinders and correct those where hazards are identified.
- Include areas of concern voiced by users/support staff noted within this report that were *not* assessed in the program self-assessment plan so they *will* be assessed.
- Incentivize procurement of gas generators (e.g., hydrogen generators) and other engineering controls to encourage inventory reductions.

Cylinder Removal and Disposal

When empty, cylinders supplied by one of the eBuy vendors (Praxair or Airgas) are placed in a "returns" bay in the building's outdoor storage area and are picked up by the vendor drivers during routine delivery visits. Overall, this process appears to be working well with the removal of cylinders owned by current vendors. A possible exception may be removal of toxic gas cylinders that require close coordination between the vendors and the users as these must be maintained in a ventilated enclosure until they are removed.

Past problems in scheduling pickups have resulted in some cylinders owned by former vendors remaining in storage at LBNL for extended periods. In the absence of a defined process, each division struggles to figure out on their own how to return their "old" cylinders to former vendors. The result is that multiple staff from multiple divisions are all working independently to achieve the same goal. Managing the process in this manner is time-consuming, frustrating and inefficient. One consequence is that old cylinders remain at LBNL for longer periods of time than necessary, and in some cases, they are tucked in a corner and "forgotten" for years and even decades. These old cylinders consume valuable storage space, are subject to deterioration and aging, and increase the risk of failure or accident.

Return of small-volume specialty gas cylinders (e.g., those used as materials in semiconductor manufacturing processes) is typically arranged by the researcher using the gases. This process typically requires scheduling a dedicated meeting with the vendor for cylinder transfer.

LBNL-owned cylinders and single use cylinders that are not eligible for vendor return receipt are managed through one of two processes. 1) Cylinders housing inert gases such as Argon and Nitrogen can be vented to atmosphere, the cylinder valve removed, and the cylinder processed as scrap metal. 2) Cylinders housing hazardous gases are disposed in accordance with Waste Management requirements. LBNL's Waste Management group has a well-organized process for users to identify waste cylinders, characterize the contents, bar code them for identification, pickup, and transfer to specialized disposal contractors. This process is implemented through periodic cylinder campaigns (about twice per year), where users are encouraged to reduce the inventory of accumulated cylinders. A targeted effort has been undertaken to proactively dispose of unused LBNL-owned cylinders, resulting in significant reduction of legacy cylinders inventory over the last few years.

Observations

- The process for returning cylinders to former vendors (Matheson, Scott Specialty Gas, etc.) is poorly defined, poorly communicated, and inefficient.
- There are no safety guidelines or work authorization to prepare gas cylinders for scrap. Lacking safety guidelines on how to inspect cylinders, properly vent the gases and remove cylinder valves, individuals within divisions are performing these tasks in whichever way they believe is safe and most appropriate.
- The cylinder disposal campaign process for disposing of hazardous gas wastes through Waste Management is not documented, and users may not know how to dispose of hazardous gas wastes as this process is managed differently than the process for hazardous chemical wastes. Waste Management does have a process for disposing of hazardous gas wastes, and this process works well once triggered; however, there is no documented information about this process including information about how to initiate this process.

Noteworthy Practices

- The Waste Management process for disposing of cylinders that cannot be otherwise dispositioned (e.g., return to vendor) is a well-organized and executed process that strengthens the "back end" of the gas cylinder life-cycle at LBNL.

Opportunities for Improvement/Recommendations

- Define the process for returning old cylinders to former vendors and designate a Lab resource to own this process. Document and communicate the newly defined process and process owner.
- Generate guidelines for safely preparing cylinders for scrap waste. Generate a work activity in the new WPC system covering this activity. Consider training dedicated staff to perform this activity. Document and communicate the process for disposal of compressed gas cylinders at the salvage yard.
- Document the cylinder disposal campaign process for disposing of hazardous gas wastes. Evaluate whether the periodic cylinder campaign can be better publicized, with the objective of utilizing the process to further reduce the legacy cylinder inventory and avoid accumulation of newer cylinders at LBNL.

