Notre Dame Safe Handling & Storage of Compressed & Liquefied gases

Seminar Overview:
- Recognize the different physical and health hazards of compressed gases.
- Obtain information about physical and health hazards of compressed gases.
- Know the general and specific storage requirements.
- Connect and disconnect a pressure regulator.
- Choose appropriate Personal Protective Equipment (PPE)
- Dispose of empty/unused cylinders
- Respond to compressed gas cylinder emergencies appropriately

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  Jason Blair, Branch Manager
Goals

• Keep you safe

• Supplement your current training

Incidents Requiring Emergency Attention

• Campus Phone    Dial 911
• Cell Phone      574-631-5555

• Both reach NDSP Dispatch
Responsibilities

Risk Management & Safety (RMS)
• Provides oversight to ensure conformance of safety procedures.
• Provides assistance, guidance, and training as necessary.
• Reviews and approves procedures for highly hazardous/toxic or special procedures as necessary.

Principal Investigators/Supervisors
• Ensure that employees are properly trained in the areas of safe storage, handling, use, and transport of compressed gas cylinders.
• Ensures that safety procedures and safe work practices are used.

Laboratory Workers
• Perform all work with compressed gases in accordance with the safety procedures discussed in this training.

Departments
• Labeling of common compressed gas cylinder storage areas.
• Follow all safety procedures.

Supplier (Airgas)
• Provides assistance and guidance.
• Provides monthly compressed gas cylinder inventory to RMS & Procurement.

University Applications

- Glove Boxes
  - Nitrogen (Dewars, Microbulk, Bulk)
  - Argon (dewars, Microbulk, bulk)
- Nuclear Magnetic Resonance (NMR) & Magnetic Resonance Imaging (MRI)
  - Helium and nitrogen cryogens
  - Cryogen handling equipment
- Cryostorage
  - Nitrogen (dewars, Microbulk, bulk)
  - Cryogen handling equipment
  - RDF, inventory systems, supplies
- Various GC
  - MS, ICPMS, ICP, ECD, FID
  - Various analytical gases – i.e., BiP
  - Various LC
  - Solvents, Helium purge
- Various LC
- Animal Research
  - Nitrous oxide
  - CO₂
  - CO₂/O₂ blends
- Mechanical and Other Storage
  - Backup cryogens (CO₂, nitrogen)
  - Scales, supply mode change equipment
  - Dry ice
- Incubators
  - Large/Small Scale
  - Carbon Dioxide
  - Triple Gas Style
  - Nitrogen Also
- Manufacture
  - Nitrogen
  - Process chemicals
  - Oxygen, air, and related gases
- Other Research
  - Electron microscope nitrogen
  - Various lecture bottle replacements
  - Oxygen for fermentation
Gas Container Examples

- Stationary Tubes
- (aka Hydril Tubes)
- Cylinders Of Various Sizes
- Lecture Bottles
- Multi-cylinder Packs
- Tube Trailers
- Other Small Cylinders

Airgas Common Cylinder Sizes

<table>
<thead>
<tr>
<th>Size</th>
<th>Specification</th>
<th>Bonded Dimension (in.)</th>
<th>Airgas Grade</th>
<th>Pressure Per Unit (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>SAE19HP</td>
<td>9 x 55 (23 x 140)</td>
<td>127 (62)</td>
<td>1.76 (48.8)</td>
</tr>
<tr>
<td>200</td>
<td>SAE19HP</td>
<td>9 x 51 (23 x 130)</td>
<td>119 (54)</td>
<td>1.55 (45.3)</td>
</tr>
<tr>
<td>56</td>
<td>SAE19HP</td>
<td>7 x 38 (18 x 96)</td>
<td>57 (25)</td>
<td>0.56 (15.9)</td>
</tr>
<tr>
<td>35</td>
<td>SAE19HP</td>
<td>6 x 34 (15 x 86)</td>
<td>42 (19)</td>
<td>0.39 (11.8)</td>
</tr>
<tr>
<td>19</td>
<td>SAE19HP</td>
<td>4 x 17 (10 x 43)</td>
<td>9 (4)</td>
<td>0.10 (0.7)</td>
</tr>
<tr>
<td>7</td>
<td>SAE19HP</td>
<td>3 x 13 (8 x 33)</td>
<td>6.5 (3)</td>
<td>0.013 (0.13)</td>
</tr>
<tr>
<td>LB12</td>
<td>SAE1800</td>
<td>2 x 12 (5 x 30)</td>
<td>2 (1)</td>
<td>0.015 (0.45)</td>
</tr>
<tr>
<td>LB18K</td>
<td>SAE1800</td>
<td>2 x 12 (5 x 30)</td>
<td>2 (1.8)</td>
<td>0.015 (0.45)</td>
</tr>
<tr>
<td>E</td>
<td>SAE1915</td>
<td>4 x 28 (10 x 70)</td>
<td>14 (6)</td>
<td>0.15 (6.0)</td>
</tr>
<tr>
<td>3HP</td>
<td>SAE4500</td>
<td>10 x 31 (25 x 79)</td>
<td>560 (130)</td>
<td>1.49 (42.3)</td>
</tr>
<tr>
<td>2HP</td>
<td>SAE5500</td>
<td>9 x 51 (23 x 130)</td>
<td>167 (65)</td>
<td>1.53 (44.3)</td>
</tr>
</tbody>
</table>
Identifying Products

