Best Practices for the Transportation of Cryogen Dewars

Purpose: This document serves to provide guidance and outline best practices for the transportation of dewars containing cryogenic materials in the University of Iowa Chemistry Building.

Hazards Associated with Transporting Cryogens

Non-flammable cryogens, such as liquid nitrogen (LN2), are hazardous materials due to their extreme cold properties (boiling point below -150 °C), asphyxiation risk, and potential for pressure buildup and explosions. Brief contact with cryogenic materials can lead to soft tissue damage or frostbite, and prolonged contact can lead to the development of blood clots. LN2 expands 695 times in volume when it vaporizes and can easily displace oxygen in confined spaces if enough LN2 is vaporized. Gaseous nitrogen is colorless, odorless, and tasteless, making leaks difficult to detect without appropriate monitoring systems. A reduction in oxygen content of the air to 12-19% can lead to symptoms of fatigue, loss of coordination, and errors in judgement. Reduction in oxygen content to 12% or less can lead to rapid loss of unconsciousness and asphyxiation. These qualities are particularly important in considering the hazards of transporting LN2 in elevators due to the small, confined area, lack of good air flow within elevators, and potential to become trapped in the elevator with the cryogen dewar if the elevator malfunctions.

Best Practices for Transporting Cryogens

Personal Protective Equipment (PPE). Appropriate PPE should always be worn when handling or dispensing cryogenic materials. Cryogenic liquids are prone to splashing due to their large volume expansion ratio. Chemical splash goggles and face shield should be worn. Loose-fitting thermal insulated or leather gloves, long-sleeved shirts, pants without cuffs, and closed-toed shoes that will not soak in the liquid in case of a spill (leather/non-woven material instead of mesh) should be worn when handling cryogenic materials. Nitrile gloves are not sufficient PPE for handling cryogenic materials as they can trap cryogenic materials between the glove and your hand.

Safe Transport to Labs. Cryogenic materials should only be transported in containers that are approved for cryogen storage. Materials such as carbon steel, plastic, and rubber become brittle at LN2 temperatures (-195 °C). They should also only be stored in containers with loose-fitting lids as tightly sealed containers will build up pressures to dangerous levels. Dewars should only be filled to 80% capacity to prevent excessive pressure buildup. Large cryogenic liquid containers should be moved using a hand truck or cart that can keep them upright to prevent spills and tipping hazards.

Additional safety precautions should be taken when transporting cryogenic materials on elevators. Cryogen dewars should be transported in freight elevators as opposed to passenger elevators when possible. Quantities of LN2 that cannot reduce the concentration of O_2 in the air to lower than 19.5% are acceptable to travel in an elevator accompanied by people. **For the elevators in the chemistry building, this is 0.5 L for the Freight elevator, and 0.4 L for the East and West passenger elevators** (see Appendix 1 for volume calculations). When transporting volumes of LN2 greater than these amounts, cryogens should be transported in elevators *without people* (i.e. unaccompanied).

To transport an unaccompanied dewar on the elevator, a sign warning other people to not enter the elevator must be clearly posted. Ideally, transporting unaccompanied cryogen dewars on an elevator should involve two people. The first person will post the warning sign and send the elevator to its destination floor. The second person will receive the cryogen dewar at its destination floor and de-post the warning sign.

If a spill of cryogenic materials in the elevator does occur, press the button to stop at the nearest floor. Block the elevator door open so that it cannot move to the next floor. Notify your supervisor and contact EHS at 319-335-8501 and ask for Rick Byrum (primary contact) or Justin Newnum (secondary contact) for spill response guidance or 911 in case of emergency. For large volume spills, alert others in the area to evacuate.

References:

National Research Council. 2011 *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, Updated Version.* (Book)

Warzyniec, Ed. "Safe Handling of Compressed Gases and Cryogenic Liquids." *Chemical Health & Safety* 7, no. 3 (2000/05/01 2000): 34-36. https://doi.org/10.1016/S1074-9098(00)00081-2. https://doi.org/10.1016/S1074-9098(00)00081-2.

University of Iowa EHS- Liquid Nitrogen Handling

Lawrence Berkley National Lab EHS- Cryogens, Published on May 1, 2018 by Candace Flores

Cornell University EHS- 16.10.3 Handling Cryogenic Materials on Elevators

Example of Oxygen Depletion Calculations, Monash University

Appendix 1. Calculation for LN2 Volume Transport Limits:

Utilizing an Oxygen Depletion Calculation with a resulting oxygen concentration of 19.5%

$$\%O_2 = 100 \times \frac{\left(0.2095 \times \left(V_r - V_g\right)\right)}{V_r}$$

$$V_r = room\ volume\ (m^3)$$

$$V_g = maximum\ gas\ release\ (m^3)$$

$$V_g = V_r - \frac{\left(\frac{\%O_2}{100}\right) * V_r}{0.2095}$$

Elevator	Dimensions (ft)	V_r (m^3)	V_g LN2 to reduce O_2 content to 19.5% (L)
Freight	8'x5'x7'	7.92	0.54
West	5'x6'x7'	5.95	0.41
East	5'x7'x7'	6.94	0.48

Oxygen Depletion Calculation from Monash University

Example of Oxygen Depletion Calculations

Nitrogen is the main component of air and is present at approximately 78% by volume, the other major components being oxygen, approximately 21% and argon, approximately 1%. Depletion of the concentration of oxygen can have an effect on life. An atmosphere containing less than 18% oxygen is potentially hazardous and entry into areas with atmospheres less than 20% oxygen is not recommended. Asphyxiation due to low oxygen concentrations is often rapid and with no prior warning.