Appendix I – SWOT (Strength-Weakness-Opportunity-Threat) Analysis

As part of this assessment, the assessment team has rated the Gas Safety Program SWOT matrix.

Strengths: • Program functioning well for users • Strong divisional ownership and support for Program • Strong institutional support for Program • Ease of procurement • Robust controls at procurement • Waste management process • Collaboration triggered through requirements management process	**Weaknesses:** • Removal of legacy cylinders • Unclear or undefined ownership, roles and responsibilities for all life-cycle elements – especially those associated with the front end and back end of the life-cycle • Poorly defined or poorly communicated processes • Process inefficiencies, particularly cylinder returns and disposal • Lack of clarity in ownership of shared gas delivery locations • Communication between process stakeholders • Communication between gas vendors and users, particularly regarding deliveries • Accuracy of program and training requirements
Opportunities: • Institutionalize and expand the capabilities and support offered through the Regulator Shop • Leverage just-in-time gas delivery to encourage inventory reductions and reduce cylinder disposal challenges • Incentivize procurement of gas generators (e.g., hydrogen generators) to encourage inventory reductions and reduce cylinder disposal challenges • Leverage approver/reviewer functions in eBuy to allow Division support staff involvement in management of gas safety	**Threats:** • Potentially hazardous configurations of some delivery areas increase risk of injury • In the absence of fully defined roles, personnel make decision and define sub-processes that may not be optimal

Appendix II – Performance Measures

As part of this assessment, the assessment team has rated the Gas Safety Program against seven performance measures using a three point scale.

Compressed Gases Program	Inherent Risk: Medium	
Performance Measure	**Rating**	**Justification**
Compliance		Due to modest non-conformances with programmatic requirements such as improper use of restraints and placement of signage
Controls		Due to modest non-conformances with programmatic controls noted above; PUB-3000, Chapter 13 does not accurately reflect current practice in many areas
Communication		Due to unclear or undefined ownership, roles and responsibilities and work processes; inadequate communication between "overlapping" process owners; poor communication from gas vendors following deliveries; and seemingly inaccurate or outdated information in Chapter 13 and EHS-0171
Efficiency		Due to process for return of "old" compressed gas cylinders to former vendors which is inefficient and contributes to incident risk
Culture		Due to strong divisional ownership; employee participation; emphasis on inventory reduction and hazard awareness
Trends/Forecasts		Due to the absence of any significant changes on the horizon
Feedback/Improvement		Due to positive feedback for the CG SME; regular communication between the Divisions and the CG SME; and objective evidence of program improvements (e.g., cylinder transportation video, Divisional ownership of common storage areas, etc.)

Appendix III – Prioritized List of OFIs/Recommendations

Opportunities for Improvement/Recommendations	Priority	Justification
Evaluate outdoor gas cylinder storage locations to identify conditions that introduce potential hazards in handling cylinders and correct these conditions where hazards are identified.	1*	Substandard storage conditions contributes to incident risk
Define the process for returning old cylinders to former vendors. Designate a Lab resource to own this process. Document and communicate the newly defined process and process owner.	1**	Inefficient process has led to unnecessary cylinder accumulation and storage which increases incident risk
Review assessment findings and determine which related to required regulatory controls and which related LBNL (i.e., non-regulatory) requirements. For deficiencies pertaining to regulatory controls, widely communicate the Lab's expectations for these controls. For deficiencies pertaining to LBNL requirements, decide if the controls are necessary for safety. If so, widely communicate the Lab's expectations for these controls. If not, remove these requirements from the program.	2	Improper implementation of safety controls increases incident risk
Augment the Gas Safety Program to specifically delineate responsibility/ownership for management of gas storage locations, including those that serve multiple users.	2	The absence of ownership has led to unnecessary cylinder accumulation and storage which increases incident risk.
Generate guidelines for safely preparing cylinders for scrap waste. Generate a work activity in the new WPC system covering this activity. Consider training dedicated staff to perform this activity. Document and communicate the process for disposal of compressed gas cylinders at the salvage yard.	2	The absence of guidance increases the risk of injury for those performing this activity
Review and revise Chapter 13 – a roll up of the following: • Map the current "as is" state of the program and define ownership, roles and responsibilities for each discrete function within the program and for each program interface where other program overlap with gas safety. Include process stakeholders in this effort. • Identify a small team of stakeholders to review Chapter 13 against current regulatory requirements and practices and bring the chapter up-to-date. Evaluate Chapter 13 requirements that exceed regulatory requirements, and remove those that are unnecessary for a safe working environment. Ensure the program addresses regulatory requirements. • Incorporate ownership, roles and responsibilities	3	Lack of clarity is contributing to safety risk and inefficiencies; other improvements cannot proceed until this issue is addressed