- The only safe means of determining product identity is by consulting the cylinder label.
- **Color codes are meant for general reference only.** Lighting, age, foreign material or coatings, visual acuity and other factors could impact on how a cylinder color appears to an individual.

Color Coding

- Gas companies use cylinder color coding to help sort cylinders.
- These color codes are **not universal** – different companies have different color code schemes.
- Never use color to identify contents. Always read the label!
Cylinder Labels

- Each cylinder must bear a label that is in compliance with current DOT regulations.

What Are Hazardous Materials?

- Substances that pose an unreasonable threat to health, safety, property and the environment
- DOT lists 9 Classes of Hazardous Materials:
  - Class 1 – Explosives
  - Class 2 – Gases
  - Class 3 – Flammable Liquids
  - Class 4 – Flammable Solids
  - Class 5 – Oxidizers / Organic Peroxides
  - Class 6 – Poisons
  - Class 7 – Radioactive
  - Class 8 – Corrosives
  - Class 9 - Miscellaneous
Information found on a SDS

16 Sections:

- Product and Company Identification
- Composition, Information on Ingredients
- Hazards Identification
- First Aid Measures
- Fire Fighting Measures
- Accidental Release Measures
- Handling and Storage
- Exposure Controls, Personal Protection
- Physical and Chemical Properties
- Stability and Reactivity
- Toxicological Information
- Ecological Information
- Disposal Considerations
- Transport Information
- Regulatory Information
- Other Information

D. O. T. Hazard Classes

- Non-Flammable Gas
- Flammable Gas
- Oxidizer
- Inhalation Hazard
Nonflammable Gas

- Most hazardous class of products
- Colorless, odorless, tasteless, non-irritating
- NO WARNING PROPERTIES
- Hazards
  - Pressure 6000 psig
  - Asphyxiation >19.5% O₂
  - Temperature Cryogenic
- Examples
  - Argon, Helium, Nitrogen, Carbon Dioxide

Hazards of Inert Gases

- All inert, flammable, and toxic gases have potential to cause an oxygen deficient atmosphere.
- Most gases are colorless, odorless and tasteless, there is no warning.
- Less than 19% oxygen may produce dizziness, fatigue, nausea, vomiting and diminished mental alertness.
- NEVER enter a oxygen deficient area believing you can hold your breath until you re-emerge.
Oxygen Deficiency
Displacement of oxygen with another gas:

- 19.5% Legal minimum concentration for humans (OSHA)
- 15-19.5% Decreased ability to do work, induce early symptoms in persons with coronary, pulmonary, circulation problems
- 12-14% Increased pulse rate and respiration, impaired perception and judgment
- 10-12% Further increase in pulse and respiration, giddiness, poor judgment, blue lips
- 8-10% Mental failure, nausea, fainting, vomiting, unconsciousness
- 6-8% 8 min 100% Fatal, 6 min 50% fatal, 4-5 min recovery
- 4% Coma in 40 sec, convulsions, breathing stops, Death

Hazards of Oxygen

- Pressure
- Oxygen should never stored with any hydrocarbons.
- Supports Combustion
  - No Smoking, No Open Flames, and No Flammables are permitted within 20 feet of oxygen storage.
Oxidizer Hazards

- Examples of oxidizing gases are:
  - Oxygen
  - Fluorine
  - Chlorine
  - Chlorine tri-fluoride
  - Nitrous oxide

- Oxidizer Enrichment-Increases reactivity
Other Safety Item

- Toxic Gas List
  - Requires Preapproval
  - Restricted Products Site Survey w/Airgas

Cylinder Markings

1. Cylinder Specification
   - DOT - Department of Transportation, which is the regulatory body that governs the use of cylinders
   - Specification of the cylinder type of material of construction (e.g., 3A)
   - Service or working pressure in pounds per square inch (e.g., 2,200 psi)

