THE UNIVERSITY OF SYDNEY

Laboratory Gas Services Standard

Design, Engineering, Planning and Sustainability

University Infrastructure

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1 Purpose

The Lab Gas Services Standard sets out the University of Sydney's minimum requirements for the design, construction and maintenance of Lab Gas services. It ensures new and refurbished systems are energy efficient, fit-for-purpose, made from durable good-quality materials, contain no or minimal environmentally harmful substances, and are cost effective to operate and maintain safely.

Applicable requirements documented in Workplace Health and Safety (WHS) legislation, Disability Discrimination legislation, State Environmental Planning legislation, Commonwealth and State legislation, National Construction Codes (NCC), the Building Code of Australia (BCA) and Australian and New Zealand Standards (AS/NZS) are the minimum and mandatory compliance requirements.
word 'shall' used within this document is defined to mean to be implemented and verified.

Where any ambiguity exists between this standard and the aforementioned mandatory requirements then:
a. The highest performance requirements shall apply.
b. Applicable requirements shall follow this order of precedence:
    1. Workplace Health and Safety legislation.
    2. Safety in Design Legislation.
    3. Disability Discrimination legislation.
    4. State Environmental Planning and Assessment legislation.
    5. All other Commonwealth and State legislation.
    6. NCC, BCA and PCA.
    7. AS/NZS.
    8. This standard and other University of Sydney standards.

2 Scope

This standard describes minimum requirements for design, purchase, construction, and operation and maintenance of lab gas services plant, equipment and infrastructure for buildings and spaces owned, operated, maintained and/or managed by the University of Sydney. It applies to:

a. New Building Construction.
b. Refurbishment spaces within existing buildings
c. Facilities maintenance services.

The standards apply to all planners, project managers, consultants, contractors, sub-contractors, tenants, managing agents and University staff involved in the design, construction and maintenance of existing, new and proposed University buildings and facilities.

The standard provides:
a. A reference document to enable consistency with the design and engineering objectives.
b. Details of the minimum performance requirements for planning, design and maintenance.
c. Support of the University vision for the built environment and best practice.

The standard addresses key objectives:
a. Quality design which responds, enhances and complements the environment.
b. Appreciation of the heritage context and cultural history of the campuses.
c. Value for money in all aspects of the project.
d. The design of low maintenance buildings and environments.
e. Longevity of construction approach to design.
f. Standardization of key fittings and ancillary details.
g. Flexible design, to future proof building usage for expansion or adaption to new uses
h. Safety in design.

All Lab Gas systems products and services provided or specified by designers, consultants, staff and contractors shall conform to this standard.

Where specific applications are not explicitly covered, or ambiguity exists, the intent of the design standard shall be satisfied. In such cases a return design brief shall be provided for review by the designers and approval by the issuer of this standard or their appointed delegate who shall have relevant technical competence in the subject matter. Additional more stringent requirements may apply on a project-specific basis dependent upon risk management and insurance requirements.

3 Glossary of Terms

AS/ NZS	Australian Standards/ New Zealand Standards
AUMS	Advanced Utility Metering System
BACnet	ANSI/ASHRAE standard that specifies a common communication protocol that allows building systems to communicate with each other using a common language.
BCA	Building Code of Australia
BMS/ BMCS	Building Management Control System (Non safety control system for control of air conditioning and other building controls)
CMS	Central Monitoring Station
COS	Central Operations Services
EMI	Electromagnetic Interference
EMO/EPO	Emergency Off/ Emergency Power Off
EP&AR	Environmental Planning & Assessment Regulation
ESS	Emergency Services Supply (generator backed up power supply)
FAT	Factory Acceptance Test
FRL	Fire Resistance Level
HAZOP	Hazard and Operability Study
HP	High Purity
HMI	Human Machine Interface
IQ	Installation Qualification
ITP	Inspection and Test Plan
LSS	Life Safety System
LOPA	Layers of Protection Analysis
LEL	Lower Explosive Limit (flammable gas)
NCC	National Construction Code
OEM	Original Equipment Manufacturer
P&ID	Piping & Instrumentation Diagram
PC	Practical Completion
PCW	Process Cooling Water
PUG	Project User Group
QMS	Quality Management System
RRL	Residual Risk Level
SAT	Site Acceptance Test
SFAIRP	So Far As Is Reasonably Practicable

SGSP	Science compressed Gases and cryogens
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
TOR	Tolerability of Risk
TSS	Technical Support Services
UHP	Ultra-High Purity
UI	University Infrastructure
UPS	Uninterruptable Power Supply (Battery Backed up Supply)
VDI	Vendor Document Index
WHS	Work Health & Safety

4 Roles and Responsibilities

This standard is issued by UI. It is approved and signed off by the Chief University Infrastructure Officer. UI is responsible for maintaining the standard and keeping it up to date.

5 University Context

Due to the complex nature of the University's Infrastructure, the requirements for construction of new buildings, and the refurbishment of existing buildings differ and shall be assessed on a case-by-case basis. Careful consideration shall be taken in relation to connection and disconnection of existing services, and the reuse of existing equipment. This section outlines the construction requirements for both new and existing buildings.

5.1 New Buildings

The Lab Gas services provided in University buildings shall be designed and installed in accordance with the minimum legislative requirements incorporating all Statutory Regulations, Australian Standards, Local Council, Work Health & Safety (WHS) and Safework NSW requirements.

Each building shall be equipped with the appropriate gas monitoring and detection, alarms, all designed and installed in accordance with the relevant Australian standard. Additional measures may also be required to meet specific building hazards and/or the requirements of University Insurers.

The consultant/contractor shall take a long-term balanced view of capital costs, energy costs, maintenance costs and longevity, comparing the capital and operational costs of each proposed solution.

The consultant/contractor will consult with UI, COS, TSS and Project User Groups, to discuss any additional lab gas services that shall be included in the design, in order to suit the proposed occupancy, associated hazards, and the overall exposure risk. Additional measures will be determined via a risk hazard assessment process, incorporating details and issues relating to the safety within the building, including business continuity, consequence of loss and likelihood of loss.

5.2 Refurbishments

All existing lab gas systems in a building shall be extended as necessary into the given project. The design for projects within existing buildings shall be assessed on a case-by-case basis and developed in

conjunction with this standard. The project scope will drive the design requirements and the extent of upgrade of the existing services.

Any items not included in the scope shall not be priced into the overall project to achieve the following aim; To reduce the need to value engineer any services.

It is the responsibility of the consultant/ contractor to obtain the gate paper from the Project Manager to understand the scope of works in relation to the space and fit out requirements. New projects within existing buildings shall assess what the expectation of the refurbishment will be. This will enable the right outcome for the given project to meet the approved budget.

Where identified, all redundant pipework, equipment and wiring, including inaccessible ceiling spaces, shall be removed as part of the project works. Make good exposed surfaces before commencing the installation of new services. This includes the removal of redundant underground services unless otherwise approved by the project superintendent.

5.3 Codes/ Standard requirements in existing buildings

The existing buildings in the University have been constructed under various Building Codes and standards, due to the ever-changing nature of Building Regulations and Australian Standards.

Whilst every endeavor is made to comply with current regulations during refurbishments and upgrades, it is unlikely that the full extent of the building regulations can always be met. Therefore, in many cases involving existing building refurbishment, 'Performance Solutions' and lab gas services upgrade strategies shall be developed in lieu of complying with the 'Deemed-to-Satisfy (DtS) Provisions' of the NCC.

Where 'Performance Solutions' are proposed to be adopted in existing buildings, the requirements listed above, shall also apply. It is also noted that many University buildings have existing 'Performance Solutions'. Where refurbishment occurs within these buildings, the refurbishment works shall be performed in accordance with the existing 'Performance Solution' or it shall be reviewed, updated and re-certified to suit both the refurbishment works and the remainder of the building.

Within any building proposed for refurbishment, the Standard of Performance for all existing Lab Gas services shall be reviewed by the consultant/contractor for compliance with the current NCC and Australian Standard requirements. The details of this review together with a proposed Lab Gas services upgrade strategy shall be submitted to UI for approval during the initial design development.

6 Technical Requirements

6.1 Introduction

The Laboratory gas services of a University building may include surrounding structures and annex buildings. In some cases, components of the Lab Gas System will be installed or are to be installed in other buildings. In these cases, the word building in this document shall be interpreted as inclusive of these structures, annexes and components. For clarity, in the University setting medical gas is also considered laboratory gas and must adhere to this standard.

6.2 Design and Documentation

6.2.1 Design Approach

The University expects consultants and contractors to provide designs that meet the project briefs. The following are priorities that consultants and designers shall consider in their designs:

- Take a long-term balanced view of capital costs, energy costs, gas efficiency, maintenance costs and longevity.
- As educational and research both progress at rapid rates, usage of buildings and areas within buildings are subject to multiple changes within the life of the building, systems shall be designed to be adaptable for such changes.
- Ensure that plant and equipment are designed with safe access, plant replacement and visual impact taken into consideration.

It is the designers and the installing contractor's obligation to document and install systems, equipment and materials that are "fit for purpose" from both a WH&S and operational perspective. Any disputes in regard to the interpretation of this clause shall be referred to NSW Fair Trading and/or the UI Project Manager for a final determination.

6.2.2 Design Inputs and Process

The University expects consultants and designers to proactively inform, advise and contribute to the design process. In particular, the following aspects:

- Building Physics - provide advice to the project team, including other design team members that would improve the inherent building performance, which may lead to reductions in both capital and energy costs. This may initially take the form of simple advice relating to existing infrastructure capacity and location, which may affect the siting of the building, and subsequently backed up by modelling or similar methods. The process may take a number of iterative steps. The consultant or designer is expected to advise, contribute and if necessary, lead such processes.
- Planning and Architecture – provide advice on the appropriate location of plant rooms and reticulation strategy to assist in both the planning of the building and the facilitation of better maintenance in the future. Such advice shall be provided in the early stages of the design and planning process so that this is taken into consideration for the architect's design and to be incorporated into his planning. Late advice will lead to poor location of plant and lack of maintenance access, thus a building of poor quality that will suffer from either poor or lack of maintenance and high owning costs to the University.
- The University of Sydney – provide advice on the availability of options, assist in assessing the advantages and disadvantages, provide analysis of life cycle costs and life expectancies, offer recommendations and assist in making decisions.

6.2.3 Engineering Process

The University expects consultants and contractors to be fully qualified, experienced and capable of carrying out all engineering design, calculations, equipment selection and construction quality checks.

As part of the design development, the University expects consultants and designers to select proven and reliable laboratory gas systems. Where medical gases are proposed, the specific requirements of the Medical Gas act must be adhered to in addition to this standard.

Where large gas systems are installed, the contractor/ consultant must coordinate with mechanical/hvac services for risks to be managed by the monitoring and controls and any lab general exhaust or purge systems.

6.2.4 Equipment Selection and Sizing

In selecting equipment, the University expects consultants and contractors to select products of proven and reliable quality, with reputable support and after sales service.

Products which are of closed systems and proprietary in nature, thus locking the University into exclusive dependence of one manufacturer shall be avoided and only used if there are no other options. University

sign off is required for one manufacturer dependence with the pros and cons fully detailed with associated cost risk provided.

The provision of 20% spare capacity for future use shall be provided when designing and sizing all new lab gas infrastructure, pipework and equipment. In making such considerations careful analysis of spare capacity against the application of diversity and balance shall be considered.

Where existing infrastructure is being used, provision shall be made to ensure sufficient capacity remains for future works in the building. Headers used as central distribution points should include spare take off points (with valves) for future connection. This shall be balanced with performance to provide an efficient system.

6.3 Design Projects

6.3.1 General

This section outlines the extent of the services to be provided by the design consultant during the process of Design. For most projects the design is provided to a level to match the project requirements.

For large projects, the space provisions for bulk tanks, condensers, fill points, risers, valve positions are important aspects of the design to be incorporated before the Lab Gas Contractor is engaged. User briefings for scope elements is also critical.

The consultant shall be fully responsible for the design of the Lab Gas services and any associated safety systems, including the selection, sizes and quantity of equipment, and shall provide calculations and drawings and other documentation as necessary to demonstrate conformance with the design parameters, industry practice, UI requirements, codes, regulations and standards. This includes all calculations required to confirm that existing infrastructure is sufficient to supply the proposed systems and equipment installed under the project.

Provision for a lab gas risk assessment shall be included in the works according to the risk present. High risk scenarios may require additional LOPA, HAZOP or Gas Hygiene studies to reduce the remaining risk so far as reasonably practicable in accordance with University of Sydney policies.

The consultant shall allow to fully co-ordinate the documentation with the Architect, Engineers and all other services consultants / contractors.

The capacity of gas storage and Life safety systems shall be coordinated and agreed with the users for filling/ replacement periods, with adequate space for spares.

6.3.2 Calculations

As part of the consultant's design, it is expected that the following design calculations as a minimum are produced for review by UI for approval prior to finalising design:

a. Equipment selections based on the overall capacities calculated.
b. Capacity calculations inclusive of tanks, evaporators, bottle numbers, manifolds, compressors etc
c. Pipe sizing, flow rates and demand calculations.
d. Electrical sizing, LSS sizing and ventilation requirements calculations.
e. All other calculations necessary to illustrate equipment reticulation and components have been selected fully in accordance with the project requirements.

6.3.3 Drawings and Documentation

The consultant shall provide design drawings to suit the project design phases to communicate the design for approval, tendering, and construction depending on the project.

The consultant is responsible for producing all design documentation, including, but not limited to:

a. Concept/ Tender Design documentation (as required).
b. Detailed Design documentation, including:
    i. Layout drawings for both pipework and safety systems.
    ii. Calculations.
    iii. Pipework Schematics.
    iv. Safety Control Schematics
    v. Design certification
    vi. Performance Based Solutions.
    vii. Specifications.

All design documentation shall be reviewed by UI prior to installation on site.

6.4 Design and Construction Projects

6.4.1 General

This section outlines the extent of the services to be provided by the contractor during the process of Design and Construction.