including responsibilities for assurance in PUB-3000, Chapter 13, Gas Safety. Consider reorganizing Chapter 13 around the life-cycle of compressed gases at LBNL. • LBNL should determine if Safety Notes are truly required for use of compressed gases when not associated with pressure safety issues. If so, implement this requirement. If not, remove this requirement from the program.		
Review and revise EHS-0171 – a roll up of the following: • Evaluate the benefits of tailoring the compressed gas portion of EHS-0171 to the job-specific needs of scientific organizations and providing more practical information. Determine if such tailoring would reduce the level of OJT currently provided. • Update EHS-0171 to remove or correct inaccurate or outdated information after Chapter 13 is revised.	3	Provides more efficient delivery of information and improves communication of program requirements
Explore options with Praxair and Airgas to notify LBNL staff when cylinders are delivered (e.g., an email notification upon delivery).	3	Allows Divisions to better manage storage locations and inventory issues, thus reducing risk
Query Division Safety Coordinators and key support staff and determine if prior notification of gas purchases is desirable. If desirable, determine if the personnel included on the ordering process for gas cylinders can be expanded to include Division Safety Coordinators or support staff or explore other opportunities to include those individuals in a notification process when these gases are ordered.	3	Allows Divisions to better manage storage locations and inventory issues, thus reducing risk
Assess the value of the Regulator Shop in the management of compressed gases at the Lab and determine the appropriate role for the Regulator Shop. Organize the Regulator Shop at a level commensurate with the ideal role it should play in the compress gas program.	3	Opportunity to optimize selection, inspection and installation of regulators
Incentivize procurement of gas generators (e.g., hydrogen generators) and other engineering controls to encourage inventory reductions	4	Emphasis on inventory & risk reduction
Increase the compressed gas user's awareness to the Praxair and Airgas contract provisions allowing for expedited delivery.	4	Emphasis on inventory & risk reduction
Modify CMS to allow designation of outdoor storage locations.	4	Current configuration in CMS leads to inaccurate data
Include areas of concern voiced by users/support staff noted within this report that were *not* assessed in the program self-assessment plan so they *will* be assessed.	5	Potential risks need to be assessed
Centralize information about compressed gases.	5	Improved communication

Consider a single location online where users and support staff can find relevant information on how to procure, receive, install, use, store, transport, return and dispose of compressed gases.		
In interviews with the Division support staff, it was suggested that researchers don't always know when an AHD is required prior to delivery. Therefore, LBNL should consider enhancing communication with researchers to clarify these requirements.	5	Improved communication
Determine if additional communication methods are needed to provide assurance that the Lab personnel are aware of training updates and lessons learned.	5	Improved communication
Reinforce communication to users and to Facilities trade workers installing systems about applicable program requirements related to restraining cylinders, labeling requirements and signage requirements.	5	Improved communication
Document the process for disposing of hazardous gas wastes. Evaluate whether the periodic cylinder campaign can be better publicized, with the objective of utilizing the process to further reduce the legacy cylinder inventory and avoid accumulation of newer cylinders at LBNL.	5	Improved communication
Work with SMEs owning programs that overlap/interface with the compressed gas program to ensure roles, responsibilities, requirements and expectations at program interfaces are accurately reflected in the individual programs.	5	Improved communication