2. Cylinder Serial Number
   - The letters SG precede the serial numbers for Specialty Gas cylinders

3. Date of Manufacture
   - The date (month-year) also indicates the original hydrostatic test

4. Neck Ring Identification
   - The cylinder neck ring displays the current owner of the cylinder

5. Retest Markings
   - The format for retest markings is: Month-Facility-Year-Plus-Rating-Star-Stamp
   - The + symbol (Plus Rating) indicates that the cylinder qualifies for 10% overfill
   - The star symbol (Star Stamp) indicates that the cylinder meets the requirements for 10-year retest (instead of a 5-year retest)
   - UT in the facility stamp area designates ultrasonic testing

6. Bar Code Labels
   - Provides a unique cylinder identifier to track cylinders through filling

7. Cylinder Manufacturer's Inspection Marking

8. Cylinder Tare (Empty) Weight

[Diagram of cylinder markings with labels 1 to 8]
Handling Cylinders

- Move cylinders in an upright position by using a suitable cylinder cart or hand truck when possible.

LET IT FALL!!
Basic Cylinder Handling and Storage

- **NEVER**: drag, roll or slide cylinders
- **NEVER**: lift cylinders by the cap
- **NEVER**: use cylinders as rollers
- **NEVER**: submit cylinders to temperature extremes
- **NEVER**: strike an arc on a cylinder
- **NEVER**: allow cylinders to contact electrical circuits or apparatus
- **NEVER**: permit oil, grease, or other readily combustible substances to come in contact with cylinders or their valves, particularly Oxygen.
- **NEVER**: use oxygen as a substitute for compressed air.

Storage of Cylinders

- Indoor storage of toxic gases shall be equipped with a continuous gas detection system that provides an alarm to warn of the presence of toxic gases in levels that present a hazard to life
- Exhaust ventilation systems shall be installed in all indoor areas used for toxic gases
Nesting Cylinders

- All free-standing cylinders must be secured by a strap, chain or other means.
Pressure During Use

Gas Container

Liquid Container

Liquified Compressed Gas

Pressure is released in a manner similar to letting air out of a tire.

Pressure is released in a manner similar to opening and closing the lid on a pot of boiling water.

Container Contents (%)
What Is This Called?

Gas Container

- Cylinder (most common, correct)
- Bottle
- Tube
- Tank

Liquid Container

- Liquid container (correct)
- Dewar (most common)
- Jug
- Can

Regulator Installation

- Before removing the cylinder cap, move the cylinder to the work site:
  - Always gloves and eye protection
  - Secure cylinder to floor, wall or bench with appropriate chain or stand to prevent toppling.
  - Remove cylinder cap
  - Be sure cylinder valve is tightly closed
  - Remove cylinder valve plug, if any
  - Inspect the cylinder valve threads for damage or contamination
Whenever Connecting or Disconnecting the Regulator

- Use a proper wrench
- Do not use pliers

Wrenches

Do not use pliers. Use an appropriate cylinder wrench.
Left Hand = Counter-clockwise
Has a V-Groove

- Right Hand = Clockwise
- Fitting is smooth – No V-Groove

Opening Valves

- Never use a gauge above 75% of its maximum face reading. (ANSI B-40.1)
- Immediately replace any gauge whose pointer does not go back to its zero point when pressure is removed.
- Be certain the CGA connection on the cylinder and the pressure reducing regulator fit together properly without being too loose or too tight. NEVER USE AN ADAPTER
Regulator Installation

- Position yourself with cylinder between you and the regulator. Keep hand off regulator while opening cylinder valve.
- Slowly open cylinder valve. Observe the high pressure gauge on regulator as it climbs to full cylinder pressure.
- Observe all connections for leaks.
  - An approved soap solution may be applied to the connections, if compatible to your usage, to indicate leaks by bubbling.
  - To further check for leaks, or if soap solution cannot be used, close the cylinder valve for five minutes and watch for a drop in pressure.

CGA Adapters – Don’t Use Them!

- Circumvents the system the Compressed Gas Association (CGA) put in place to help prevent accidents
  - Each class or individual gas will have a unique connection
  - CGA Connections prevent hydrogen from being hooked up to an oxygen line
Regulator Components - Pressure

What's The Difference Between Single and 2-Stage Regulators?

**Single Stage**
- Not Precise Delivery Pressure
- Due to Supply Inlet Effect

**Two Stage**
- Precise Delivery Pressure
ANY QUESTIONS ON CYLINDERS?

Cryogenic liquids

- Cryogenic liquids are kept in their liquid state at very low temperatures (-240° C)

- Different cryogens become liquids under different conditions of temperature and pressure, but all have two properties in common: they are extremely cold, and small amounts of liquid can expand into very large volumes of gas.