The contractor shall be fully responsible for the complete design of the Lab Gas services (for every project) and any associated safety systems, including the selection, sizes and quantity of equipment, and shall provide calculations and drawings and other documentation as necessary to demonstrate conformance with the design parameters, industry practice, UI requirements, codes, regulations and standards. This includes design of delivery access (including truck swept path), all calculations required to confirm that existing infrastructure is sufficient to supply the proposed systems and equipment installed under the project.

Provision for a lab gas risk assessment shall be included in the works according to the risk present. High risk scenarios may require additional LOPA, HAZOP or Gas Hygiene studies to reduce the remaining risk so far as reasonably practicable.

The contractor shall allow to fully co-ordinate the documentation with the Architect, Engineers and all other services consultants / contractors.

The capacity of gas storage and Life safety systems shall be coordinated and agreed with the users for filling/ replacement periods, with adequate space for spares.

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b. Capacity calculations inclusive of tanks, evaporators, bottle numbers, manifolds, compressors etc
c. Pipe sizing, flow rates and demand calculations.
d. Electrical sizing, LSS sizing and ventilation requirements calculations.
e. All other calculations necessary to illustrate equipment reticulation and components have been selected fully in accordance with the project requirements.

6.4.3 Drawings and Documentation

The contractor shall provide design, construction and as-built drawings, including design drawings produced by the contractor and shop drawings produced by equipment manufacturers.

The contractor is responsible for producing all design and as-built documentation, including, but not limited to:

a. Concept/ Tender Design documentation (as required).
b. Detailed Design documentation, including:
    i. Layout drawings for both pipework and safety systems.
    ii. Calculations.
    iii. Pipework Schematics.
    iv. Safety Control Schematics
    v. Design certification
    vi. Performance Based Solutions.
    vii. Specifications.
c. Workshop drawings, including:
    i. Drawings to meet manufacture requirements / system installation.

All design documentation shall be reviewed by UI prior to installation on site.

6.4.4 Workshop Submittals

Technical submittals shall be provided with the full technical and spatial requirements of each proposed plant item. The technical submissions shall include, where applicable, but not be limited to:

a. Certified shop drawings of each item complete with sectional weights and point loads.
b. Certified noise levels from each plant item.
c. Electrical requirements including starting current, running current, operational voltage, power consumption, recommended protection devices, wiring diagrams, connection and terminals details. Also detail of how cables are terminated to the plant item and earthing requirements shall be provided.
d. Pump Curves as applicable.
e. Gas bottle or VIE compound usage and delivery calculations.
f. Recommended spares schedules and projected future availability (to ensure that redundant components are not used).
g. Requirements for specialist tools to maintain the plant item.
h. Maintenance zones and requirements including weights of any replaceable components.
i. Manufacturer's recommendations for installation including ventilation and thermal requirements.
j. Confirmation of product lifespan assuming maintained to manufacturers recommendations.
k. Where equipment model numbers / references are stated in a specification these are indicative only and the Contractor SHALL ensure the selected plant fully complies with UI standards.

6.5 Lab Gas Safety Criteria – Tolerability of Risk

For all refurbishments requiring the installation and use of laboratory or medical gases, a risk assessment shall be conducted by the consultant/ contractor based on the proposed installation. For smaller jobs, this will be done by USYD Central WHS. Based on the outcome of this risk assessment, further assessment may be required in order to reduce the risk to occupants to an acceptable level. All risk assessment must be done in accordance with the University of Sydney Risk management framework and tolerability of risk statement.

Where the initial risk assessment results in a low or medium residual risk rating, the installation shall incorporate the recommendations from WHS and potentially a further risk assessment. Where a residual risk rating is High, an additional Gas Hygiene or LOPA study shall be conducted to determine additional local controls required for the space in accordance with USYD policies. This may include SIL rated equipment.

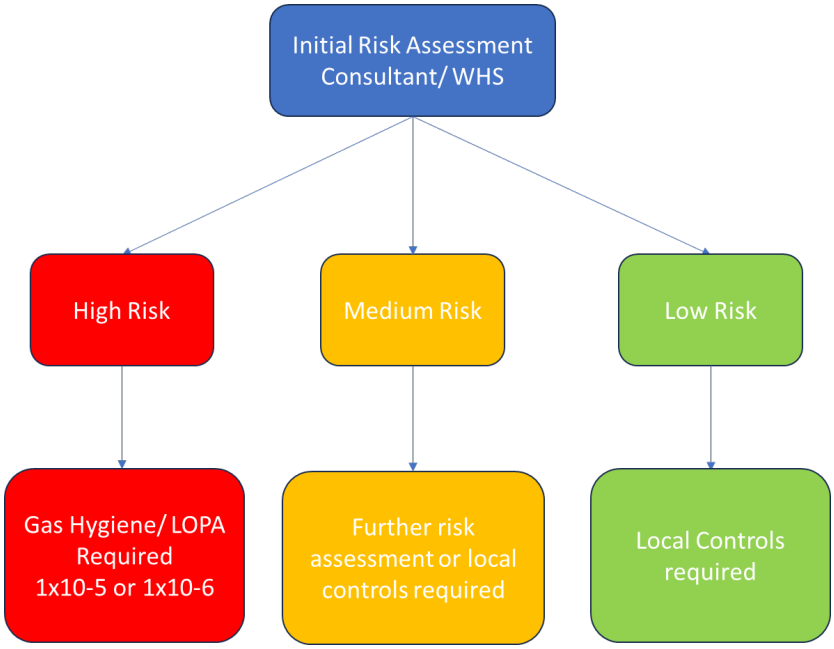


FIGURE 1: RISK ASSESSMENT PROCESS

The NSW WHS Act 2011 requires the University to meet a standard of occupational safety and health that reduces risks to workers to So Far As Is Reasonably Practicable (SFAIRP).

The "Tolerability of Risk" (TOR) criteria was developed by the UK Health and Safety Executive in response to major industrial nuclear and chemical incidents that resulted in significant loss of life both in the industrial establishment but also off site to the public. This has been widely adopted around the world for hazardous industrial plant design. This resulted in a standard of public safety risk tolerance of 1 fatality in 1,000,000 in a year (1 x 10-6 per year).

The NSW Government published a Hazardous Industries Planning Advisory Paper (No.4 January 2011) adopting a fatality risk level of one in a million per year (1 x 10-6 per year) as the limit for risk acceptability for residential area exposure for industrial development proposals. It is also referenced in considering land use proposals in the vicinity of potentially hazardous facilities.

For hazardous industries the tolerable fatality risk level of 1 x 10-5 is used in relation to the risk to workers. This is used in high volume industrial chemical manufacturing and process plants where very significant volumes of inert or toxic gases have the potential to be released and workers exposed.

The tolerable range for risk to workers (generally in hazardous industries) is 1x 10-3 to 1x10-5 with the risk assessment demonstrating that the risk has been reduced to As Low as Reasonably Practicable (UK) or So Far As Is Reasonably Practicable (NSW) using a range of engineering and administrative controls. Prior to any works occurring in University of Sydney Laboratories, a risk assessment shall be done during design phase by the faculty and WHS.

The University has established the risk criteria for the design principles for the Engineering Technology Precinct at 1 fatality in 1,000,000 incidents per year (1x10-6) where there is the possibility of public being exposed.

Where there is no possibility of the public being exposed, a conditional modifier has been agreed and this risk tolerance has been reduced to 1 fatality in 100,000 incidents per year (1x10-5).

The use of this 0.1 conditional modifier is subject to the following:

a. The laboratory is physically constrained from the public with vapour barriers or extraction ventilation in place to prevent leakage to adjacent public spaces,
b. An explosion or over pressure reaction cannot occur that will result in the

compromise of the laboratories constraints and expose the public to harm,
c. Key lock and or swipe card access is provided for trained laboratory researchers only,
d. Untrained visitors shall be escorted by a trained person at all times,
e. Visitors are not present in laboratories for more than 17 hours in any week, and;
f. Signage, as appropriate, is provided at all entry doors stating "Authorised Access Only"

The contractor/ consultant shall demonstrate a risk assessment process (include a Layer of Protection Analysis as appropriate) to accommodate the University's tolerable residual risk rating.

Additionally, as many projects are taken to tender via the design and construct format, the final layout, controls and residual risk may not be known in the early stages of the project. Therefore, acceptable risk shall be documented through the different stages of the project from design through to tool hookup. The University is to retain ownership of the documents at each stage.

The stages are:

1. Design – Specialist consultant
2. Delivery – Specialist subcontractor
3. Operations - Lab User/Stakeholder/SHW
4. Modifications in use – Lab User

Minimum residual risk and assumptions shall be documented at each stage, to arrive at the final tolerable risk as per the paragraph above.

6.5.1 Managing Laboratory Risk

The use of gases in laboratories is associated with significant risks related to
a. Asphyxiation
b. Oxygen enrichment
c. Toxic Gas Exposure
d. Fire and Explosion

Figure 2 below details the process for managing the Medium/ High risks associated with the use of gases in laboratories.

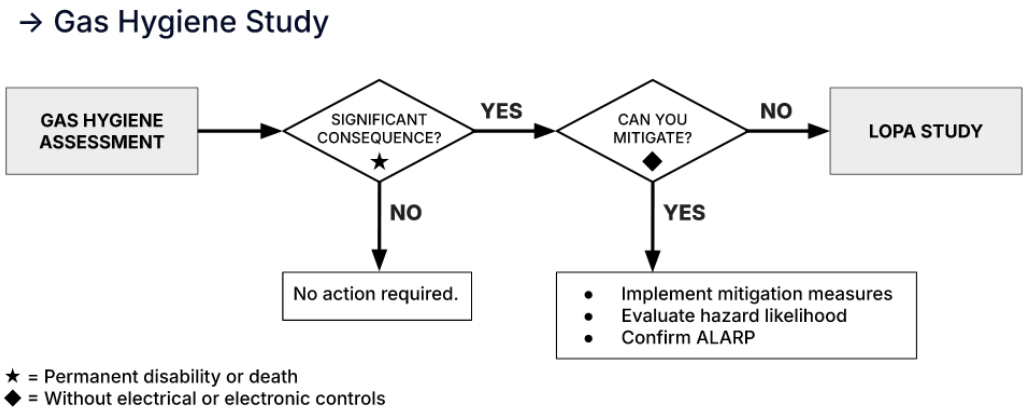


FIGURE 2: MANAGING RISKS ASSOCIATED WITH THE USE OF GASES IN LABORATORIES

The first step in managing these risks is to complete a gas hygiene study to determine the consequences of an inadvertent gas release in the laboratory. Gas hygiene studies need to be completed for all enclosed spaces where gases are reticulated and shall be performed according to the method outlined in

the BCGA Guidance Note 11 (GN11) which covers risk management for using gases in enclosed spaces. The analysis of the possible gas concentration based on a leak of gas or spill of liquified gas should consider:

a. standard ventilation rates for laboratories at 6 air changes per hour and at 0.4 air changes per hour for mechanical ventilation failure.
b. The worst-case release rate should be based on the flow rate from an open outlet or broken pipe which is a function of the valve/line size and reticulation pressure

If the consequences of a gas release in a laboratory are determined to be above the following thresholds, then mitigation provisions will be required and further analysis to verify the effectiveness of the mitigation steps.

a. Flammable gas concentration exceeds 25% of the lower flammable limit. (For lighter than air gases such as Hydrogen and Methane the room volume should be based upon the top 10% of the room.)
b. Toxic gas concentration exceeds the Threshold Limit Value for the gas
c. Oxygen concentration is less than the 18%
d. Oxygen concentration exceeds 23.5%

Determination of a hazardous scenario above these thresholds will require mitigation. Initially only non-electronic/electrical engineering controls should be considered. These can include:

a. Reducing the volume of gas available by decreasing the cylinder/ storage tank size
b. Reducing the distribution pressure to limit the release rate
c. Installing an orifice plate to limit the maximum release flow
d. Substituting a less hazardous gas. Eg by using a gas mixture with an inert diluent to reduce the concentration of a toxic or flammable component
e. Improving the natural ventilation rate

The gas hygiene analysis with the non-electrical engineering controls must be reassessed. If the consequence falls below the above thresholds, then the risk is acceptable and no further controls or analysis is required.

Where the consequences cannot be reduced below the thresholds then it will be necessary to complete a Layer of Protection Analysis (LOPA study) to quantify the risk and to compare this to the University of Sydney tolerable risk criteria. LOPA studies shall be performed by suitable qualified persons having experience with the risks and handling of hazardous gases. The LOPA study should be completed using independently published risk metrics wherever possible. The key inputs required to complete a details LOPA study include;

a. The University of Sydney Tolerable risk criteria being 1x10-6
b. Probability of failure data obtained from independent sources such as the CCPS (Center for Chemical Process Safety) or OREDA (Offshore and Onshore Reliability Data)

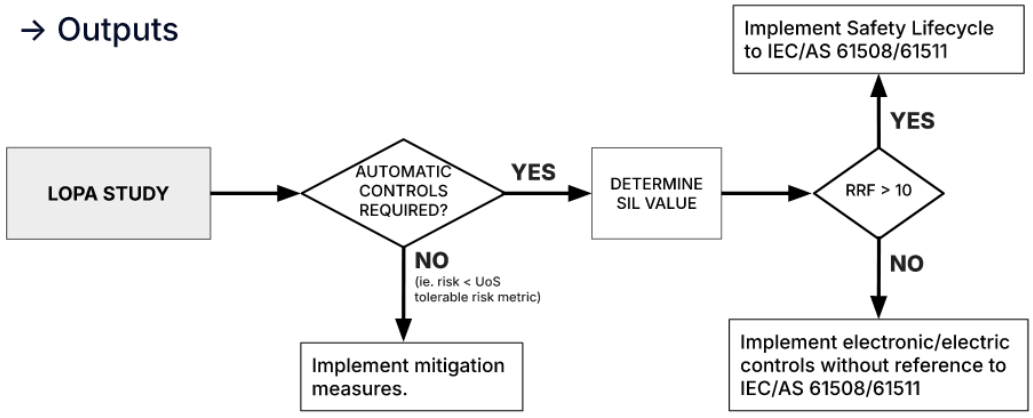


FIGURE 3:LOPA STUDY OUTCOMES

If possible, implement non electrical/ non electronic control measures to mitigate the risk to below ALARP levels. Where electrical or electronic elements are required to meet risk reduction targets greater than a factor of 10 a life safety system shall be implemented complying with the requirements of AS61508 / AS61511. The detailed design and installation shall be completed by the contractor and shall be fully documented and tested in accordance to the AS61508 life cycle.
The type of control system required shall consider the system architecture including the number of mitigation elements, Eg. gas sensors, airflow sensors etc. Multilevel laboratory buildings may require significantly different implementation strategies compared to single laboratories with minimal mitigation elements.