*Several interviewees strongly indicated this condition is the one most likely to produce a "prompt" injury or other event. Site observations verified that potentially hazardous conditions exist (e.g., material handling issues at B62 & B67 associated with manipulating cylinders inside the confined space of the cylinder cages; narrow walkway that is routinely wet due to the liquid nitrogen tank at B67; and sloped walkways at B58 & B67)

**Several interviewees expressed frustration with returning old cylinders to former vendors. This process is the least efficient process associated with compressed gases, and it results in unnecessary accumulation of cylinders which contributes to the overall risk of an adverse event.

Appendix IV – Interviews/Sites/Documents

The following staff were interviewed during this assessment:

- Martin Neitzel, Chemical Sciences
- Ron Scholtz, EETD
- Doug Taube, ALS
- Kurt Ettinger, EHS
- Mike Botello, Facilities
- Kevin Homon, Facilities
- Jon Cleveland, Facilities
- Ben Sandmann, PBD
- Tim Lease, PBD
- James Gardner, PBD
- David Standish, PBD
- Kurt Van Allsburg, MSD
- Yuyi Li, EETD
- John Kerr, EETD
- Tracy Mattox, MSD
- Erin Wood, MSD
- Nick Palaio, Physics
- Billy Johnson, EHS
- Roshan Shadlou, EHS
- Jeff Beeman, MSD
- Susan Synarski, EETD
- Bruce Rude, Chemical Sciences
- Oleg Kostko, Chemical Sciences
- Manuel Sturzbecher-Hoehne, Chemical Sciences
- Dan Slaughter, Chemical Sciences
- Laura Saunders, Procurement
- Scott Taylor, LSD
- Laurel Davis, EHS
- Scott Scagliotti (plus drivers), Praxair

The following buildings/labs were visited during this assessment:

- ALS
- JCAP
- JBEI
- ABPDU
- B62, Exterior storage area
- B67, Exterior storage area

- B58, Exterior storage area
- B64, Exterior storage area
- B2A, Exterior storage area
- B70/70A, Exterior storage area
- B62, Room 218, 246
- B70A, Room 4457A
- B2, Room 260A
- Regulator Shop

The following documents were reviewed during this assessment:

- PUB-3000, Chapter 13, Gas Safety
- PUB-3000, Chapter 6, Safe Work Authorization
- Restricted Items List, February 6, 2014
- AHD 2028, 2046, 2062, 2069, 3259 and 3501
- CleanHarbors Cylinder Evaluation Form
- Empty Gas Cylinder Return Request Form
- Berkeley Lab Packing Slip
- Hazardous Waste Disposal Requisition
- OSHA 1910 regulations
- California Fire Code 2007, Table 2703.1.1(1)-(4)
- Compressed Gas Association Pamphlet P-1, 2000, Safe Handling of Compressed Gases in Containers
- EHS-0171, Pressure Safety
- NFPA 55, Compressed Gases and Cyrogenic Fluids Code, 2013 Edition
- NFPA 45, Standard of Fire Protection for Laboratories Using Chemicals, 2011 Edition