- Without adequate venting or pressure-relief devices on the containers, enormous pressures can build up.
Cryogenic liquids will vent (boil off) from their storage containers as part of normal operation. As an example, a 160-liter tank will vent the gas equivalent to 2 liters of liquid a day.

### Cryogenic Gases

<table>
<thead>
<tr>
<th>Gas</th>
<th>Boiling Temperature °F</th>
<th>Liquid Evaporation Rate Per Day</th>
<th>Expansion Ratio Cu.Ft Liquid. To Cu.Ft. Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>-297.33</td>
<td>1.20%</td>
<td>1 to 861</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>-320.36</td>
<td>1.85%</td>
<td>1 to 696</td>
</tr>
<tr>
<td>Argon</td>
<td>-302.55</td>
<td>1.20%</td>
<td>1 to 841</td>
</tr>
<tr>
<td>Helium</td>
<td>-452.1</td>
<td>1.20%</td>
<td>1 to 754</td>
</tr>
</tbody>
</table>

Cryogenic liquids will vent (boil off) from their storage containers as part of normal operation. As an example, a 160-liter tank will vent the gas equivalent to 2 liters of liquid a day.

### Cryogenic Liquid Hazards

- **Physical Hazards**
  - Over Pressurization
    - Proper Venting of Liquid Systems (Inline PRV between shutoffs)
    - Max. Allowable Working Pressure (MAWP) exceeded on components
  - Oxygen rich atmospheres (increased fire potential)
  - Mechanical Failures
    - Material Embrittlement (i.e carbon steel)
- **Material Handling**
  - Pinch Points
  - Muscle Strain
  - Back Injuries

Use Approved Carts
Hands on Handle
Push Dewar
**Cylinder Tipping or Damage**

- Keep Liquid containers upright
- If Container Falls - Let it!
  - Allow 15 minutes for container to settle
  - Assess for structural integrity before approaching it. Check if venting, Air monitoring may be required.
  - Minimum 2 person team to lift in upright position
    - PPE Full Face Shields & Gloves
    - Use mechanical lift, hoist, tripod assembly to upright if possible
- Notify Airgas of the Incident
Cryogenic Liquid Hazards

• Health Hazards
  – Frostbite
  – Skin Tearing
    • Touching Super Cooled Metal & Plastics
  – Asphyxiation
    • These gases are colorless, odorless
    • Deadly consequences
    • See a person down, what’s your first reaction?

Personal Protective Equipment (PPE)

A picture is worth a thousand words!
**LN2 Consumption Example - CryoStorage**

- 1-3% Volume/Day + 30% Transfer Loss/Fill + 7.5 L/Day NER @ 1.4 Fills/Week ≈ 100 L/Week
- (LN2 Supply NER) (Transfer Losses) (Freezer NER) (Total Consumption)

**LN2 Supply**
- LN2 Transfer Hose
- Inline Pressure Relief Valve?

**He Vapor Freezer**

Expansion in a 230 Liter Liquid Nitrogen Dewar

<table>
<thead>
<tr>
<th>Cylinder Contents</th>
<th>230</th>
<th>Liters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation Rate</td>
<td>1.85%</td>
<td>Percent</td>
</tr>
<tr>
<td>Daily Conversion</td>
<td>4.25</td>
<td>Liters</td>
</tr>
<tr>
<td></td>
<td>104.7</td>
<td>Cubic Feet per day</td>
</tr>
</tbody>
</table>
What is a cryogenic liquid cylinder?

• A pressurized, double-walled, insulated container
• Holds either cryogenic liquefied gas or refrigerated liquefied gas.
• The inner vessel is insulated from the outer vessel by a vacuum space.

Liquid Operation

• Configurations

• Product Withdrawal
  - liquid
  - Gas

• Pressure Control
  - pressure build-up
  - economizer
  - relief
## Liquid Operation

<table>
<thead>
<tr>
<th>Part No.</th>
<th>DOT Rating</th>
<th>Relief Valve</th>
<th>Normal Operation Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI NF230LT22</td>
<td>4L100</td>
<td>22</td>
<td>5-18</td>
</tr>
<tr>
<td>NI NF230LT230</td>
<td>4L200</td>
<td>235</td>
<td>120</td>
</tr>
<tr>
<td>NI NF350LT350</td>
<td>4L300</td>
<td>350</td>
<td>300</td>
</tr>
</tbody>
</table>