6.6 Laboratory Gas Delivery Systems

Laboratory gas systems across the university are complex systems that vary in size, purity, hazard level and ownership. During the design development phase of a project, it is the responsibility of the designer to determine, in consultation with the laboratory users and the project manager, the demand, purity and hazard levels associated with the required gas delivery systems.

The designer shall calculate the demand diversity and flow requirements for the gas delivery and also determine the appropriate gas storage, manifolds, gas cabinets, valve manifold boxes and piping delivery systems that will provide the required gas purity and flow.

The design must also consider the requirements and limitations of existing infrastructure within the university campus and allow for future expansion, changes of use and the requirement for different types of gases.

Laboratory gases are a critical input to research at the University of Sydney, and all installation shall comply with the design and safety requirements nominated in this standard, other codes listed herein as a minimum.

The design shall provide an efficient and coordinated solution that provides a functional, accessible, safe and maintainable installation.

6.6.1 Design and Installation Criteria

6.6.1.1 Gas System Criteria
The specific requirements, detailed specification and safety provisions shall be appropriate for the type of gas, the flow and total supply requirements and the required gas purity level.
The University of Sydney has adopted the following purity designation for the provision of laboratory gases throughout its facilities.

Purity Rating	Purity Level	Purity Notation
2 Nines	99%	Standard
3 Nines	99.9%	Industrial
4 Nines	99.99%	High Purity (HP)
5 Nines	99.999%	Ultra High Purity (UHP)
6 Nines or greater	>99.9999%	Extremely High Purity

Table 1. Gas purity levels at USYD

Laboratory gases can also be classified according to their hazards. The type and level of hazard being as listed below.

a. Inert Gases,
b. Flammable Gases,
c. Oxidising Gases,

d. Corrosive Gases,
e. Pyrophoric (Spontaneously Combustible) gases,
f. Toxic Gases, and
g. Highly Toxic Gases.

The total supply demand and hazard of the gas will also determine the most appropriate supply storage. The following supply systems may be implemented for laboratory gas delivery

a. Cryogenic (liquified gas delivery), typically used for high delivery requirements including Nitrogen, Argon, Oxygen, Helium. Storage can be in large vacuum insulated fixed vessels or portable liquid dewars.
b. Large Volume Pressurised Liquid Delivery for gases including LNG, CO2 and Propane.
c. Single Cylinder Storage of pressurised or liquified low vapour pressure gases.
d. Manifolded Single Cylinders (Man Packs)
e. Adsorbed Gas Delivery Systems. Low pressure storage of gas molecules held on a porous adsorbent material within a tank. Gas is delivered by controlled heating of the adsorbent.
f. Vacuum Actuated Cylinders are used for safe delivery of highly toxic gases. The gas is stored under high pressure in a cylinder but uses sets of valves and pressure regulators to deliver the gas sub atmospherically. (typically used for ion implanters/ particle accelerators.)

The following general design and installation criteria for laboratory gas services shall be adopted by the consultant/contractor for all projects.

6.6.2 Equipment and Materials

6.6.2.1 Piping

Piping material specification shall be selected according to its gas type, purity and design pressure requirements. Refer to Tables 1 to 5 in Appendix A to select the correct piping. Testing and certification requirements for applicable piping are provided in Table 2. Continuity testing is required for all gas systems.
Gas Manifolds

a. Piping material of construction and test requirements for gas manifold piping as per system piping specification.

    i. Pipework and fittings shall be selected to suit the requirements of hazardous class, gas type, purity and pressure.
    ii. Minimum requirements are welded copper tube type 'B' Oxygen cleaned pipework.
    iii. Compression fittings or crimped pipework shall not be used unless prior approval has been given by UI.
    iv. Fully brazed medical grade Copper pipework to be used for HP and below installations (4 nines) – no mechanical fittings to be used.
    v. Stainless steel to be used for UHP installations (5 nines and above) also for Hydrogen.
    vi. Where connecting to incubators, stainless steel pipework to be used
    vii. Mechanical fittings are only permitted where specified (e.g., tool connection, connection of piping immediately to and from point-of-use pressure regulators, at connection to manifold panel etc.).
    viii. High-silver content solder required for brazing with internal Nitrogen / Argon purge - no flux to be used for brazing.
    ix. Pipework to be reticulated in a ring main for larger installations.
    x. Where not covered in this standard, the pipework (including components) shall comply with AS 4041 as a minimum.
    xi. Pipework shall not be cut with grinders or hack saws, any evidence of this shall be removed for a horizontal distance of 2m either side of the cut.
    xii. Pipework stored on site or installed with open ends shall be capped at all times to avoid contamination.

b. Copper Pipework
    i. All copper pipework for laboratory/ medical gas purposed shall be medical grade 'B' oxygen cleaned for medical use type.
    ii. Copper tube used other than for house supply shall be drawn seamless tube, compatible with oxygen and cleaned – free of oil, grease and particulates.
    iii. Joints shall be brazed with fluxless brazing and continuously purged.
    iv. Pipework shall be cleaned in accordance with AS1432 and AS1571 prior to handover and be suitable for medical grade gases as required.
    v. This includes pipework waiting to be installed, stored on site.
    vi. Copper tube bracketing to be installed in accordance with AS2896

c. Stainless Steel Pipework
    i. All stainless-steel pipework is to be of the medical grade oxygen cleaned for medical use type at a minimum
    ii. Depending on the purity requirements, cleaning, storage and handling of the tubing shall be in accordance with AS1432 and AS1571
    iii. UHP pipework shall be double bagged at all times when not in use and capped prior to installation.
    iv. House purity gas is required to be capped at all times when not in use
    v. Orbitally welded pipework shall be continuously purged with Argon.
    vi. For some pipework it may not be possible to obtain "pre-cleaned", this pipework shall be cleaned prior to installation.

d. Storage and Handling of materials
    i. All pipework, materials and valves shall be stored in their original manufacturer's packaging prior to installation.
    ii. They shall be handled carefully to avoid damaging packaging materials. Any materials not properly packed shall not be used.
    iii. The outer packaging shall only be removed immediately prior to installation or transport into lab.
    iv. The inner packaging shall only be removed immediately prior to use.
    v. Pipework which is stored during the construction works shall have end caps covered with plastic caps to prevent dust ingress

e. Lab taps
    i. Shall be labelled with gas type and purity.
    ii. To be Enware, Galvin, Broen or approved equivalent
    iii. To be compatible with specified gas and purity requirements

f. Filtration
    i. Liaise with the users to determine the purity requirements.
    ii. If required, install in line filter on house supply to provide.
    iii. Filters to be Mott, TEM or approved equivalent

g. Dryers
    i. Liaise with the user to determine requirement for dryness.
    ii. To be provided with a waterless tundish for drainage

h. Isolation Valves
    i. All valves shall be quarter turn to identify when they are isolated.
    ii. Valves shall be located to allow for isolation of individual gas where installed adjacent to other services.
    iii. Valves shall be accessible without specialty access equipment.
    iv. Where exposed to student areas, valves shall be in a lockable enclosure and provided with a lock at project handover.
    v. Unions are to be installed either side of the valve to allow for easy removal of the valve without cutting the lab gas pipework.

vi. To be Swagelok, Draeger or approved equivalent

i. Solenoid Valves
    i. Solenoid valves are to be 24V DC normally closed type.
    ii. Unions are to be installed either side of the valve to allow for easy removal of the valve without cutting the lab gas pipework.
    iii. All solenoids valves shall be installed in a lockable stainless steel cabinet, with a plexiglass viewing panel
    iv. The cabinet itself shall be lockable with a university bilock key
    v. Valves to be AP Tech, Swagelock or approved equivalent

j. Check Valves
    i. Check valves may be required for PC2/ PC3 requirements
    ii. Check valves to be Swagelok, Truelock, Gasflo or approved equivalent

k. Pressure reducing valves
    i. Laboratory gases are generally reticulated at higher pressure to allow for a wide range of laboratory usage.
    ii. At the entrance to the lab, or at the point of use, pressure reducing valves are to be wall mounted.
    iii. Wall mounted valves are to be dual stage scientific type.
    iv. Regulators are to have isolation valves upstream to allow for gas shutoff and removal of regulators with minimal disruption.
    v. Regulators to be installed at 1500mm Above finished floor level (AFFL) to be accessible behind equipment or above bench.
    vi. Where under Fume Cupboards, regulators to be coordinated to allow easy access to the regulators.
    vii. Regulators are to be installed for the appropriate intended gas use and the correct rated pressure for the downstream equipment
    viii. Regulators to be SMC, Festo or approved equivalent.

l. Pressure Gauges
    i. Pressure gauges to be provided at all points where there is a change in pressure and at central plant.
    ii. Pressure gauges to be Brooks, Wika or approved equivalent.

m. Pipe Supports
    i. Pipe supports shall be Beringer or Stauff style Polyethylene or Polypropylene two-piece clamp or approved equivalent. All lines shall be supported adequately to prevent sagging. Lines shall be installed parallel to building elements.
    ii. The contractor shall provide detailed drawings and samples of all pipe support methods for approval to UI

n. Pipework Markers
    i. All pipework shall be provided with labelling stickers indicating the gas type and purity.
    ii. These shall be installed at min 3m intervals, including adjacent to the tap and valve location.
    iii. Where pipework markers have been damaged during construction, these shall be replaced for handover of the project.
    iv. All pipework markers shall be legible from the ground level

o. Penetrations
    i. All services penetrations shall be fully air sealed to minimise air leakage to different laboratory areas with differing air classes. Including ductwork, pipework and associated electrical power and control cables.
    ii. For penetrations through walls with an FRL rating, the penetration shall be sealed with the appropriate FRL rating and included in the Passive Smoke and Fire Containment report.
    iii. For more information refer to the USYD Essential Fire Safety Measures Standard

p. Materials

i. All valves, fittings, supports, gauges and manifolds required to operate the installed lab gas system shall be provided by the installing contractor and be suitable for the installation requirements.
ii. All materials shall comply with the relevant purity requirements.
iii. Where there is a discrepancy between this standard and the manufacturers requirements, the higher requirement shall be used.
iv. Material selection shall avoid corrosion between components having different galvanic potential.
v. Install isolating elements where there is a change in pipework materials

q. Flexible Connections

i. Braided stainless steel flexible hoses shall be used only when the hose is concealed in joinery or the like and as pre-formed connections to equipment (such as fume cupboards).
ii. They shall be the correct length to match the installation requirements.
iii. Braided flexible hoses shall not be joined to another braided flexible hose under any circumstance.

r. Operating Pressure

For clauses i and ii, final regulator and required pressure for tool is to be determined in collaboration with the users.

i. Reticulation of lab gases is to be at the following pressures:

Gas type	**Pressure**
Argon	700 kPa
Carbon Dioxide	700 kPa
Compressed Air	700 kPa
Dry Air / Instrument Air	700 kPa
Helium	700 kPa
Hydrogen	700 kPa
Nitrogen	700 kPa
Oxygen	700 kPa
Vacuum	-60 / -90 kPa
Other	700 kPa unless specified

ii. Reticulation of medical gases is to be at the following pressures:

Gas type	**Pressure**
Medical Gas	415 kPa
Surgical Tool Air	1200 kPa
Medical Suction	-60 kPa

iii. Outlets – as per user requirements
iv. Storage – as per specified storage type
v. Pressure regulators shall be used to control maximum pressures.

s. Building Management Control System (BMCS)

i. The following gas supply equipment shall be connected and monitored by the BMCS in real time:
i. Flow fault
ii. Cylinder empty
iii. Meter usage (if installed)
iv. LSS outputs
v. Status

vi. Warning activation
vii. Alarm activation
viii. Fault
ix. High level Interface

t. Laboratory Protection (PC3 & PC4)
    i. Each individual laboratory rated as PC3 and above may require check valves where the pipework enters the PC3 boundary.
    ii. Maintainable items are to be located outside of the PC rated area to enable servicing without entering the laboratory facility.

u. Leak Testing
    i. All high purity gas lines shall be tested on completion. In order, the following tests shall be executed.
    ii. Pressure Test - All ends shall be capped or plugged and pneumatically pressure tested using cleaning grade filtered nitrogen. Suitable precautions shall be taken to avoid over pressurisation of the system.
    iii. Under no circumstances shall bubble/soap type leak detector fluid be applied
    iv. Oxygen testing - Prior to setting to operation the lines shall be purged with ultra-high purity Nitrogen gas to verify that the Oxygen concentration does not exceed 1ppm at each outlet.
    v. Function Testing - All equipment installed on high purity gas lines shall be function tested. A checklist shall be prepared and signed off verifying correct installation, correct item complying with specification, correct labelling and correct function.
    vi. Only suitably experienced operator shall perform the above testing.
    vii. All test devices shall be calibrated. A test certificate shall be prepared for each instrument to be included in the commissioning documentation.

Gas manifolds are to be functionally tested by the contractor prior to connection of process gas.