If you are using liquid nitrogen or non-hazardous compressed gases (DG class 2.2) in cylinders, you should be aware of the potential for oxygen depletion in the work or storage area. This can be calculated, typically assuming that all power to ventilation systems has failed (eg in a fire or a blackout) and a sudden spillage of liquid nitrogen or release of gas.

Resulting Oxygen Concentration (%):

$$\%O2 = 100\ X\ \frac{0.2095\ x\ (Vr - Vg)}{Vr}$$

Vr = room volume (m^3)

Vg = maximum gas release (m^3)

A G size cylinder of an inert gas contains approximately 6-8 m^3 of gas. For liquefied gases, the expansion ratios are – N_2 678, Ar 824, He739, ie 1 L of liquid nitrogen produces 678 L of or 0.678 m^3 of gas.

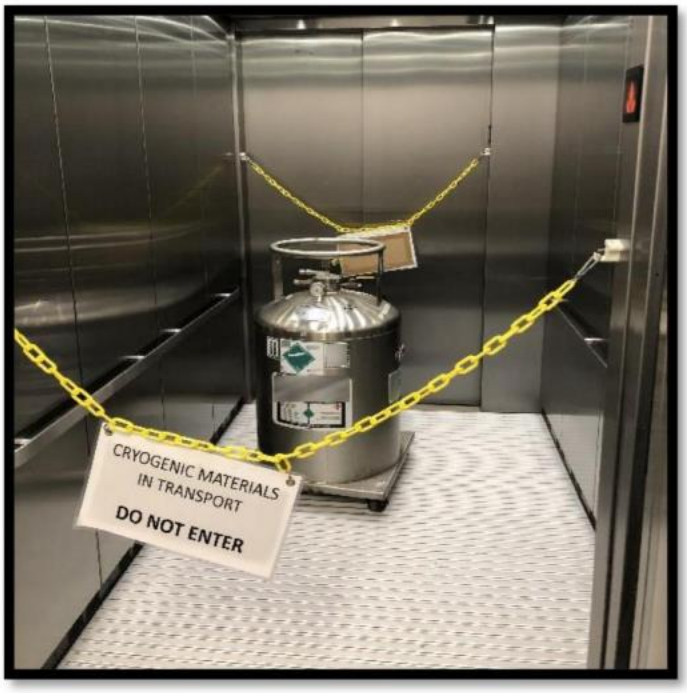
A typical laboratory in the School of Chemistry is approximately 250 m^3 (eg level 1, 109-125 and 152-173) is *ca* 8.75 x 7.5 x 3.0 m (ie Vr = 200 m^3) or in GCF (eg level 3, 302-306 and 310-315) is *ca* 6.25 x 12.50 x 3.5 m (ie Vr = 270 m^3)

A 25L dewar of liquid nitrogen would produce 25 x 0.678 = 16.95 m^3 of gas (Vg).

Therefore:

$\%O_2 = 0.2095\ x\ (250 - 16.95)/250 = 19.5\%$

Appendix 2. Potential Options for Elevator Signage:



CSARS had discussed utilizing some sort of physical barrier like a chain or rope that can be moved back and forth on the elevator entrance using a magnet. This way people are less likely to ignore the sign and ride the elevator anyways.

This is an example of an elevator sign used by the University of Illinois at Urbana-Champaign. Including an area where you need to write which group/person is handling the transport may be useful in case they need to be contacted for any reason. A dry-erase marker will need to be included with the sign.

Appendix 3. Guidance from other institutions:

- General guidance for transporting dewars containing cryogenic materials on elevators is that people should not ride the elevator with the dewar inside, as it is an asphyxiation/fire/explosion hazard due to poor air circulation inside elevators and if you become trapped in the elevator with the dewar. You should also post a visible sign to warn others to not enter the elevator while the dewar is present. If possible, two people should transport the dewar so that one person can send the elevator to the appropriate floor and the other can receive the dewar on the appropriate floor.
- Lawrence Berkley National Lab
    - **Elevators: Additional Safety Precautions**

