# Transporting Dangerous Substances in Lifts

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**Abstract**. Hospitals, Universities and Research Laboratories often need to transport liquid Nitrogen and other hazardous substances in lifts. Passengers are at unacceptably high risk if they travel along with these substances and employers have a duty to avoid employees being put at risk. The paper examines the design features required for a lift, management arrangements and training requirements to establish a safe system of work for these situations. The paper concludes that a code of practice is required to set best practice for what is currently dealt with on an ad hoc basis.

## 1 INTRODUCTION

There are many organisations which rely on lifts to transport dangerous substances around their buildings. Some substances when contained by appropriate measures present little danger to passengers travelling with them in a lift. Some substances, however, are so volatile that any risk of compromised containment will lead to serious injury or fatality. At first glance it may appear that such cases are rare and the numbers of lifts involved are few; however, as every Hospital, University College, Research Facility, Chemical plant etc. may carry these substances in lifts it quickly becomes apparent that the problem is common and control measures to mitigate these risks must be addressed. The objective of this paper is then to make suggestions which will ensure that passengers cannot travel in lifts with dangerous substances and these suggestions may in time be developed into a Code of Practice.

Cryogenic gases fall into the category of substances which are dangerous for passengers to accompany in a lift. A common example of a cryogenic gas is Liquid Nitrogen. This demonstrates unacceptable hazards to passengers travelling in a confined space such as a lift car for the following reasons.

The properties of liquid Nitrogen create four distinct hazards [1]:-

1) Because the liquid-to-gas expansion ratio of nitrogen is 1:694 at 20 °C (68 °F), a tremendous amount of force can be generated if liquid nitrogen is rapidly vaporized in an enclosed space. In an incident on January 12, 2006 at Texas A&M University [1], the pressure-relief devices of a tank of liquid nitrogen were malfunctioning and later sealed. As a result of the subsequent pressure build up, the tank failed catastrophically. The force of the explosion was sufficient to propel the tank through the ceiling immediately above it, shatter a reinforced concrete beam immediately below it, and blow the walls of the laboratory 0.1–0.2 m off their foundations. Clearly damage to a lift car would also be catastrophic.
2) As liquid nitrogen evaporates it reduces the oxygen concentration in the air and can act as an asphyxiant, especially in confined spaces such as a lift car. Nitrogen is odourless, colourless, and tasteless and may produce asphyxia without any sensation or prior warning. In these incidents, asphyxiation is usually sudden. The victims inhale air with little or no oxygen content, causing immediate collapse into a layer of dense, cold, nitrogen-enriched air. Unconsciousness followed rapidly by death is inevitable without

immediate rescue and resuscitation. Rescue attempts often result in the rescuers being overcome as well. Smaller leaks or spills, or normal boil-off from liquid nitrogen containers in confined spaces such as lift cars may give rise to lesser reductions in oxygen content, but they may still carry a risk of asphyxiation.

3) Because of its extremely low temperature, careless handling of liquid nitrogen and any objects cooled by it may result in cold burns. In that case, special gloves should be used while handling. However, a small splash or even pouring down skin will not burn immediately, because the evaporating gas thermally insulates to some extent, like touching a hot element very briefly with a wet finger. If the liquid nitrogen pools anywhere, it will burn severely. As it is heavier than air it would probably accumulate on the floor of a lift car and add to the suffering of anyone laying there through asphyxiation.
4) Vessels containing liquid nitrogen can condense oxygen from air. The liquid in such a vessel becomes increasingly enriched in oxygen (boiling point 90 K; −183 °C; −298 °F) as the nitrogen evaporates, it can cause violent oxidation of organic material. It also causes structural damage to steel.

The conclusion of any risk assessment is that the only acceptable preventative measure to control the risks is to not allow passengers to travel with these dangerous substances. The objective of this paper as previously stated is to make suggestions which will ensure that passengers cannot travel in lifts with dangerous substances and these suggestions may in time be developed into a Code of Practice.

The British Compressed Gases Association has already published a code of Practice CP30 THE SAFE USE OF LIQUID NITROGEN DEWARS UP TO 50 LITRES Revision 2: 2013 [2].