6.6.2.2 UHP and HP Gas Manifolds – General

All UHP gas manifolds shall have the following design features,

a. Minimal dead volumes to ensure optimal purging
b. Piping specification, jointing method, valve type and surface finish as per Table 2 in Appendix 1.
c. Minimal mechanical connections
d. Regulators for flammable, pyrophoric, corrosive, toxic and highly toxic gases shall be connected poppet style to minimise regulator creep and to ensure tight shut off
e. Screwed connections shall not be used for any components in contact with UHP gases
f. Pigtail, (bottle connections) must be hard tubing. Flexible hose connections shall not be permitted
g. Gas cylinder connections must be coordinated with the university project manager and users. (Typically, UHP gas cylinders are imported and do not use Australian standard type connections)
h. Dedicated inert gas purge cylinders shall be used for all 5 valve manifolds
i. House Nitrogen may be used for venturi vacuum drive
j. Pressure driven switching regulators or cylinder pressure sensing with pneumatic switching valves may be used for UHP / HP gas delivery systems where gas usage demands the use of a semi-automated switching manifold.
k. A 0.4µm conical filter gasket shall be fitted on the high-pressure side of the regulator to protect downstream components

6.6.2.3 UHP / HP Inert and Oxidising Gases

a. 3 valve self-purging manifold design as shown in Figure 1.0
b. Manifolds shall be wall mounted in services spaces external to laboratories or externally in naturally ventilated spaces. Gas cylinders and manifolds should not be installed within occupied laboratory spaces.

c. Consideration should be given to using venturi vacuum assisted purging for expensive inert and oxidising gases
d. Pressure relief valves shall be installed downstream of the pressure regulator to prevent over pressure in case of regulator failure
e. For expensive inert, oxidising or greenhouse gases high delivery pressure switches should be installed with remote sensing to alert users to prevent unnecessary venting of gas through relief valves
f. Low supply pressure switches with remote notification may be required to alert users to change cylinders
g. Cylinder scales should be provided for low vapour pressure liquified gases and they should include remote notification to alert users to change cylinders
h. A 0.4µm conical filter gasket shall be fitted on the high-pressure side of the regulator to protect downstream components

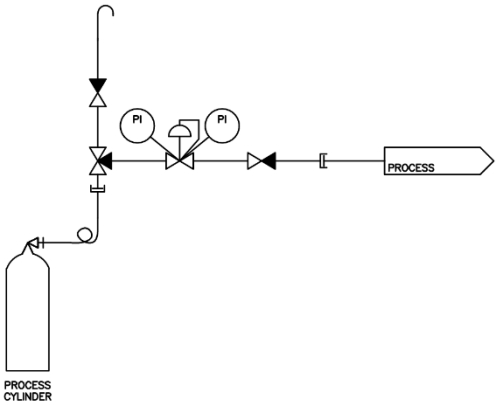


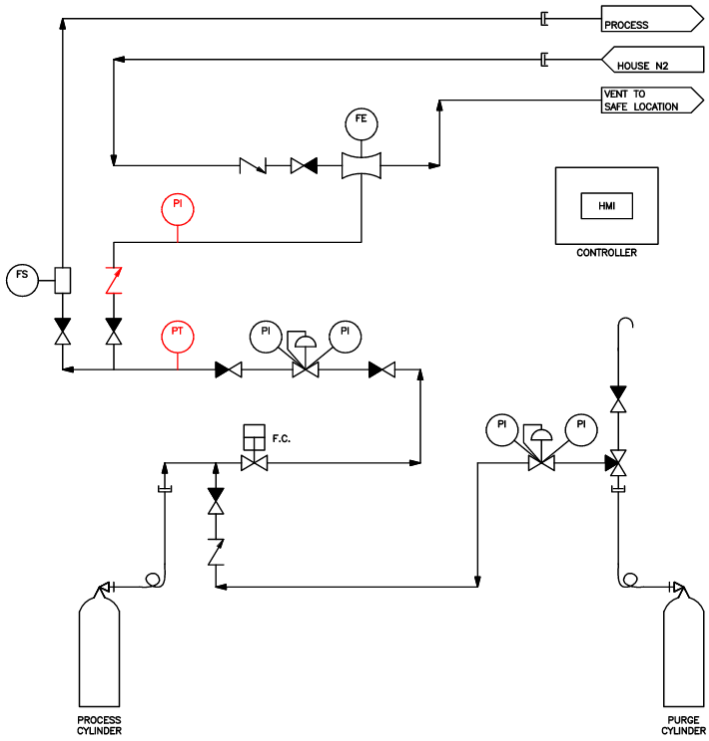
FIGURE 4: 3 VALVE MANIFOLD

6.6.2.4 UHP / HP Toxic, Corrosive and Flammable Gases

a. 5 valve manifold with venturi vacuum assisted purging as shown in Figure below
b. Manifold can be installed in external naturally ventilated enclosures or indoors in ventilated gas cabinets
c. Where gas cabinets are required they shall meet the following requirements;
    i. The ventilation rate shall comply with the requirements of the Semi S2 and Semi S12 and shall be monitored with alarm and gas shutdown upon ventilation failure.
    i. A trace gas detector shall monitor the exhaust and the gas supply shall be shutdown at the automatic shut off valve in the gas cabinet.
    ii. They shall be fitted with an operator window and the ventilation rate shall be sufficient to maintain an air velocity of at least 1m/s across the window opening.
    iii. Construction shall be of minimum 12 gauge steel with low level filtered, louvred air inlet.
    iv. To keep cylinders cool in the event of a fire, gas cabinets should be fitted with a fire sprinkler.

d. Manifolds shall be, as a minimum, semi-automatic, (i.e. providing remote shut off on the high-pressure side). Fully automatic manifolds may be used if frequent cylinder changes are required
e. The emergency shut off valve shall be pneumatically actuated, normally closed and shall be SIL 2 capable. The solenoid valve providing the pneumatic supply to the gas cabinet shall also be SIL 2 capable.
f. Mechanical connections where required shall be VCR style unions with Stainless steel or Nickel gaskets
g. A high delivery pressure switch with automatic supply shut off shall be included to prevent overpressure in case of regulator failure. Pressure relief valves should not be used unless safe venting of hazardous gases can be provided.
h. Mitigation for downstream leakage of gas should be included. This can be provided by use of orifice plates to restrict flow or by using excess flow switches to shut off the supply.
i. The manifold configuration and controls must provide a reliable means, by manual or automatic procedure, to verify that the cylinder valve is closed prior to cylinder disconnection.

j. The manifold configuration and controls must provide a reliable means, by manual or automatic procedure, to verify that the cylinder connection is leak tight prior to opening of the cylinder valve
k. All automatic valves shall be pneumatically actuated, normally closed diaphragm valves complying with the piping specification.
l. All manifolds shall be configured with onboard dedicated purge capability. Where 3-cylinder cabinets are used for compatible gases only one purge cylinder is required.
m. Venturi vacuum assisted purging is required and shall be capable of creating a vacuum of at least 20" of mercury. House Nitrogen should be used for the venturi vacuum drive.



n.

FIGURE 5: 5 VALVE MANIFOLD

6.6.2.5 UHP Highly Toxic Gases

a. Highly toxic gases include gases with a LC50 of less than 200ppm or as nominated in the Santa Clara County Toxic Gas Ordinance or equivalent reference guides.
b. Manifolds for highly toxic gas shall include all of the features listed above for toxic, flammable and corrosive gases
c. All supply lines for highly toxic gases shall be double contained with a vacuum maintained within the outer containment. Loss of containment shall shut off the gas supply at the high-pressure side of the gas manifold.
d. Only fully automatic manifolds should be used for highly toxic gases

6.6.2.6 UHP Silane and Silane Mixtures (Pyrophoric Gas)

a. Silane is a commonly used gas for Silicon and Silicon Nitride deposition in solar cell and semiconductor processes. Silane is pyrophoric, (spontaneously combustible in contact with air) and high-pressure release can be metastable and highly explosive
b. All Silane gas installations shall comply with the requirements listed for toxic, flammable and corrosive gases above and also the CGA G13 guidelines for Silane and Silane mixtures. This includes but is not limited to the following provisions
c. All Silane cylinders shall be fitted with pneumatically actuated cylinder valves and these shall include manual lock nuts to prevent automatic actuation
d. Suitable sized orifice plates shall be fitted to the cylinder outlet to minimise the release flow rate

e. Gas cabinet exhaust flow rates shall be sufficient to ensure that the Silane gas concentration of any inadvertent release within the gas cabinet cannot exceed the lower explosion limit. The flow rate is a function of the orifice plate and the maximum cylinder pressure. Typically cylinder pressure should be less than 1270 psi with an orifice of 0.01"
f. Only one Silane cylinder should be installed in a gas cabinet
g. Gas cylinder connections should be CGA V-1 standard type DISS 632
h. UV/IR fire detectors suitable for detecting Silane fires should be installed in all Silane gas cabinets

6.6.2.7 Standard and Industrial Grade Gas Manifolds

Piping specification, jointing method, valve type and surface finish as per Table 2 in Appendix 1.

6.6.2.8 Inert Gas Manifolds

a. 1 valve manifold or cylinder regulator as shown in Figure 3.
b. Regulator material chrome plated brass or brass.
c. Screwed connections are permitted.
d. Flexible hoses shall be Teflon or Tefzel lined with outer protective stainless steel braid and anti-whip device that upon rupture shuts off gas supply in both directions.
e. Semiautomatic switching manifolds as determined by usage / bottle change frequency.
f. Downstream pressure relief assumed to be provided as art of reticulation system.

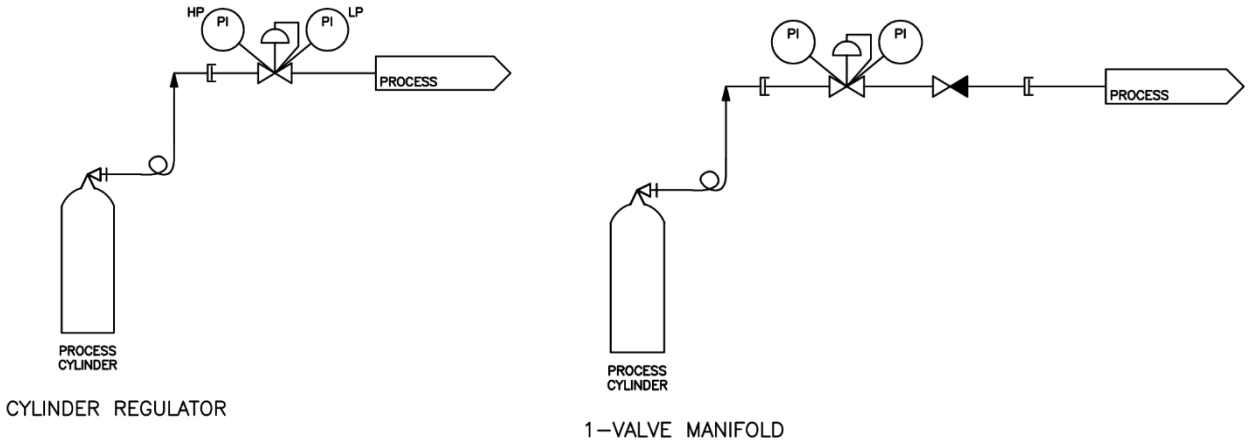


FIGURE 6: CYLINDER REGULATOR AND 1 VALVE MANIFOLD

6.6.2.9 Oxidising Gas Manifolds

a. 3 valve manifold design – self purging (refer Figure 1)
b. Regulator material chrome plated brass or brass.
c. All components must be Cleaned for Oxygen Service (CFOS)
d. Pressure relief valves shall be installed downstream of the pressure regulator to prevent over pressure in case of regulator failure
e. No venting of oxidising gases into unventilated indoor areas.
f. Hoses shall be appropriate for Oxygen service. Teflon lined hoses are not acceptable.

6.6.2.10 Flammable, Toxic, Corrosive and Highly Toxic Gas Manifolds

Requirements for flammable, toxic, corrosive and highly toxic industrial and standard purity manifolds are the same as those stipulated for UHP manifolds of the same gas type. There are two exceptions; Piping / material internal surface finish may be mill finish. Threaded connections are permitted ONLY if they are in continuously monitored well ventilated spaces.

All materials supplied and installed shall be approved by the local authority have the respective Australian Standard's mark and manufacturer's licence number. Where equipment is imported from overseas, documentation shall be provided showing that it is fit for use in Australia.

All materials shall be first quality and the best of their respective kinds. Second quality or inferior materials shall be rejected. All costs associated with replacement of rejected materials shall be the contractor's responsibility.