    - The transportation of cryogenic liquids in elevators represents a potential asphyxiation and fire/explosion risk if workers become trapped in an elevator with a dewar of cryogen. Additional safety precautions include:
    - People must not ride in an elevator in which large cryogen dewars are being transported.
    - When large dewars are transported in an elevator, a clearly visible sign must be used to warn staff and students not to enter the elevator while the dewar is present. After the dewar reaches its destination, the person transporting the dewar will remove the dewar from the elevator and return it to normal service.
- Cornell EHS
    - There is typically little or no fresh air supplied inside of elevators. Cryogenic materials displace air. To avoid a situation in which there is insufficient breathable air, the following are expected in Cornell buildings:
    - Quantities up to 5 liters of a cryogenic material are acceptable to travel in an elevator accompanied by people.
    - Quantities greater than 5 liters of cryogenic material must be transported on an elevator unaccompanied as it travels between floors. **Do NOT transport a pressurized container in an elevator with any person/s in the elevator car.**
    - Transport in a freight elevator, if possible.
    - Post a sign on the vessel in the elevator reading "**DO NOT ENTER – CRYOGEN ASPHYXIATION HAZARD**" to warn potential passengers.
    - Have another person available on the receiving floor to take the container off the elevator at its destination.
    - Beware of tipping the vessel while moving on or off the elevator. This is especially important for uncapped dewars of liquid nitrogen.
        - Wear insulated cryogen safety gloves, safety goggles, long shirt, and long pants without cuffs. Wear footwear that will not soak in the liquid in case of a spill (e.g., leather instead of woven mesh).
        - In case of a spill of any quantity on an elevator:
        - Press the button to stop at the nearest floor;
        - Block the elevator door open so that it doesn't move to the next floor;
- Ames National Lab
    - Cryogenic materials shall not be accompanied by personnel when transported by elevator. An oxygen deficient atmosphere could occur if the cryogen is released in the elevator.
- University of Michigan EHS
    - Use no fewer than two personnel to transport cryogenic liquids in large Dewars and cryogenic liquid cylinders; use handcarts equipped with brakes.

    - Never transport cryogenic liquids on an elevator with live passengers. When transporting cryogenic liquids via elevator the sender should remain outside the elevator, push the button for the desired floor and let the doors close. Another person should be ready on the receiving floor to take the container off the elevator. All elevator doors from the starting floor to the floor of the final destination should be manned to prevent entry by anyone between floors.
- Iowa State University Safety Poster
    - Avoid transporting cryogen dewars alone, and choose the smoothest route to minimize risk of tipping
    - Never ride in an elevator with a cryogenic liquid container
- University of Wisconsin-Madison EHS
    - Cryogenic liquid containers should always be moved using a hand truck, cart, or another suitable transportation device. It is essential to secure containers during transport and keep them upright at all times to prevent spills and maintain safety. When transporting inert cryogenic liquids by elevator, it is important to carefully evaluate routes and procedures to ensure safe movement. In the event of a power failure, a passenger could become trapped in the confined elevator space with the cryogenic containers. As the liquids evaporate, oxygen displacement may occur, creating a hazardous environment. For this reason, best practice is to transport cryogens only in unoccupied elevators. Ideally, two people should be involved in the process: one to load the container into the elevator and another to receive it on the destination floor.

Effects of Oxygen Deficiency

Oxygen Levels (%)	Symptoms of Exposure
19.5	Minimum acceptable oxygen level.
15 to 19	Decreased ability to work strenuously. Impaired coordination. Early symptoms.
12 to 14	Breathing rate increases, increase in heart rate. Impaired coordination, perception, and judgment.
10 to 12	Breathing further increases in rate and depth, lips turn blue. Poor judgment
8 to 10	Mental failure. Fainting. Nausea Unconsciousness. Vomiting.
6 to 8	8 minutes - fatal, 6 minutes - 50% fatal, 4-5 minutes - possible recovery.
4 to 6	Coma in 40 seconds, Convulsions, Breathing stops, Death

Figure 1: Typical Symptoms of Oxygen Depletions

- University of Illinois Urbana-Champaign Division of Research Safety
    - Wear cryogenic gloves and eye protection when transporting containers. Never tip, slide, or roll them on their side. Keep containers vertical at all times. Avoid mechanical or thermal shock. Always push containers on wheels. Pulling can cause injury if they tip and fall on you.
    - Use appropriate carts when moving heavy containers with no wheels and always secure the container during transport.

Do not transport containers holding cryogens inside elevators at the same time as people. Put the container into the elevator and place a sign on it the cylinder facing the door "Do not enter elevator, asphyxiation hazard" (Elevator Sign). Send the elevator to the desired floor and have somebody there to pick it up. It is best to use service elevators with good ventilation (e.g., with screen walls or doors).

Additional CSARS Recommendations:

We suggest posting an infographic (that we can help to develop) of the elevator transport steps in the gas cylinder room as well in the elevator.

We suggest that this information is communicated to the Safety Liaisons as well to disseminate it to the research groups.

We also suggest posting this information on the CSARS website.