The advice provided by the guide is as follows:-

“8.2.1 The use of lifts when transporting Dewars

Transporting Dewars containing liquid nitrogen in an occupied lift is hazardous and should be avoided whenever possible. The main hazards are the operation of the safety relief device on the liquid withdrawal unit, liquid splashing or boiling liquid vaporising into the lift, creating an oxygen-deficient atmosphere. The majority of lifts have small internal volume and therefore the effects of oxygen deficiency could overcome a person in the lift in a relatively short time. Spillage of liquid nitrogen can cause embrittlement and subsequent failure of certain materials, e.g. carbon steel. If liquid nitrogen is spilled onto a lift floor, the lift should subsequently be checked for mechanical damage. When it is necessary to move a Dewar to another floor in a building using a lift a detailed risk assessment must be carried out to establish the potential hazards that may occur and to identify the risk mitigating procedures to ensure the safety of the operator or the any other person who potentially could use the lift. The preferred method of transporting a Dewar in a lift is to use a key operated lift that permits the Dewar to be carried unaccompanied in the lift and prevents any other person from getting into the lift with the Dewar. Dewars should be transported unaccompanied in key operated lifts.
Where this is not possible to use a key operated lift, a detailed risk assessment in accordance with the Management of Health and Safety at Work Regulations and the Confined Spaces Regulations shall be carried out and suitable procedures established. The risk assessment should take into consideration how other personnel could enter the lift, the type of Dewar being moved and the potential for liquid nitrogen being spilt. Refer to BCGA TIS 27, Model risk assessment for the safe use of liquid nitrogen Dewars.

Where the use of lifts cannot be avoided, one or more of the following (in order of preference) shall be adopted:

i. Dewars shall only be filled to 90 % of the net capacity to reduce the risk of spillage.
ii. Dewars fitted with liquid withdrawal devices shall be vented to less than half the relief-valve set pressure.
iii. Only an operator who has received suitable training shall be allowed in the lift during the transportation of Dewars containing product.
iv. The operator should have a fully functional oxygen depletion monitor that will warn him when the oxygen level has depleted to 19.5 %, allowing immediate evacuation from the lift before a dangerous level is reached.
v. The operator shall have control of the lift to enable immediate evacuation at the next available floor, in the event of an escape of product.
vi. The lift shall be fitted with an emergency alarm /telephone.
vii. If the lift is equipped with an extraction fan it should be switched on before the operator takes the Dewar into the lift.

In addition to the above, the following rules should be rigorously applied:

viii. Do not transport in a lift a Dewar that is venting gas; this especially applies to Dewars that have just previously been filled.
ix. Do not vent Dewars whilst in a lift.
x. Do not transport a leaking or defective Dewar in a lift.
xi. Do not transport in a lift a Dewar that has ice forming on the outside.
xii. Do not transport an overfilled Dewar in a lift.

The transportation of Dewars in lifts containing product should be supervised /monitored outside the lift by a competent person who is aware of the potential hazards and of the action to take in an emergency."

Whereas the Code offers sensible advice on the handling precautions it is somewhat deficient in the detail necessary to create a suitable lift control design. For example, on page 12 of the code it states:

"8.2.2 Stairs and doorways

Stairs present an increased tripping hazard, which may lead to a nitrogen spillage.

Where possible, avoid carrying Dewars upstairs or steps. If the negotiation of stairs is unavoidable:

(i) Two people are recommended for carrying the Dewar.
(ii) Consider the installation of a stair lift where practical."

Stannah Stairlifts however would not recommend this deviation from a stair lift's design as a passenger carrying device.

## 2 DESIGN CONSIDERATIONS FOR LIFTS

### 2.1 Tanks

If we consider the tanks that used to transport cryogenic gasses that are likely to be carried in lifts we find that they are usually in vessels called Dewars as stated in CP30. Dewars are insulated flasks which carry up to 50 litres of liquid. The maximum weight of this type of container is about 56 Kg and its size is about 850mm high with a diameter of 400mm.