6.6.3 Gas Storage

a. Cryogenic Gas storage (Bulk Gas)
   i. Shall be sized to account for typical use of the building/ lab with 0.7 diversity factor.
   ii. Shall be sized to include future expansion of gas requirements.
   iii. Shall be sized to minimise the requirement for refilling – weekly filling to be used as a guide, not to exceed fortnightly refills.
   i. Location of storage tanks to prevent damage to surrounding trees and foliage, and be located min 3m from any surrounding trees or foliage.
   iv. VIE compound to have min 600mm clearance around structure and tanks to allow individual removal of tanks
   v. Remote fill point may be required – liaise with UI, Architect, COS and TSS for final location.
   vi. Underground pipework may be required to locate the LN pipework remote from the building.
   vii. Size and visibility of condenser fins to be reviewed by architect – concealment may be required.

b. Internal Gas bottle stores
   i. Internal gas bottle stores shall not be installed without prior approval from UI.
   ii. Where proposed, adequate gas monitoring is to be installed with alarms and ventilation.
   iii. Shall also be reviewed and approved by SHW
   iv. Refer to USYD WHS gas storage requirements - Working with Gases Guide

c. External gas bottle stores
   i. Gas storage location is to be accessible by delivery trucks without the need for long traverse with trolleys or access via lifts.
   ii. Shall be installed to consider future expansion if minor storage.
   iii. Class 2.1 gases shall have sloped roof to prevent build-up of gases.
   iv. All bottle chains to be installed to allow individual replacement of bottles without removing the whole chain.
   v. Bottle supports to be at approx. 1/3 and 2/3 bottle height mounted on Unistrut or a proprietary system.
   vi. Typical installation is 1000mm AFFL and 300mm AFFL to accommodate a G size cylinder.
   vii. Confirmation of bottle sizes are to be checked by the proposed users prior to design finalisation.
   viii. Smaller gas bottles are to be accommodated as required.
   ix. Shall have a hose tap at a minimum – refer to AS4332 for full compliance.
   x. Shall be on university bi lock key as per TSS requirements

d. Gas Cabinets
   i. Gas cabinets are preferred to house hazardous or toxic gases.
   ii. These are to have dedicated exhaust, with provision for future connections to prevent the need for additional risers.
   iii. Gas cabinet alarms are to be connected to the LSS and BMS
   iv. Shall be provided with fire trip and interlock as required by LOPA study.
   v. Bespoke inert gas manifolds can be provisioned with wall mounted manifolds unless dedicated exhaust is required

e. Flow Meters
    vi. Flow meters are generally requires in gas cabinets, to shut off the flow of gas on ventilation failure
    vii. Flow meters to be Dwyer, Gemu or approved equivalent.

f. Existing Supplies
    i. Prior to any connection to an existing system, gas shall be tested for pressure and purity.
    ii. Test results shall be provided to UI Engineer prior to acceptance of house supply use.

g. Lifts
    i. Where lifts are required to be used for the transport of gas bottles and Dewars, lockout functionality shall be provided.
    ii. Oxygen depletion sensors shall be installed at a minimum.
    iii. Other sensors may be required as per risk assessment.
    iv. For more information refer to the USYD Vertical transportation standard.

h. Gas cabinets
    i. Shall be ventilated.
    ii. Shall have dedicated exhaust for each type of hazard (toxic, flammable, corrosive)
    iii. Shall be monitored on the LSS/ BMS

i. Compressed Air Plant
    i. Compressed air plant shall be sized, filtered, dried and installed for the correct laboratory use.
    ii. Floor mounted plant shall be installed on a 100mm concrete plinth, with anti-vibration mounts.
    iii. Each piece of equipment shall be installed to allow maintenance or replacement without removal of other equipment.
    iv. All plant items are to be installed with stainless steel flexible hosing and union to allow for removal if needed.
    v. All received are to be installed with DYNA bolts to the plinth to prevent tipping.
    vi. All alarms to be connected and shown on the BMS.
    vii. All condensate drains to be run to a dedicated tundish or floor waste within the plant room.
    viii. Any oil injected compressors shall be provided with an oil/ water separator to prevent oil from entering the sanitary system.
    ix. Noise levels to be approved by UI prior to selection/ installation of the system. If excessive noise, acoustic treatment shall be provided.
    x. For more information refer to the USYD Mechanical services standard.

j. Vacuum Plant
    i. Vacuum plant shall be sized, filtered, dried and installed for the correct laboratory use.
    ii. All plant items are to be installed with stainless steel flexible hosing and union to allow for removal if needed.
    iii. All alarms to be connected and shown on the BMS.
    iv. All condensate drains to be run to a dedicated tundish or floor waste within the plant room.
    v. Exhaust from the vacuum pump shall be vented to atmosphere, with a trap to prevent water ingress.
    vi. Vent shall have mesh or a cowling to prevent vermin entering

k. Nitrogen Generators
    i. Nitrogen generators may be installed in lieu of cylinders as an additional safety control.
    ii. Shall be sized for the intended use including any potential works in the future.
    iii. To be connected with compressed air supply as required by user.
    iv. Shall be installed to allow removal without interrupting other equipment adjacent to the nitrogen generator.

l. Hydrogen Generators
    i. Hydrogen generators may be installed in lieu of cylinders as an additional safety control.
    ii. Shall be sized for the intended use including any potential works in the future.
    iii. To be connected with compressed air supply as required by user.
    iv. Shall be installed to allow removal without interrupting other equipment adjacent to the hydrogen generator.

6.6.4 Specialty Gas Delivery Systems

Unless specified, laboratories are to be supplied from High purity gas (99.99%). Where higher purity gases are requested, they are to be supplied by Ultra High Purity Cylinders. The requirement for UHP grade gases should also consider Generators for Hydrogen and Nitrogen as applicable.

A number of specialty gases are used in the University for various processes. These gases are sourced from ultra-high purity (UHP) and high purity (HP) cylinder sources.

6.6.4.1 Gas cylinder requirements

a. UHP Gas Systems

Where Ultra-High Purity (5.0 Nines) gas is required it shall be supplied in the following format:
    i. The UHP gas is to be reticulated to point-of-use isolation and pressure regulation points in the lab. The regulators and all components shall be suitable for ultra-high purity gas and shall utilise high integrity VCR style mechanical connections where required.
    ii. Isolation valves shall be mounted on a suitable valve manifold panel, close to the location of the equipment. Location of the valve shall be coordinated with the equipment to ensure ease of access and future connections to the valve.
    iii. From the location of the point-of-use pressure regulators, the tool hook-up contractor shall install piping to reticulate the UHP gas to the research tool. Mechanical connections shall only be permitted between the valve and the connection to the research tool.
    iv. The standards of construction for the UHP gas line shall electropolished stainless steel tubing according to piping specification.
    v. The manifold panel shall be configured with an automatic monitoring system which shall provide a local alarm to alert the lab staff upon low supply of helium on either side of the manifold (primary side and backup side). In addition, the low-pressure alert shall interface with the LSS controller to notify the operators at the main LSS controller when a cylinder has been depleted. Details of the gas cylinder manifold are included in the table below

b. Oxygen
    i. Oxygen can be provided via dedicated cylinders or bulk liquid gas storage vessels, depending on the volume required.
    ii. Cylinders are preferred for flexibility to ensure purity and flexibility of installation.
    iii. Any purity requirements above 4 nines shall be provided by cylinder storage.

c. Hydrogen
    i. The contractor shall verify the electrical exclusion zones surrounding the hydrogen generator and associated piping in accordance with Australian Hazardous Area Standard AS60079.10.1 and any other applicable standards.
    ii. All high-pressure hydrogen proposals shall first be approved by WHS before proceeding

d. Nitrogen
    i. The standards of construction for the Nitrogen line shall be bright annealed stainless-steel tubing according to piping specification upstream of the purifier, and electropolished

stainless steel tubing according to piping specification downstream of the purifier Appendix A for details.

e. Instrument Air
    i. Where existing house compressed air is proposed to be reticulated to the space, the contractor shall first test and confirm adequate for the space.
    ii. The contractor shall verify that it achieves Class 3.2.3 air quality according to ISO 8573.1. In the event that the existing building air does not achieve this standard, the contractor shall submit for review a design for an air purification system to remove the relevant contaminants in order to achieve the specified class.
    iii. The standards of construction for the Instrument Air piping shall be bright annealed stainless-steel tubing according to piping specification in Appendix A.

f. Carbon Dioxide
    i. The standards of construction for the Carbon Dioxide line shall be bright annealed stainless-steel tubing according to piping specification Appendix A upstream of the purifier, and electropolished stainless steel tubing according to piping specification SS1 downstream of the purifier.
    ii. Cylinder Scales to be included where automatic or manual changeover is proposed.
    iii. Cylinder scales are to be connected to the BMS and local alarms.

g. Specialty Gases
    i. All specialty gases to be installed in gas stores unless otherwise approved.
    ii. Calculations shall be provided for expected use of the cylinders with indicated estimated usage time for size D cylinders, unless specified otherwise.
    iii. Where hazardous or toxic gases are proposed, gas cabinets are to be installed with dedicated exhaust pipework.
    iv. Provision is the be left for other levels to connect to this exhaust to prevent the need for future risers

h. Manifolds
    i. Gas manifolds can be automatic or manual changeover as per user requirements.
    ii. Cylinder depletion and changeover shall be indicated on the lab gas panel
    iii. Automatic Gas manifolds shall be installed where high gas usage is designed.
    iv. These shall be designed to allow for gas specific yoke connection from supplier cylinder packs.
    v. Manifolds shall not be linked to any one supplier.
    vi. Semi-Automatic Switchover (1 x 1 configuration) with upstream purge and outlet isolation.
    vii. Low cylinder pressure alarm on side A and side B shall be indicated on the BMS and lab gas panel
    viii. Manifolds are to be SDC Flexgas, Gascon or approved equivalent

i. Bulk storage
    i. Bulk storage of liquid nitrogen, oxygen, argon or other gases shall be selected to accommodate the frequency of refills according to access and user requirements.
    ii. An estimated refill rate of 2 weeks should be utilised for any sizing calculations.
    iii. More frequent refill rates, accompanied by an access strategy shall be submitted with the proposal.
    iv. It may be required to provide backup cylinders which shall incorporate a manual changeover valve for periods when the bulk tank is offline.

6.7 Life Safety Systems

Where laboratory gas systems are proposed to be installed, in accordance with the risk assessment, a life safety system shall be installed to mitigate the relevant risks. The contractor/ consultant shall fully investigate the existing system and any extensions or modifications required.

Where a new LSS controller is proposed, it shall be installed in accordance with the following:

Where required, it shall meet the SIL requirements for safety related elements as specified.

6.7.1 Gas Safety Risk Management in Laboratories

The use of gases in laboratories is associated with significant risks related to:

a. Asphyxiation
b. Oxygen enrichment
c. Toxic Gas Exposure
d. Fire and Explosion

Figure 7 below details the process for managing the risks associated with the use of gases in laboratories.

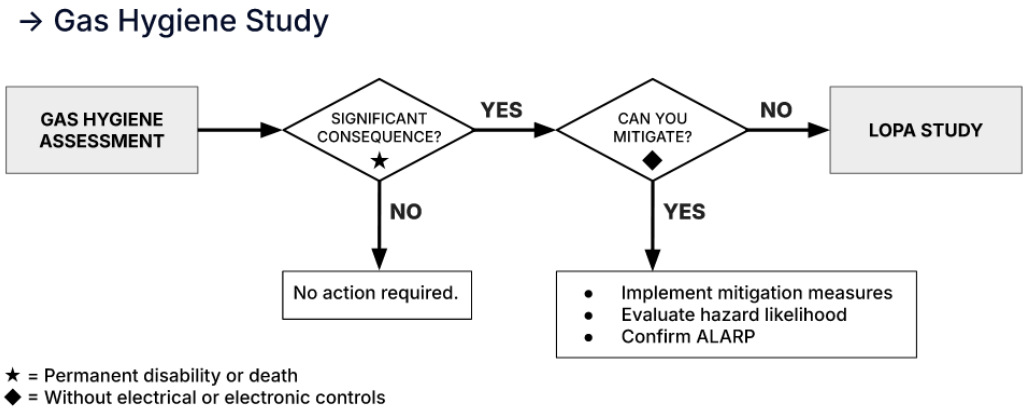


FIGURE 7: MANAGING RISKS ASSOCIATED WITH USE OF GAS IN LABORATORIES

Where the consequences cannot be reduced below the thresholds then it will be necessary to complete a Layer of Protection Analysis (LOPA study) to quantify the risk and to compare this to the University of Sydney tolerable risk criteria. LOPA studies shall be performed by suitable qualified persons having experience with the risks and handling of hazardous gases. The LOPA study should be completed using independently published risk metrics where ever possible. The key inputs required to complete a detailed LOPA study include;

- The University of Sydney Tolerable risk criteria being $1x10^{-6}$
- Probability of failure data obtained from independent sources such as the CCPS (Center for Chemical Process Safety) or OREDA (Offshore and Onshore Reliability Data)

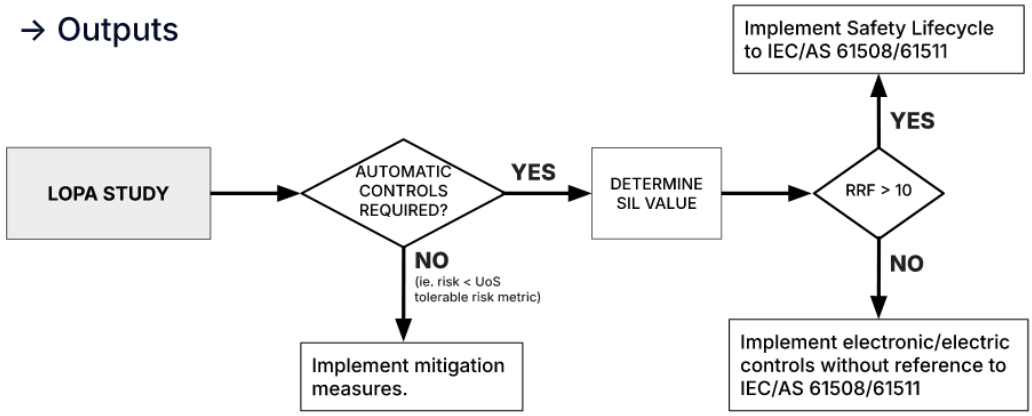


FIGURE 8: LOPA STUDY OUTCOMES

The type of control system required shall consider the system architecture including the number of mitigation elements, Eg. gas sensors, airflow sensors etc. Multilevel laboratory buildings may require significantly different implementation strategies compared to single laboratories with minimal mitigation elements.

6.7.2 Safety Instrumented Functions

The life safety system comprises of one or more safety instrumented functions (SIFs). Each SIF comprises of a sensor, a controller and a final element. For laboratory gas systems sensors can include;

a. Gas detectors
b. Pressure switches
c. Pressure Transmitters
d. Excess Flow Switches
e. Exhaust Flow Switches
f. Temperature Switches

Controllers can be simple safety relays or complex safety Programmable Logic Controller (PLC) systems. Final elements are typically emergency gas supply shut off valves but can also include emergency exhaust boost systems. The number of SIFs included in a system will typically determine the most economical architecture.

6.7.2.1 Gas Detectors

Where gas detectors are required, they shall be installed according to the safety life cycle and also in compliance with AS60079.29 parts 2 and 3. There are multiple different sensing technologies available and this makes the optimal selection of sensors a complex subject. For laboratories that use a wide range of chemicals this is even more difficult due to the cross sensitivity of sensors to commonly used reagents and cleaning chemicals. Many gas sensors are cross sensitive to isopropanol and ethanol, which are commonly used for cleaning and sterilisation.
The life safety contractor must consider the type of laboratory and typical operations prior to selecting gas sensors to avoid spurious trips due to sensor cross sensitivity.