Appendix V – Lines of Inquiry and Checklist

Users

	What is your involvement with compressed gases and the compressed gas safety program at LBNL?
cm	How did you learn about the safety controls that apply to those compressed gases?
cm	How do you typically learn of changes to the compressed gas safety requirements?
cm	Where would you go for information about the compressed gas safety requirements if you had questions?
cm	Was institutional compressed gas safety training material sufficient and appropriate for your activities? If not, why?
cm	Considering information you have reviewed (program documents, training, etc.), how would you describe the information? Did it clearly communicate requirements, could you find the answers you were looking for, etc.?
sc	How do you know compressed gases are being used safely in your lab?
fi	What issues, if any, have you encountered when procuring and using compressed gases? If you encounter difficulties procuring or using compressed gas cylinders, what action do you take that successfully resolve the issues?
fi	What issues, if any, have you encounter when you are done using a compressed gas? If you encounter difficulties disposing of unwanted cylinders, what action do you take that successfully resolve the issues?
sc	How would you describe LBNL support for this program? Is the Lab providing adequate resources to support the program?
tf	What significant changes do you foresee in the use of compressed gases over the next 12 to 24 months (e.g., usage increasing or decreasing, transporting for field work, using more toxic gases, etc.)?
fi	What do you believe are the most significant strengths and weaknesses associated with compressed gas use at the Lab?
e	How would you improve the efficiency of the program to make it easier/faster (yet just as robust) for users using compressed gases?
fi	How would you improve compressed gas safety at LBNL?

Subject Matter Expert

	What is the scope of the compressed gas safety program? What is excluded from the scope of the program?
	How would you describe the compressed gas safety program?
co, fi	Have there been any recent adverse events related to compressed gases (i.e., injuries, ORPS, NTS, etc.) in the last 12 to 24 months? If so, what actions were taken in response, and do you believe these are sufficient and sustainable?
co, fi	What types of issues do you commonly see when you are assessing compressed gas use? How do you typically manage any non-conformances, deficiencies, etc.?
fi	Have there been any recent assessments involving compressed gas safety? If so, what types of issues were identified and what action was taken in response?

sc	Are you asked for assistance/help by users? How frequently? Are you able to respond within a reasonable time frame? Are you able to address user's issues?
sc, fi	What type of feedback do you receive about the program? How frequently do you receive feedback? How do you typically receive feedback?
tf	Do you notice any particular trends related to the compressed gas safety?
co	How do you typically communicate information about the program including changes or "hot topics?"
fi	What do you believe are the most significant strengths and weaknesses of the program?
fi	What do you believe researchers would say are the most significant strengths and weaknesses of the program?
	What consensus standards are we *required* to follow (including standards referenced by OSHA)? How do you ensure the compressed gas program meets applicable requirements?
cp	LBNL has a copy of CGA P-1, 2000 (referenced by 1910.6). The consensus standard has been revised twice since then (in 2006 and 2008). How do we verify that our program meets CGA P-1, 2008 and 1910.101(b)?
cp	What is the expectation for visual inspections of cylinders? How is this accomplished at LBNL? Are PIs/Supervisors required to do inspections? How do we ensure that inspections are conducted in accordance with 1910.101 and CGA C-6?
fi	What methods or techniques are used to ensure compressed gases are being used safely? Are safety inspections performed? Are there automated systems used to detect "something going wrong?" Are other methods/techniques used?
co	Are <u>all</u> NFPA Health Hazard 3 and 4 gases, NFPA Health Hazard 2 gases with poor warning properties and pyrophoric gases routed to you for approval prior to purchase? How do you verify this? Can you provide objective evidence to demonstrate this process is working?
co	Once approved for purchase, are NFPA Health Hazard 3 and 4 gases, NFPA Health Hazard 2 gases with poor warning properties and pyrophoric gases evaluated at this point for the need for an AHD?
co	How do you ensure that gases that need an AHD have an AHD? WP-A(2)(a)
co	Have we issued AHDs for flammable gas greater than 400 cubic foot? Where does this requirement come from?
co	Do you verify that compressed gases meet quantity limitations? If so, how? WP-A(2)(b)(i)
co	When are users required to post a list of gas quantities and storage locations? How is this typically accomplished by users? WP-A(2)(b)(ii) Do they need to post information on hazard type as well?
co, cp	Are exterior storage locations required to be covered by a non-combustible canopy? WP-A(4)(c) What is the specific driver for this requirement considering CGA P-1, 2000, 3.7.3, Outdoor Storage states "cylinders may be stored in the open," the 2007 California Fire Code states "compressed gas containers, cylinders and tanks are allowed to be stored or used in the sun except in locations where extreme temperatures prevail" and that OSHA, NFPA 55, NFPA 45 seem silent on this requirement?
co, cm	Can a pyrophoric cylinder be stored next to a corrosive gas cylinder?
co, cm	What are the requirements for securing cylinders? Is a single restraint at mid-cylinder height ever acceptable?
co	What is the disposal process for older cylinders? Who manages this process? What information is available about it?