**Figure 1 Dewars**

### 2.2 Service Lifts

A simple dedicated floor loading service lift designed to BS EN 81-3 [3] could be provided as a dedicated method of moving these dangerous substances. With a car size of 1000mm wide X 1000mm deep X 1200mm high and a rated load of 250Kg up to four Dewars could be carried simultaneously. The car height and the lack of car controls would make the probability of a passenger being able to accompany the goods very small in fact it could be considered “Highly Improbable”. The installation of dedicated service lifts should be considered as a safe and probably a most cost effective solution in most cases in building up to 4 or 5 floors. The floor plan needed for the installation of such a device is approximately 1.5 metres square.

However, many existing buildings do not have dedicated service lifts, and in many cases there are valid reasons why they cannot be retrospectively installed. It is therefore necessary to consider design features which may, when suitably combined, provide an equivalent level of safety to that of a Service Lift.

### 2.3 Passenger Goods Lifts with Manual or semi-automatic doors/gates.

Lifts of this type can only travel once the car and landing doors have been closed which requires a deliberate action. The possibility of unintended travel in the lift with the dangerous substance is therefore significantly reduced. The main focus is to establish a car preference control which cancels or ignores any landing calls. This method of control can be easily established by the use of a security card triggering a card reader, or a key operated switch positioned on the car operating panel.

The safety of operation of this type of lift control system may therefore assume that the Trained and Authorised person in charge of the transportation of the substances will not chose to risk travelling in the lift. However, Lift Designers should not make that assumption. Work pressures, time management, and, in particular, familiarity with working with dangerous substances can easily make fools of us all in time. Familiarity breeds contempt and Lift Designers should therefore augment their designs to protect the contemptuous as well as the hapless and even accidental companions to dangerous substances travelling in lifts.

The objective of any suitable solution is to stop a lift loaded with a dangerous substance closing its doors and travelling to any floor other than its intended preselected destination, and then only to open or allow the doors to be opened at the destination floor once a trained and authorised person is there to unload it.

## 2.4 Passenger Goods Lifts with Automatic doors

There is no existing guidance for lift companies to follow, and as a result each company provides a solution for its clients on an individual basis, usually based on the requirement as defined by the client. The most common solution is provided by a series of key switches which provide a simple call and send function at the main access level. This type of system requires two trained and authorised staff on at both departure and arrival floors, and a method of communication between them. A better and more robust solution is required.

If the design is developed to cover Passenger Goods lifts with manual or semi-automatic doors then further development of a design for automatic doors should be a simple next step solution as proposed and detailed below. The features required by this design are:-

a) Selection and implementation of a “special service” feature including audio-visual confirmation thereof.
b) Cancelling or suspending all existing car and future landing calls other than selected under special service for the duration of the special service.
c) Registration of a single or possibly multiple special service calls.
d) Parking at the departure landing with car and landing doors open to allow for loading materials into the lift and exiting the lift car by all passengers.
e) Continuous operation of the departure floor landing push button to allow the doors to close and reversing the landing and car doors if the continuous pressure on the landing button is not maintained until the door close limit is broken, thus enabling travel of the lift car direct to the destination floor. Audio visual warning of these actions should/could be included by the car indicator and voice annunciator.

Continuous operation of the destination floor landing push button to allow a similar functionality required by firefighting lifts under EN81-72 [4] the so called “peek a boo” type operation to open the landing and car doors at the destination floor except in this instance the failure to maintain constant pressure on the destination floor landing button would result in the closing of the doors. Audio visual warning of these actions again should/could be included, as before. This would give the operator the opportunity of checking oxygen depletion levels before entering the lift car to unload the materials.

Once opened the car and landing doors remain open until the lift is unloaded and special service control is disengaged via the security card or key switch and normal service is resumed.

## 3 ADDITIONAL SAFETY CONSIDERATIONS, EVENTS AND SCENARIOS

3.1 There are some residual risks which given the severity of the hazard may in certain environments or under certain scenarios may need to be addressed for example:-

a) Two complacent or careless operators working together - one who is operating the landing controls whilst the other deliberately or accidentally remains in the lift car.
b) Lifts operating in a busy public access environment where potential passengers may not be aware of the risks in traveling in a lift with an unknown substance.
c) Potential passengers at the destination floor ignore the landing and car indication and maintain pressure on the destination landing push button opening the car and landing doors and entering the lift without checking for oxygen depletion.