Gas detectors are available as:
a. Aspirated suction sensors or
b. Environmental sensors

Typically, suction sensors are required for sampling from enclosures and ducts or when sampling from inaccessible locations. Suction sensors typically use miniature diaphragm pumps to continuously sample small flows (typically 0.5SLPM). Sampling lines shall not be longer than 10m and should be inert and low permeability; typically, stainless steel or Teflon. To avoid pressure issues with sampling pumps the

exhaust flow from the sensor shall be routed back to the duct or enclosure downstream of the sampling point in the same pressure zone.

Environmental gas sensors should be installed in the operator breathing zone (1.2 to 1.5m AFFL) except for significantly lighter or heavier than air gases that will stratify. For lighter than air gases with molecular weights less than or equal to 20g/mol the gas will rise strongly and the sensor should be mounted on the ceiling or high up on the wall (>90% of the ceiling height). For heavier than air gases with molecular weights greater than or equal to 35g/mol (approx. 20% heavier than air) detectors should be mounted for floor level detection approximately 300-600mm AFFL.

Gas temperature, ventilation and release velocity need to be considered also as these factors may dominate over molecular weight. Leaks of cryogenic gases will initially sink and stratify at low level and for this scenario the sensor should be located at 300-600mm AFFL. Where there is uncertainty due to these factors, CFD modelling should be undertaken to determine the best sensor location. Where there is significant uncertainty about mixing behaviour, the contractor should consider the installation of sensors at multiple levels.

In larger spaces (>30m2), or when considering the usage of highly toxic gases CFD modelling should be completed to determine both the optimum location and / or the number of sensors required to mitigate the risk. Coverage radius heuristic guidelines should not be used to determine gas sensor coverage in large spaces.

6.7.2.2 Excess flow switches

Excess flow switches shall be fitted to all gas manifolds used for highly toxic, toxic, pyrophoric and flammable gases that supply gas to enclosed and occupied laboratory spaces. Excess flow switches shall trip the emergency gas shut off valve installed on the high-pressure side of the manifold. Excess flow switches cannot be used as a safety rated mitigation and the maximum risk reduction factor for their use shall be 10.

6.7.2.3 Final Elements

For safety rated systems requiring a risk reduction of greater than 10 all final elements shall be configured as detailed below.

6.7.2.3.1 Shut off valves

a. For flammable, toxic, highly toxic, corrosive and pyrophoric gases the final element shut off valve shall be installed in the gas supply manifold and shall be SIL 2 minimum tight shut off with a maximum leak rating of 1 x 10-8 std cc/s.
b. The manifold shall be configured to allow for manual or automatic proof testing of the gas shut off valve. A 100% proof test shall be possible.
c. Shut off valves for inert and oxidising gases, typically house bulk supply, shall be installed external to the monitored space, preferably in a naturally ventilated space. Multiple shut off valves should be installed to minimise the inconvenience of shutting off supply throughout a multilab / multilevel facility. Shut off valves for safety rated systems (risk reduction target ≥10) shall be SIL 2 rated.
d. Suitable provisions to allow for 100% proof testing of automatic shut off valves shall be provided. This shall include a shut off valve, vent valve and pressure gauge to enable pressure monitoring to verify leak tightness of the shut off valve.
e. If required an automated bypass valve can be incorporated so that supply can be maintained during proof testing.
f. Whilst proof testing is undertaken a blue tower light shall be activated on the central control panel. The red strobe light in the affected laboratory shall also be activated. An output shall be enabled to the BMS. The control system shall reset the automatic valves to normal operation state and reactivate all alarm outputs at the expiration of the proof test timer or when the proof test mode is deactivated on the control panel. The timer shall be a maximum of 45 minutes.

g. Control system access to initiate proof test / system bypass shall require high level password access.
h. Shut off valves must not be installed within monitored laboratory spaces.

6.7.2.3.2 Ventilation boost

a. In situations where shutting off the gas supply can cause a safety incident or major disruption to process continuity a ventilation boost may be a suitable mitigation. A visual and audible evacuation alarm should be included.
b. The additional ventilation shall be sufficient to ensure that the dilution within the lab space is sufficient to prevent a hazardous situation.
c. Ventilation boost systems should only be considered for Oxygen depletion risks and must prevent Oxygen concentration of less than 15% within the space.
d. Ventilation boost systems should not be used for highly toxic, toxic, pyrophoric or flammable gas delivery systems.
e. Ventilation boost shall also be considered for Liquid Nitrogen filling stations and CO2 incubator spaces where filling/ doors opening may temporarily increase gas concentration.

6.7.2.3.3 Evacuation Alarms

a. Evacuation alarm systems cannot provide a risk reduction of 10 times or greater. They should be provided as secondary safety elements only.

6.7.2.3.4 Life Safety System Controllers

There are many different life safety controller options available for laboratory safety systems and the correct selection is dependent upon the size and type of system.

a. Non safety rated systems having a risk reduction target of less than 10 times can use off the shelf simple relay or PLC based controllers but should always operate separately from building management systems.
b. Safety rated systems can use safety relays, safety rated PLCs or hybrid configurations (safety relay combined with non-safety PLC).
c. Simple safety relay systems are suitable for small systems with less than 10 SIFs; they are economical for smaller systems but have limited capability for interfacing with external systems or providing more sophisticated control such as voting logic. They are, however, easy to reconfigure and expand by adding additional relays without having to revalidate existing program code.
d. Safety PLC's systems are very powerful and provide more sophisticated controls and better user interfaces. They are the only controller option that can be easily configured for when sensor voting (eg 1002, 2003) is necessary to reduce spurious trip likelihood. The biggest disadvantage of safety PLCs is the need to revalidate the program code if changes are required. For any changes to the system, it is necessary to perform a documented risk analysis to demonstrate that existing code will not be detrimentally impacted or to revalidate the entire system after any code changes.
e. Hybrid systems use a non-safety rated PLC and HMI combined with safety relays. The safety relays must act independently but must also provide a retransmitted signal to the PLC. The hybrid systems provide for easy reconfiguration without having to revalidate non safety rated PLC programs but still provide the same ease of operation and external outputs.

All life safety systems must provide local and external visual and audible alarms and also the capability for local and remote shutdown of the gas services.

6.7.2.3.5 Emergency Response

a. Emergency shut off systems should be configured in compliance with the requirements nominated in AS 4024.
b. Local emergency stop push buttons should be on laboratory egress paths and at the LSS controller location. Remote emergency stop push buttons shall be provided external to and outside entry doors to gas storage rooms. Break glass controllers shall be wall mounted. This

being required to confirm that room exhaust ventilation systems are operating correctly and that there are no active gas detector alarms within the space. In the event of an evacuation alarm, entry to these spaces shall not be permitted except for trained emergency responders

6.7.2.3.6 Life Safety Systems

a. Life Safety Systems
   i. The system shall include all critical components identified in the SIL as applicable.
   ii. To be housed in a lockable cabinet at the entrance to the lab, or centrally located if serving multiple labs.
   iii. To be located outside of any PC boundary to allow for maintenance without entering the lab.
   iv. To be clearly identified with a traffolyte label of cabinet and areas it serves
   v. Be provided with an LED tower light

b. LSS Tower Strobe
   i. The LSS tower strobe light shall be installed to indicate the status of the system (healthy, fault, alarm and maintenance mode)
   ii. power requirements 24V DC,
   iii. visibility – 360 degrees,
   iv. siren volume > 70dB(A),
   v. type – LED,
   vi. lens colours – red, yellow, green and blue

c. Main Control Cabinet
   i. The LSS main control cabinet shall be supplied with power from the building power system. The contractor be responsible for the running and termination of a power supply cable from a suitable distribution board to the LSS main control cabinet.
   ii. Handles to be T-bar style with removable lock cylinder suitable for bi-lock, initial key type is to be CL001 key.
   iii. Dual / redundant power supplies (24V DC) are required in the main control panel to maintain continuity of supply to all LSS devices.
   iv. The LSS main control cabinet shall include the following infrastructure.
      - circuit breakers,
      - isolator,
      - power supplies,
      - PLC CPU and cards,
      - terminal blocks,
      - safety relay,
      - HMI panel,
      - earth bar,
      - DIN rail,
      - cable duct,
      - overhead light,
      - power point – 240V AC,
      - cooling fans.
      - UPS
   v. The HMI shall be mounted in one of the doors. The control cabinet shall be constructed from powder coated mild steel and mounted on a plinth.

d. Power supply
   i. LSS system shall be supplied with a 24V DC power supply and include a 240V UPS backed up supply.
   ii. UPS battery life to be minimum 2hrs and shall be sized not to invoke additional fire rating requirements.

iii. During the design process, an assessment of the UPS requirement for gas panel or solenoid activation must be done where gas is required to continuously run for the equipment in the event of power outage or emergency.
iv. All 24V cabling shall be individually screened twisted pair double insulated and segregated from all other low voltage electrical cables to minimise electrical interference.
v. For more information refer to the USYD Electrical Services Standard

e. Human Machine Interface (HMI)
   i. The LSS shall include an HMI to allow for local control of the system.
   ii. The screen shall include room layout, alarms, sensors and valves including all inputs to the panel.
   iii. Provide legend on HMI to distinguish status of all elements.
   iv. Display trend data for all sensors and faults included in the LSS.
   v. The screen needs to be large enough to see information from all sensors simultaneously, rather than waiting for it to cycle through.
   vi. The HMI provides and interface between the operator and the PLC. It displays an interactive layout of the facility with key LSS devices, alarms, and trends. There shall be one HMI located in the at the main LSS control panel. The HMIs shall meet the following requirements:
      - Typical 12-inch touch screen (or equivalent),
      - power – 24V DC,
      - interface – ethernet or RS 485,
      - preferred vendor – Siemens,
      - external memory – functional SD card slot or equivalent
      - Power Supply

f. Sensors
   i. Gas sensors to be installed in the lab according to the gas type and risk present
   ii. Gas sensors shall be shown on the LSS for status, fault and maintenance mode.
   iii. All sensors to be labelled with type and room serving.
   iv. Shall be able to be tested individually while in maintenance mode, without taking other sensors out of service.
   v. Gas sensors to be Draeger, Monicon, BIE or approved equivalent

g. Alarms
   i. All alarm signals from each device shall be fail safe and latching.
   ii. Provide an alarm mute button on the cabinet, this shall be set to the maximum of 2 minutes.
   iii. Alarm resetting shall be localised at the device via login to the engineering profile

h. Programmable Logic Computer (PLC)
   i. A PLC is used to control the logic processes as defined in the Cause-and-Effect matrix. The PLC shall be capable of controlling both safety and non-safety components. The PLC shall meet the following requirements.
      - power – 24V DC,
      - CPU – portionable for safety and non-safety elements,
      - cards – analogue input, digital input and output,
      - spares capacity – 20% additional I/O wired to terminals in board,
      - preferred vendor – Siemens,
      - connection to BMS via BACnet or Modbus HLI,
      - connection to floor flood sensing monitor unit, and
      - connection to 4 phase separators - ethernet.
   ii. Where required, meet SIL requirements as per SIL assessment

i. Building Management Control System (BMCS)
   i. The LSS shall interface with the BMCS to notify of alarm systems and faults/ isolations. The following output signals shall be provided on the BMCS:
      - Sensor activation
      - Sensor fault

- Gas cabinet fault
- Power Supply
- UPS active
- E-Stops
- Break Glass (gas)
- Fire Alarm
- Ventilation flow failure
- Gas flow failure
- Cylinder empty
- PLC fault
- Trend data should be available on the BMCS if compatible.

ii. The contractor is to liaise with the users to finalise the cause and effect matrix, to eliminate unwanted impacts to experiments such as fire alarm/ ventilation failure shutdown of gases causing additional risk.
iii. The Contractor shall liaise with the University's BMCS contractor to coordinate the configuration and connection of the signal outputs.
iv. Where a new LSS controller is proposed to be installed, the contractor shall provide a high-level interface (HLI) to allow the transfer of data from the LSS to the BMCS (no data shall be transferred from the BMS to the LSS). The HLI is to be via BACnet MSTP or Modbus MSTP protocol.
v. Where IP based connection is required for the BMCS contractor is to nominate for project team location of data port.
vi. Any requirement for remote monitoring of any data from the LSS will be via the BMS – no other remote monitoring of the LSS is required.
vii. The final BMS points list is to be developed by the contractor and provided to USyd for final approval prior to final testing. The lab gas and life safety system contractor are to liaise with and provide the BMS contractor with the address of each point and work with the BMS contractor to test / configure the interface / points.
viii. The contractor shall provide dry contacts for interface with Sydney University security to allow for notification of high-level safety alarms. No data shall be transferred from Sydney University Security to the LSS.

6.7.3 Gas Safety Monitoring

Gas safety monitoring shall be installed in accordance with the risk assessment of the space. Where applicable, the requirements set out in the SIL assessment shall be followed.

The Contractor shall include for field calibration of gas sensors prior to setting to operation, 6-month bump test and 12-month operation calibration. Additional consideration to be taken for special gases, high solvent spaces etc.