## Theory of Operations

- Keep the liquid from reaching the relief valve rating of the dewar
- Liquid converts to gas at or above evaporation rate
- Venting of gas through relief valve is product lost
- The lower the pressure the colder the liquid.
- The lower the safety setting the colder the liquid temperature in the dewar
Types of Liquid Cylinders

- Liquid cylinders come in many configurations
  - Liquid withdrawal only
  - Liquid withdrawal only with pressure builder
  - Gas and Liquid withdrawal with high and low pressure relief valves
  - Gas and Liquid withdrawal with high pressure reliefs
  - Relief valve settings ranging from 22 to 500 PSIG
Common Configurations

- Liquid Level Gauge (10)
- Liquid and Fill Valve (2)
- Relief Valve (7)
- Vent Valve (4)
- Rupture Disk (5)
- Liquid Valve (2)
- Liquid Level Gauge (10)
- Pressure Building Valve (9)
- Gas Use Valve (11)
- Rupture Disk (4)
- Vent Valve (4)
- Relief Valve (7)

Low Pressure Design  High Pressure Design

Container Cross Section

- Inner Vessel
- Vacuum Space
- Outer Vessel
- Vapor Space
- Liquid Level
- Liquid Product
Flow Diagram

1. Gas withdrawal vaporizer
2. Liquid withdrawal valve
3. Economizer regulator
4. Vent valve
5. Inner tank rupture disk
6. Pressure gauge
7. Pressure relief valve
8. Pressure building regulator
9. Pressure building valve
10. Liquid level gauge
11. Gas withdrawal valve and integral check valve
12. Check valve in house line
13. Outer tank rupture disk
14. Pressure building vaporizer

Control Valves

- Most cylinders can be used for either gas or liquid withdrawal.
  - Top of cylinders have the following valves:
    - Liquid Withdrawal Valve
    - Vent Valve
    - Liquid Fill Valve
    - Gas Withdrawal Valve*
    - Pressure Building Valve*

* not available on all cylinders
Product Withdrawal

1. Gas withdrawal vaporizer
2. Liquid withdrawal valve
3. Economizer regulator
4. Vent valve
5. Inner tank rupture disk
6. Pressure gauge
7. Pressure relief valve
8. Pressure building regulator
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Liquid Withdrawal

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Gas Withdrawal

1. Gas withdrawal vaporizer
2. Liquid withdrawal valve
3. Economizer regulator
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5. Inner tank rupture disk
6. Pressure gauge
7. Pressure relief valve
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9. Pressure building valve
10. Liquid level gauge
11. Gas withdrawal valve and integral check valve
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Pressure Building Circuits

- Designed to maintain constant supply of liquid or gas over prolonged periods of use.
- Dewars without pressure builders are not designed for continuous withdrawal
- Pressure builders are set to operate below safety pressure ratings
Pressure Building

1. Gas withdrawal vaporizer
2. Liquid withdrawal valve
3. Economizer regulator
4. Vent valve
5. Inner tank rupture disk
6. Pressure gauge
7. Pressure relief valve
8. Pressure building regulator
9. Pressure building valve
10. Liquid level gauge
11. Gas withdrawal valve and integral check valve
12. Check valve in house line
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Economizer Circuit

- Set at 25 PSIG above pressure building builder setting
- Releases excess pressure buildup into gas use valve.
- Attempts to keep pressure from reaching safety setting which would allow release of gas to atmosphere
**The Economizer**

1. Gas withdrawal vaporizer
2. Liquid withdrawal valve
3. Economizer regulator
4. Vent valve
5. Inner tank rupture disk
6. Pressure gauge
7. Pressure relief valve
8. Pressure building regulator
9. Pressure building valve
10. Liquid level gauge
11. Gas withdrawal valve and integral check valve
12. Check valve in house line
13. Outer tank rupture disk
14. Pressure building vaporizer

**Pressure Relief**

- Pressure relief valve to prevent building pressure above desired use and DOT rating of Dewar.
- Rupture disc in case of failure of relief valve

Call 911?

Normal Operation is to vent periodically.
Monitoring

1. Gas withdrawal vaporizer
2. Liquid withdrawal valve
3. Economizer regulator
4. Vent valve
5. Inner tank rupture disk
6. Pressure gauge
7. Pressure relief valve
8. Pressure building regulator
9. Pressure building valve
10. Liquid level gauge
11. Gas withdrawal valve and integral check valve
12. Check valve in house line
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Pressure Relief

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2. Liquid withdrawal valve
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14. Pressure building vaporizer
Safety & Cryo Supplies Items Available from Airgas

THANK YOU!
And be Safe!

Lab Design & Engineered Solutions