3.2 There are residual risks to the structure of the lift from spillages which will require additional inspections after any such incident before the lift is put back in to general use.

3.3 There are additional risks working in the lift pits or car tops of lifts used to carry dangerous substances.

3.4 There are other less likely but more serious implications of the effects or consequences of a serious lift fault such as the high-speed operation of the safety gear and the rescue of materials from the lift car.

Risk assessments for these 4 considerations should be carried out on a project by project basis in the format of ISO 14798 [5]. For substances other than Cryogenic gases separate risk assessments could also be required.

### 3.5 Additional safety features

The solution to 3.1a and b would be by installing equipment to detect the presence of a passenger remaining in the lift car once the goods had been loaded. A combination of additional sensors such as PIR’s and detection of the incorrect sequence of other existing signals such as safe edge detector operation, changes in loading sensing devices readings. Another simple mechanical method would be to install a retracting full width roller blind just under the car handrail height to effectively temporarily partition off the lower half of the lift car. The blind could be electrically interlocked at its retaining point thus preventing a passenger travelling without the blind in place. This measure would also be a partial solution to scenario 3.1c.

Structural surveys of the car floor and car sling after a substance spillage would have to be conducted by a competent person, who would require additional knowledge of the properties of the substance spilt and be equipped with a safe system of inspecting those areas. This is essentially a problem to be resolved by an appropriate management system.

Persons working on lift maintenance on lifts used to carry dangerous substances may require appropriate PPE and oxygen depletion sensors but again this is a management issue to establish a safe system of work.

Additional consideration of emergency release procedures in case of the entrapment of dangerous substances is required. Where there are a range of substances involved or handing of the substances involves particular risks and control procedures it would be prudent to train scientific staff in lift release as teaching lift staff science is a more daunting prospect! Such training should be site specific well documented assessed and repeated at regular intervals. Guidelines for the training of such staff are referred to in HTM08-02 [6].

## 4 CONCLUSIONS

As an Authorising Engineer for Lifts for several NHS Trusts and having worked with a number of Educational Institutions I have seen a range of design features applied to modify Passenger Goods lifts for carrying dangerous substances. No two solutions however appear to be the same and whilst Management systems are generally in place they do not always cover all the likely risk presented by realistic scenarios. The design solutions tabled in this short paper are intended to provoke a discussion on this subject and out of that discussion a plan put in place to develop a Code of Practice for transporting dangerous substances in lifts. The code of Practice should additionally define the extent of hazardous scenarios and events and correlate the escalation procedures required by a suitable management system. The Code should also propose the additional training that is required by all the duty holders involved.

## REFERENCES

[1] Wikipedia, Cryogenic Gases

[2] The British Compressed Gases Association, CP30 the safe use of liquid nitrogen Dewars up to 50 litres revision 2: 2013

[3] BSEN 81-3 2001 Safety Rules for the construction and installation of electric and hydraulic service lifts

[4] BSEN 81-72 2015 Safety Rules for the construction and installation of lifts – Fire fighters lifts

[5] ISO 14798 2013 Lifts Escalators and Moving Walks Risk Assessment Methodology

[6] Barney et al, Healthcare Technical Memorandum HTM08-02 2015.

### BIOGRAPHICAL DETAILS OF THE AUTHOR

Michael Bottomley joined MovvéO (formerly Lerch Bates in 2002) after working for Gregson & Bell Lifts for 21 years. He holds a degree, with honours, in Engineering and Marketing from the University of Huddersfield, and has over 36 years experience in lift engineering and lift design. In 1999 he was the second lift designer in the UK to achieve Notified Body approval under the Lifts Regulations 1997. He is an affiliate member of the Chartered Institute of Building Service Engineers (CIBSE) and is currently Vice Chairman and a Past Chairman of the CIBSE lifts group. He is a contributory Author to the 2015 edition of HTM 08-02.