The Gas Safety Monitoring system shall be constructed as a safety instrumented system, to the safety integrity level targets in accordance with AS61511 & AS60079.29.3. The sensors shall be configured to alarm under the conditions noted in the below table, subject to the sensitivity of the gas sensors available:

Target Gas	Warning Level	Shutdown Level
Hydrogen/ Methane	¼ LEL	½ LEL
Carbon Dioxide	0.5% CO_2	3% CO_2
Carbon Monoxide	50ppm	100ppm
Hydrogen Sulfide	10ppm	20ppm
Ammonia	25ppm	100ppm
Oxygen Depletion	19.5%	18-16%
Oxygen Enrichment	21%	23.5%

FIGURE 9: GAS SENSOR MINIMUM SETPOINTS

Gas sensor ranges should be selected for maximum sensitivity without causing spurious tripping.

a. Strobes and Evacuation Sirens -
    i. The LSS and gas detection sensors shall be configured to activate strobes and sirens upon alarm.
    ii. LSS Strobes shall meet the following requirements:
    iii. Be LED, colour red and visible from 360 degrees.
    iv. Provide traffolyte label indicating that it is a lab gas alarm.
    v. Power requirements 24V DC,
    vi. The sirens shall meet the following requirements:
        - Power requirements 24V DC,
        - Siren volume > 70dB(A),

b. Hydrogen Sensor
    i. Fixed Gas monitor required.
    ii. environmental diffusion-type catalytic type sensors
    iii. local digital display
    iv. 4-20mA output signal, optional relay outputs
    v. Acceptable drift: <3% over 3 months
    vi. Provide contactor to shutdown Hydrogen gas at ½ LEL or greater and alarm shall be raised by the LSS.

c. Carbon Dioxide Sensors
    i. Fixed Gas monitor required.
    ii. environmental diffusion type infrared type sensors
    iii. local digital display
    iv. 4-20mA output signal, optional relay outputs
    v. Acceptable drift: <3% over 3 months

d. Solenoids
    i. Where assessed as high risk provide solenoid shutoff valve
    ii. Valve type - 2-port solenoid valve.
    iii. Piping specification – SS3
    iv. Fail close upon power loss.
    v. Be installed outside the laboratory for which it services to prevent shutdown to critical devices such as CO2 incubators

e. Portable/ Temporary Gas Detectors
    i. Portable gas detectors will only be considered for existing labs where a new gas panel is not feasible.
    ii. Where portable gas detectors are proposed, they shall be calibrated at least annually.
    iii. They shall include a remote readout external to the lab.
    iv. Shall include a strobe/ sounder.
    v. To be located at the point of use of the gas being monitored

6.7.4 LSS requirements

The below requirements are applicable for both new and existing refurbishments. Where the extension of an existing LSS is proposed, applicable modules and components shall be identified and sourced by the contractor/ consultant during the design phase of the project.

a. Program Structure
    i. The LSS program shall be coded in PLC ladder logic format. The safety specific elements shall be partitioned from the non-safety elements. Partitioning of the code means that if future changes are required to the non-safety elements these may be completed without revalidation of the entire safety system.

b. HMI Screen
   i. The HMI shall be coded in winCC or approved equal. All HMI screens shall be approved by the UI Engineer prior to procurement.
   ii. The screen is to be mounted in a cut-out on a panel door mounted between 1400 and 1600 mm FFL.
   iii. The following screens shall be provided as minimum:
      - home screen
      - legend screen
      - settings screen
      - access control screen
      - alarm / alarm history screen
      - all relevant devices layout / status screens
      - trend screens

c. Access Control
   i. Four levels of user access shall be provided: Guest, Operator, Engineer and Admin. The passwords for these levels of access are to be listed in the O&M
      - Guest: View floor layout, view current alarms, view alarm history, view trends, view alarm set points, view Legend.
      - Operator: View floor layout, view current alarms, view alarm history, acknowledge/mute/reset alarms, view trends, view alarm set points, view legend.
      - Engineer: All above login permissions, activate maintenance mode, change alarm set points.
      - Admin: All above login permissions, change passwords

d. Trending
   i. Trending is to be provided for the following variables:
      - All sensors
      - Critical Alarms
      - Power Fault
   ii. Trending data shall be captured at a resolution of 60 seconds or higher. Trend data shall be visible for the previous 6 months. The operator shall be able to zoom in on specific trend events for higher resolution of data.
   iii. Alarms
   iv. There are three general levels of alarm in the LSS: High Level Safety, Critical Safety, Safety, and Non-Safety.

e. High-Level Safety Alarms
   i. High Level Safety Alarms are those associated with devices that have an assigned shutdown function. If a High-Level Safety Alarm is triggered, either the CO2 supply to the lab or the power supply to the hydrogen generator is shut down, the red strobe light and evacuation siren is triggered in the lab, and the red light and siren shall be activated at the LSS main control panel. The high-level safety alarms may be SIL rated and may also be non-SIL rated.
   ii. The High-level safety alarms shall be on a separate partition of the PLC.

f. Safety Alarms
   i. Safety Alarms are triggered when the system detects a warning or fault condition on a gas sensor. In the event of a warning level alarm the red strobe lights in the affected area will be activated, and the orange lights shall be activated on the LSS panel tower lights.
   ii. In the event of a sensor fault the red strobe lights in the affected area will be red, and the tower light at the LSS panel shall have its orange components activated.

g. Non-safety Alarms
   i. When an abnormal condition is detected on a non-safety element a Non-Safety Alarm is triggered. These include (but not limited to).
   ii. Sensor XXX maintenance mode active
   iii. The light tower shall display a solid blue light in the affected area and in common areas.

h. Alarm Screen:
    i. On this screen there will be a list of all current alarms in the LSS. Each alarm will have the time the alarm was triggered, alarm status, the instrument number and the description of the instrument. Alarm text will match the level of alarm (i.e., red text for Critical Safety Alarm, yellow text for Safety Alarm, etc).
    ii. An alarm "Silence" button shall be utilised, to silence the alarms for a preset period to allow for investigation by the contractor, this should be confirmed with the project team, and should be maximised to balance safety and minimise nuisance noises.
    iii. A "Reset" button will be located on the alarms screen. Pressing this button will do one of two things;
    iv. if the cause of an alarm is no longer present, pressing the reset button will clear the alarm from the list. It will do this for all alarms on the list, and
    v. if the cause of an alarm is still present, pressing the reset button will acknowledge all the alarms on the list. This will add the word "Acknowledged" in the status column of each of the listed alarms and silence all LSS sirens in the facility. Once the cause of the alarm is no longer present, the acknowledged alarms will automatically clear themselves.

i. Alarm History
    i. The alarm screen also shows all the past alarms triggered in the LSS. The text colour of the alarms will match the alarm level and the time they were triggered will also be displayed. Cleared alarms automatically move to the alarm history.

j. Maintenance Mode
    i. Gas sensors shall be serviced to maintain their reliability. They are calibrated (usually every six months – frequency to be determined by the contractor based on SIL verification calculations, or sensor manufacturer recommendations where SIL verification is not required). The sensor elements shall be periodically replaced (usually every 1.5 – 2 years for catalytic style sensors, 5 years for Infrared type sensors). To prevent facility downtime and alarms when sensor maintenance is conducted a maintenance mode is provided on the LSS.
    ii. When a sensor is in maintenance mode the LSS does not take any action as a result of signals from the device. When maintenance mode is activated, a timer shall run. If the maintenance mode has not been reset by the time the timer expires the LSS shall automatically reset the system to normal mode and again take action on all alarms.
    iii. Maintenance mode is indicated by a solid blue light on the tower lights at the LSS panels, and a red strobe being activated in the corresponding room. Maintenance mode shall display on the Alarms screen. A signal shall be sent to the BMS when a device is in maintenance mode.

6.8 Electrical Panels

All electrical panels and wiring shall comply with the following requirements and the USYD Electrical Services Standard.

a. Main Electrical Panels
    i. Floor standing with a plinth not less than 50 mm. If the contents are such that there is more than 50% free space in the cubicle a wall mounted cubicle may be used.
    ii. Floor standing panels shall be between 1800 mm and 2200 mm high and not less than 400 mm deep.
    iii. May be of standard off the shelf construction.
    iv. Powder coated steel construction.
    v. Will contain the main isolation points for utilities such as mains voltage and control air.
    vi. Main isolator to be mounted not higher than 2000mm
    vii. All equipment shall be mounted on a gear sheet, which shall be of steel construction of at least 3 mm thickness.

viii. The only items that may be mounted on the side of an enclosure are:
ix. A main isolator
x. Cable tray or cable duct
xi. Field terminals
xii. Pneumatic equipment used for control applications (e.g., solenoid valves, pressure regulators).
xiii. All panels will have a minimum protection rating of IP43.
xiv. Handles to be T-bar style with removable lock cylinder suitable for bi-lock, initial key type is to be CL001 key.

b. Low Voltage Distribution – Incoming Isolator
   i. May be an isolator, fused isolator or circuit breaker.
   ii. There will be a separate isolator for each supply that comes into the system e.g., normal and UPS supplies.
   iii. If more than one isolator exists a warning sign indicating multiple supplies will be mounted next to each isolator.
   iv. The isolator label shall reference the point of supply i.e., Distribution Board and Fuse number.
   v. The frame rating of the isolator shall exceed the rated load of the control system by at least 25%.
   vi. If an isolator is used, then cabling to the first level of protection devices will be rated to the last protection device rating.
   vii. All isolators shall have an actuator accessible from the outside of the cubicle and shall be lockable in the off position.
   viii. The terminals of the isolator shall be shrouded to prevent direct hand contact.

c. Supply Protection and Monitoring
   i. The system shall have the following power supply protection and monitoring:
   ii. Surge protection devices shall be fitted between each phase and earth and between neutral and earth.
   iii. A Phase Failure / Phase Rotation protection relay will be installed in all 3 phase systems.
   iv. The Phase Failure Relay will be protected by a circuit breaker.
   v. The Phase Failure Relay shall use an interposing relay to send a status input to the PLC or controlling logic system.
   vi. All distribution busbars will be protected by a suitably rated circuit breaker.
   vii. Provide electrical meter on the incoming supply to the panel/ board – refer to the USYD Electrical Services standard for more detail.

d. Distribution
   i. After the main isolation device there will be link blocks to facilitate distribution.
   ii. There shall be a Neutral Bus Bar, an Earth Bus Bar and a Clean Earth Bus Bar. The Clean Earth shall be connected to the Main Earth through a removable link unless the customer is able to supply an instrument earth connection. Rail mounted terminals shall not be used for the main neutral and earth links.
   iii. All 415 VAC 3 phase and 240 VAC single-phase distribution will be by bus bar systems.
   iv. The bus bar will be shrouded.
   v. The bus bar will be rated to at least twice the rated load.
   vi. All un-used combs on the bus bar will be either fitted with a circuit breaker or shrouded.
   vii. The bus bar will be protected by a supply circuit breaker.
   viii. Each sub-circuit will have a suitably rated circuit breaker

e. Manufacturers specifications
   i. Provide from the manufacturer.
   ii. As-built manufacturing/ shop drawings and layout drawings.
   iii. Factory Acceptance Testing documentation.
   iv. Any departures from the layout will be agreed with the Project Engineer before implementation. Any layout changes will be shown in the “as-built” drawings.

f. Testing

i. The contractor is to develop a procedure for client review of Factory Acceptance Testing and Site Acceptance Testing prior to procurement of the control panels. This procedure and accompanying documentation shall be provided for review prior to client acceptance of the satisfactory FAT and SAT tests.

6.8.1 Electrical Layout Drawings

Electrical Layout drawings shall be produced for each and every panel manufactured under this Standard. The following shall apply:

a. The drawings shall be scaled.
b. All items on the Bill of Materials shall be identified on the layout drawing with the following exceptions:
    i. Individual rail mounted terminals
    ii. Snubber components
    iii. Auxiliary contacts on motor contactors
    iv. Similar small items
    v. ID labels
c. All items of groups of items to be identified.
d. Any departures from the layout will be agreed with the Project Engineer before implementation. Any layout changes will be shown in the "as-built" drawings.

6.8.2 Electrical and Control System Testing

Refer to the USYD Electrical Services Standard

6.9 Equipment Labelling and Identification

6.9.1 Below Ground Services

All underground services to have marking tape of correct distances above pipework complying with relevant Australian Standards for that service. Where the service is non-metallic, provide a tape incorporating metallic locating wire. Brass plates shall be installed at finished RL identifying all inground services located at 30m intervals and at changes in direction of services.

6.9.2 Above Ground Services

All pipework and cabling shall be labelled with adhesive markers indicating pipe contents or system type and directional arrows indicating flow. Markers shall be installed at a minimum of every five metres.

Labelling shall not be restricted only to close proximity of access panel openings.

6.9.3 Asset Labelling and Bar Coding

Equipment shall be provided with asset labels and bar codes as per COS Asset Identification and Labelling Standard or financial barcodes if faculty owned assets. Liaise with COS and the faculty for final requirements.

6.10 Pipework and Cabling Installations

6.10.1 Below Ground Services

All pipework and cabling installed below ground shall be fully surveyed and documented in accordance with the details required for Quality Level A, as per AS5488-2019 – Classification of Subsurface Utility Information (SUI).

The Permit to Dig Form (UI-ENG-F003) shall be submitted and approved by UI prior to installing or repairing any pipework or cabling located below ground.

For further details and requirements of all pipe and cabling installations below ground, please refer to the COS Excavation Standard, UI Hydraulic Services Standard and UI Electrical Services Standard.

6.10.2 Above Ground Services

All pipework and cabling installations, including the materials, supports, jointing, etc, shall satisfy the relevant Australian Standards, UI Hydraulic Services Standard and UI Electrical Services Standard.

6.10.3 Core Holes and Sleeves

Details of all proposed core holes in floors, walls, beams and columns shall be checked and approved by a structural engineer and slab scan results prior to coring the hole.

All pipework and cabling passing through a core hole or masonry/concrete wall, or floor shall be provided with a 0.6 mm thickness sheet copper sleeve having a grooved and seamed joint. Sleeves shall be cylindrical having a diameter to provide a 25mm gap all around the services passing through the sleeve. Alternatively, copper tubing may be used as the sleeve if a 25mm gap around the service can be achieved. Each service passing through the sleeve shall be positioned centrally in the sleeve to ensure the annular space between the service and the sleeve is equal and round.

Fire rating of all pipe and cabling penetrations shall be installed to comply with all statutory requirements and the requirements of this standard.

6.10.4 Corrosion Protection and Finishes

All surfaces exposed or susceptible to corrosion will be suitably painted, including external surfaces of all machinery, apparatus, equipment, fittings, tanks, vessels and services including supports, hangers and brackets.

Ferrous metal exposed to the atmosphere or in humid conditions is to be hot dip galvanised having a minimum coating thickness 0.1mm. Hot dip galvanising shall be carried out after all welding, cutting, drilling and swarf removal has been completed. The university will not accept cold galvanising process.