tf	Are there any changes to OSHA standards or consensus standards expected in the next 12 to 24 months?
tf	Are there any significant changes to research as it relates to compressed gases on the horizon?
fi	How has the program improved over the last 12 to 24 months?
e	How would you improve the efficiency of the program to make your job easier?
e	How would you improve the efficiency of the program to make it easier/faster (yet just as robust) for staff using compressed gases?
fi	How would you improve compressed gas safety at LBNL?

Division Safety Coordinators/Support Staff

	How does the general process of ordering, using, storing and disposing of compressed gases work in your division?
	What is your involvement with compressed gases in your Division?
	How would you describe the compressed gas program and how well it is working in your division?
fi	Does the program address the hazards of all the various compressed gas uses within your division? What gaps do you see?
cm	How do you typically learn of changes to the program?
cm	How would you like to learn about changes to the program?
co	Are cylinders typically delivered to the proper location when initially delivered?
co	Is safe use of compressed gas cylinders verified as part of an established inspection process?
co	Do cylinders storage areas have clear owners with responsibility for maintaining the area? If not, who resolves potential conflicts within the area?
e	How would you improve the efficiency of the program to make it easier/faster (yet just as robust) for staff using compressed gases?
fi	How would you improve compressed gas safety at LBNL?

Procurement

	What is procurement's involvement in the ordering and purchasing of compressed gases?
co	How are NFPA Health Hazard 3 and 4 gases, NFPA Health Hazard 2 gases with poor warning properties and pyrophoric gases identified during ordering and purchasing?
co	Are <u>all</u> NFPA Health Hazard 3 and 4 gases, NFPA Health Hazard 2 gases with poor warning properties and pyrophoric gases identified during purchasing?
co	Are all NFPA Health Hazard 3 and 4 gases, NFPA Health Hazard 2 gases with poor warning properties and pyrophoric gases routed to EHS for approval prior to purchasing?
e	What is the average turnaround time for EHS to review and approve these orders for purchase?
co	Is it possible to order NFPA Health Hazard 3 or 4 gases, NFPA Health Hazard 2 gases with poor warning properties and pyrophoric gases through non-normal channels that would not be routed to EHS for approval?

e	How well is this process working?
	What is procurement's involvement in removal of unwanted or empty compressed gases?
cm	What information about this process is available to researchers?
e	How well is this process working?
e	How much does LBNL pay each year to "rent" gas cylinders?
fi	What suggestions do you have for improving compressed gas purchasing and removal?

Receiving and Transportation

	What involvement does Receiving and Transportation have in transporting compressed gases?
cp	How do you transport cylinders?
co	What training do staff have specific to compressed gases?
co	Do you transport toxic or highly toxic gases? If yes,
co	Do you keep these gases in an exhausted enclosure until they can be delivered to the gas user?
co	How do Transportation staff check for gas leaks? When and how do they check for gas leaks?
co	Have Transportation staff received any training specifically on handling highly toxic or toxic gases?
e	How would you describe the process for compressed gas cylinder receiving and transportation?
fi	Do you have suggestions for improving the process?

Vendor

	Does LBNL clearly communicate which gases it wants to order and where these need to be delivered?
	Does LBNL accurately communicate where gases need to be delivered? Have there been times when the delivery point was incorrectly communicated? (If so, how frequently does this occur?)
	How is the delivery experience? Are there often obstacles, obstructions or other hazards between the delivery truck stopping point and the actual delivery location that make it difficult to deliver the cylinders to the drop off locations?
	Does LBNL provide adequate restraints for cylinders at drop off locations?
	Does LBNL clearly mark where incompatible cylinders should be located if these are going to the same drop off point?
	Does LBNL clearly identify empty cylinders for pick up?
	Does Praxair have any safety concerns related to drop off or pick up of compressed gas cylinders at LBNL?
	Does Praxair have any suggestions from improving compressed gas cylinder delivery/pick up at LBNL?

