Chemical Sciences Division

Fiscal Year 2014

Environmental Health and Safety

Self-Assessment Report

Safety of Compressed Gases:

Storage, Transport, Use, and Disposal

Approved By:_____ _____

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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.

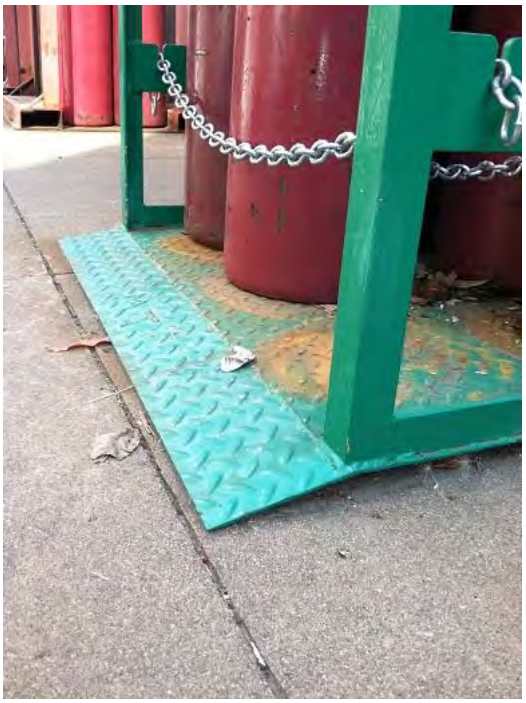
The first example is of several cylinders being stored with their regulators attached (figure 4). These cylinders had their regulators removed and the protective caps were installed. However, in the past, a special variance has been given by EHS for cylinder storage with regulators attached for very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

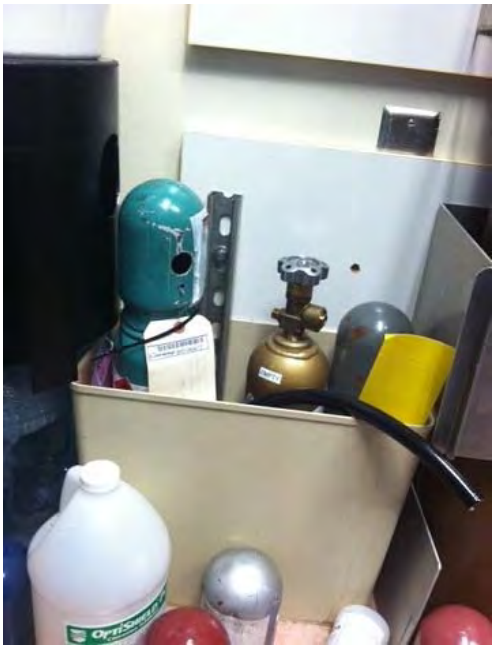
The pictures below (figure 8) show a variety of small cylinder storage solutions that were less than ideal. These were identified through the course of this division self assessment and all have been addressed. I do want to stress here that these pictures were isolated cases and in no way represent a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

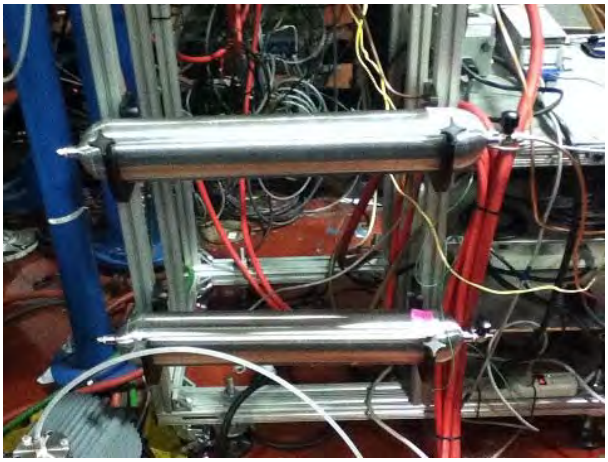
When cylinders are in use, the same set of basic criterion for securing the cylinder apply. Below are a series of pictures depicting cylinders in use and secured in acceptable ways (figure 10).

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

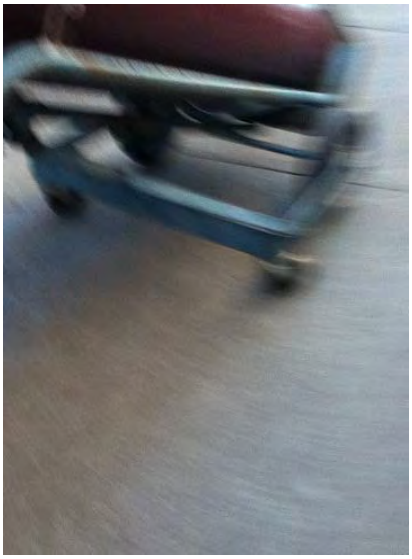
than one type of cart, including the most common type of cart at LBNL has a fatal flaw that if not properly secured, the cart will fold and the cart and cylinder will fall to the ground (see related picture sequence in figure 12). As these carts age, it is an ever increasing possibility that one will 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.

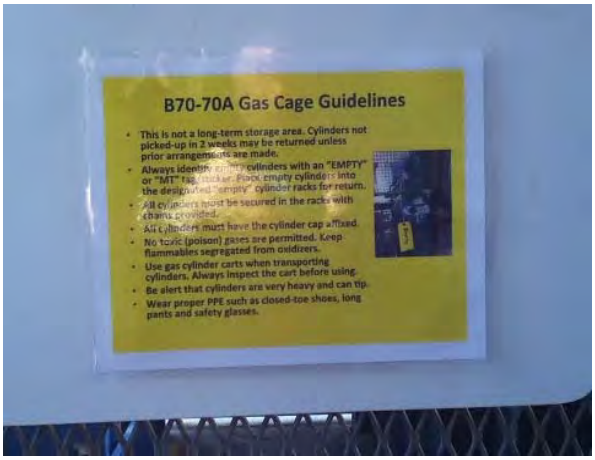
New cylinder cart on left, and old style folding cart on right.

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

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 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.

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