Compressed Gas Cylinder Safety Checklist

Issue	Y/N	Notes
General Safety		
A list of hazardous gases is maintained at each storage location identifying gases, hazard class, and gas quantities [WP-A(2)(b)(ii), 1910.101, CGA P-1]		
Storage areas are kept clear of all weeds, grass, brush, trash and other combustible material for 15 feet [WP-A(4)(c), 1910.101, CGA P-1]		
Space in exit corridors, exit routes and doors are not used for storage or use of compressed gases (unless in gas cabinets) [WP-A(4)(a)]		
Entrances are posted with visible and durable gas-hazard identification signs [WP-A(4)(b)]		
Exterior storage and use areas *with flammable gases* have signs posted prohibiting smoking [WP-A(4)(b), 1910.101, CGA P-1]		
Exterior storage locations are protected from vehicle damage [WP-A(4)(c)]		
Cylinders are stored on paved ground and on surfaces where water won't accumulate [WP-A(4)(c), 1910.101, CGA P-1]		
Incompatible gases are properly segregated by distance, barriers, cabinets or lab hoods [WP-A(4)(e)]		
Compatible pipes, valves, fittings and related components used for each gas		
Valve protection caps are on when cylinders are not in use [WP-A(5)(d)(i), 1910.101, CGA P-1]		
Cylinders stored in upright position (cylinders with less than 5 L excluded) [WP-A(5)(b), CGA P-1]		
Cylinders secured by [WP-A(5)(c), 1910.101, CGA P-1]: o 2-point non-combustible restraint system, or o Non-combustible rack, cabinet, cart, or o Rectangular metal device		
Labels are in good condition (unless cylinder is empty) [CGA P-1]		
Cylinders are not used for any other purpose than containing and using its contents [1910.101, CGA P-1]		
Cylinders are not lifted using the protective cap or with a magnet [1910.101, CGA P-1]		
Ropes, chains, or slings shall not be used to suspend cylinders unless the cylinder has appropriate lifting attachments [1910.101, CGA P-1]		
Gases are within CFC maximum allowable quantity limits [2007 CFC]		
Cylinders in labs are being "used" (i.e., not being "stored" in labs) [NFPA 45]		
Health Hazard Gases		
NFPA Health Hazard 3 and 4 gases (and Health Hazard 2 with poor warning properties) used in labs are stored in a lab hood or gas cabinet [NFPA 45]		
Highly toxic/toxic gases leak points are contained within exhausted enclosures		
Highly toxic/toxic gases have a ventilation monitor with audible and visual alarm on hood or gas cabinet		
For gases with poor warning properties, ventilation monitoring interlocked with automatic gas shutdown and gas detection is provided		
Pyrophoric Gases		
Cylinders are stored in gas cabinets (or ventilated enclosure if a lecture bottle) [NPFA 45]		

Cylinders larger that lecture bottle size in labs are stored in a sprinklered gas cabinet [NFPA 45]		
Remote manual shutdown devices for gas flow provided outside gas cabinets		
Gas flow, purge and exhaust systems have redundant controls that prevent gases from igniting or exploding in an unsafe and uncontrolled manner		
Flammable Gases		
Flammable gases are stored in well-ventilated areas away from oxidizers and heat/ignition sources [CGA P-1]		
Fire extinguishers or other fire suppression systems are available at storage locations [CGA P-1]		
Pipes and components approved and non-combustible design and construction (exception for lengths up to 5 feet where flexibility is required) [CGA P-1]		
Exterior storage is not located under a window or within 20 feet of combustion sources		
25% of perimeter is open to the air (without walls)		