Surfaces that shall not be painted include:

a. All fibreglass and plastic surfaces.
b. Chrome plated and stainless-steel surfaces.
c. Bearing surfaces, slides, adjusting screws and any surface that is required to be unpainted for the correct operation or adjustment of the equipment.
d. Flexible duct connections to plant, rubber or canvas hoses, flexible rubber mountings and any other non-metallic flexible connections.
e. Piping where installed in ceilings, trenches, underfloor, and similar concealed spaces shall not be painted throughout their entire length but shall be labelled with identification bands. However, steel piping installed in damp conditions in any of the above shall be hot dip galvanised.
f. Bare copper tanks.
g. Motor and equipment nameplates.

6.11 Materials and Equipment Selection

Only new materials, equipment and components will be installed, and these shall be of good quality, fit for purpose and selected to minimise life-cycle costs and maximise efficiency. All products shall be supported locally and internationally by factory trained service networks. All spare parts shall be available ex-stock factory for a period of 10 years from purchase date. Equipment and materials that are obsolete, discontinued, about to be discontinued or superseded, shall not be installed. Selected equipment shall have the ability to be backwards compatible.

Uniformity of the type of materials shall be consistent throughout all individual installations and shall match, or be fully compatible, with the existing equipment.

All Lab Gas equipment shall be designed and manufactured to the relevant Australian Standard.

Details of all major items of Lab Gas services proposed to be installed during new or refurbishment projects shall be submitted to UI for approval prior to installation. This will include, but is not limited to, pipe material selection, Life Safety Panels, Sensors, alarms, regulators, valves and gas enclosures.

Identification of a proprietary item of equipment will not necessarily imply exclusive preference for the item identified but indicates a deemed-to-comply item.

6.12 Service Access Requirements

The following servicing and access requirements shall be provided:

a. Position all equipment and arrange access provisions at equipment, to optimise future maintenance and repairs.
b. Service access doors and panels shall be hinged and lockable with a University plantroom bi-lock key. Lift off panels with screw fixings are not acceptable.
c. The University will not accept major plant within ceiling spaces and plant in tight spaces. Plant that is located in a ceiling space shall have free and easy access. This includes ability to service system without reaching around or over columns, beams, cable trays, pipe work, lights and duct work.
d. All motors are to be provided with isolators within 3 meters distance from motor. Isolators shall be traffolyte labelled with details of the source of electrical supply (DB/CB).
e. A plus 20% additional dimension access allowance is to be provided for above the manufacturers access requirements.
f. Major plant located above 3m height will have permanent stair/ladder access provisions with permanent workable platform.
g. Trip hazards to be identified and painted in yellow.
h. Electrical hazards shall be identified and labelled appropriately.
i. Confined spaces to be noted and appropriate signage applied.
j. Fixed switchable lights are to be provided in all areas where Lab Gas equipment is installed.
k. Access to plant and equipment shall comply with all WHS regulations.
l. Minimum 600mm access required around plant and equipment unless specified otherwise.

6.13 Redundant Equipment

All redundant lab gas systems and equipment and associated services (pipework, manifolds, power etc) must be removed as part of the project. Building surfaces and finishes must be made good wherever redundant services are removed. Where a service is unable to be removed appropriate tags and labelling shall be installed to indicate that the service is temporarily out of use or redundant. Liaise with the users of the space and TSS to confirm which direction to proceed with when removing equipment and pipework from the space.

6.14 Interruption to Existing operational lab gas services

Where any new, refurbishment or maintenance works require interruption or isolation of existing lab gas services, to prevent disruption to experiments and to allow work to be performed on the system, contractors shall gain approval from UI and COS prior to the works occurring.

A notice for "Lab Gas Interruption" shall be submitted to the project manager and approved by the faculty at least 72 hours prior to any proposed interruption.

When refurbishment works occur within occupied buildings, Lab gas services in occupied areas shall not be interrupted or isolated for periods longer than eight (8) hours. Where the project requires shutdown for longer than this period of time, the occupants may need to be relocated or provided with temporary bottle supplies to maintain gas supplies for their experiments.

Prior to refurbishment works commencing within buildings proposed to remain occupied during the course of the refurbishment works, the contractor shall consult with UI the proposed strategy and methodology relating to interruption Lab Gas services within the building for the duration of the project works. The contractor shall also provide appropriate safe work method statements (SWMS) for review and approval by UI.

The interruption and isolation of existing Lab Gas services required for new and refurbishment projects will be included in the project works, and planned with the affected users.

7 Commissioning

Comprehensive pre-commissioning, commissioning and quality monitoring shall be specified by the consultant/designer or contractor.

A project specific commissioning plan is to be developed and provided to the University for review and approval.

Detailed testing and commissioning records shall be provided for each system and each component as appropriate. All such records shall be witnessed and verified by the project consultant/head contractor prior to witness commissioning by UI engineers.

Project handover plan shall be developed by the consultant/designer to allow the system to be handed over to The University. A 12-month building tuning process will commence at Project handover with systems monitored monthly, reported and assessed quarterly, and include assessment of feedback from the occupants.

A project specific commissioning plan shall be developed and provided to the University for review and approval. UI have developed a Lab Gas Services Commissioning Checklist (UI-ENG-F026) which should be used as a minimum guide when preparing the project specific commissioning plan.

8 Safety in Design

The contractor shall consider risk during the design. A design safety report shall be submitted to the relevant UI Project Manager for every design project. Contractors shall confirm, so far as it is reasonably practicable, that the structure is without risks to health and safety.

Design risks shall be considered for the asset lifecycle covering construction, operational and maintenance, refurbishments and decommissioning.

The design safety report shall include the following:
a. Description of design element.
b. Description of potential risks and hazards associated with the design element.
c. A low/medium/high risk assessment considering likelihood and consequence.
d. Proposed measures to eliminate risks where practicable.
e. Control measures to mitigate and manage design risks.
f. Nominating responsibilities for managing the design risks.

This may be provided as a design risk register where appropriate and shall include results of any calculations, testing and analysis etc.

9 Documentation and Records

9.1 Design Documentation

Prior to commencing construction of new or refurbishment projects, the consultant/contractor shall fully investigate and document the requirements for each Lab Gas system required to be installed, altered or modified as part of the project works.

This shall include:
a. Provision of a BCA/ NCC Compliance Report.
b. Return Brief defining the systems proposed and any deviations from this standard.
c. Calculations to be provided on the sizing of the pipe work. Future allowances are to be included in these calculations\sizing.
d. Calculations & selections on the proposed equipment.
e. Budget calculations.
f. Provision of Design Certification of each Lab Gas service.
g. Requests for all variations to this Standard submitted using the Request for Dispensation Form (UI-ENG-F001).
h. Complete the Design & Construct Checklist Form (UI-ENG-F009).

This documentation shall be provided by the consultant/contractor in both electronic and hard copy formats and approved by the University.

9.2 Completion Documents

At the completion of all projects, the following documentation shall be provided by the contractor for each Lab Gas Service installed or altered as part of the project works:
a. O&M manual(s).
b. As-built drawings (including schematics in both PDF and CAD format).
c. Design and Install Certification (indicating BCA/ NCC clauses & Australian Standards year/amendment).
d. Asset schedules and labelling (as per the Asset Identification and Labelling Standard).
e. Commissioning test results.
f. Product manufacturer specific information.
g. Copies of Safety Risk Assessments and SIL assessments
h. Details of all usernames and passwords required to access all equipment and software.
i. Warranty schedules for all major items of equipment.
j. Maintenance requirements for all items of equipment.
k. Building User Guide.
l. Where NCC performance solutions are provided, copies of final Fire Engineering Report (FER) and a specific FER Emergency management plan are to be provided.
m. Supply authority completion forms and inspection record.
n. Installers Statutory certificates.

o. Fully surveyed and documented underground services drawings depicting all as built water, drainage and gas pipework and services, to suit Quality Level A information, in accordance with AS5488 Classification of Subsurface Utility Information (SUI) in both PDF and CAD format.
p. Certification of compliance to Australian Standards, The University Standards and the National Construction Code.
q. The Contractor must provide pressure vessel design certification and pressure vessel certification prior to practical completion or activation of the system.

This documentation shall be provided by the contractor in both electronic and hard copy formats and approved by the University prior to Practical Completion being granted.

10 Assets and Warranties

Assets are to be tagged in accordance with the COS Asset Identification and Labelling Standard for the purpose of maintenance and operation of University Assets. For refurbishment projects the project manager is to provide the existing asset list to the contractor to ensure modified and redundant equipment are captured in the contractors submitted asset list.

Each asset required to be collected can be found in the Form COS-ASSET-F001, for more information refer to the COS Asset Identification and Labelling Standard.

Asset lists must be submitted prior to practical completion of the project for review and approval.

Equipment Warranties are to be provided for a minimum of 12 months from the date of practical completion. Warranties are to be provided as certificates as part of the O&M from the supplier of the equipment. It is the responsibility of the installation contractor to ensure all maintenance/ servicing required to the equipment is provided to ensure warranties are valid at the end of the project DLP period.

11 Defects and Liability Period

Consultants/designers shall include in the project specification detailed requirements for the defects and liability period following completion of the Lab Gas services installation.

The contractor shall include and allow for recommissioning of all major plant and equipment in the last month of the 12-month defects and liability period and confirm they achieve the original design requirements. In addition, all commissioning shall be witnessed by UI Engineering staff with commissioning reports/results formally submitted to UI Engineering. Where specific items are required to be re-witnessed after PC, the 12-month DLP period will commence from this re-witnessing date. Where specific items are required to be replaced within 2 years (such as gas monitoring sensors) these shall be replaced under the 12 month annual DLP maintenance prior to handover.

11.1 Maintenance and Testing

For Lab Gas Services installed as part of a refurbishment project of an existing building, regular statutory maintenance and testing shall be carried out by the University's services maintenance contractor during the Defects Liability Period (DLP). The installation contractor shall provide a comprehensive handover and the required completion documentation at Practical Completion including DLP maintenance schedule for all installed assets, comply with any warranty requirements.

All defects arising from regular statutory maintenance and testing performed during the DLP will be documented and passed onto the installation contractor for rectification. The installation contractor shall be responsible for all defect rectification works identified during the DLP.

For new buildings, the installation contractor shall provide statutory maintenance and testing of all Lab Gas Services throughout the DLP. Prior to the completion of the DLP, the installation contractor will perform all annual maintenance procedures in the presence of the University services maintenance contractor and provide documentation confirming the provision of all statutory maintenance has been performed during the DLP.

Any details which will affect the future maintenance and performance of the new or upgraded equipment shall be supplied by the installation contractor at Practical Completion.

Prior to completion of the DLP, a final inspection of the installed systems will be carried out by the: installation contractor, appropriate UI and COS staff, and University services maintenance contractor, in order to reconcile the performance of the equipment during DLP to produce a final list of project defects. All project defects identified shall be rectified by the installation contractor prior to finalisation of the DLP.

12 Operations & Maintenance Manuals

Consultants/designers must include in the project specification detailed requirements for operation and maintenance manuals, including system description, operation procedures, testing and commissioning records, maintenance instructions, product support information and recovery protocols for any computer related systems. Contractors must provide these to the satisfaction of the consultant/designer. Providing a collection of manufacturers' brochures and catalogues is not acceptable to the University.

The O&M manuals must be submitted in the format outlined in **Operation and Maintenance Manuals Standard**. The **O&M Manuals Folder Template** must be used to submit the final O&M manuals. O&M manuals must be provided electronically in the zip folder via a USB and a large file downloadable link or platform. **O&M Manuals Review Checklist** must be submitted with O&M manuals package. For more information refer to the **Operation and Maintenance Manuals Standard.**

Contractors must submit the university designated **Asset Management Master Asset Data Capture Spreadsheet (COS-ASSET-F001)** designed for recording operational and maintenance activities including materials used, test results, comments for future maintenance actions and notes covering asset condition. Completed logbook pages recording the operational and maintenance activities undertaken for Practical Completion and during the Defects Liability Period must also be provided. For more information refer to the **COS Asset Identification and Labelling Standard**.

Facilities Maintenance must establish, document and implement procedures for operation and maintenance of hydraulic services, plant and equipment to hydraulic services are fit-for-purpose, provide secure, efficient, safe and reliable electrical power, and comply with requirements of this standard.

13 Authorisation of Variations

Project managers, consultants, contractors, commissioning agents and facilities maintenance personnel shall ensure compliance with these requirements is achieved.

Variations to this standard shall only be considered where:

a. The University Standard's requirement cannot physically or technically be achieved.
b. The Performance solution delivers demonstrated and proven superior performance for the same capital and life cycle cost or better.

Consultants and contractors shall identify and justify requirements of the standard that do not apply to the project, or which need to be varied and these which shall be approved by the issuer of this standard. Formal requests for all variations to this Standard shall be submitted using the UI Request for Dispensation Form (UI-ENG-F001). The issuer of this standard or their delegated authority shall review and consider requirements of stakeholders from clients, projects and facilities management before deciding whether to approve variations. Their formal sign-off is required for acceptance of any non-compliances and departures from this standard's requirements.

14 Quality Control

14.1 Design Standard Compliance

Compliance with requirements of this standard shall be checked throughout the design, construction and commissioning phases of projects by UI' services consultant. Any issues or deviations from this standard shall be reviewed and approved in writing by the issuer of this standard.

Competent UI consultants and representatives shall check compliance with this standard during design reviews and formal site inspections. Any non-conformances with requirements of this standard shall be documented and provided to the University Project Manager for issue to contractors and their consultants.

Project Managers shall maintain a formal register of non-conformances and manage close out of outstanding non-conformances. Contractors and their consultants issued with non-conformances shall take appropriate corrective actions. The UI Project Manager shall ensure:

a. Proposed corrective actions are implemented.
b. Close out of non-conformances in relation to this standard is formally approved and signed off by the author of the standard or their delegate.

14.2 Design Standard Certification

Contractors and Consultants shall certify compliance to the design standard by submitting a company Design Certification Form to the UI Project Manager at each of the following project phases:

a. Design and Documentation.
b. Tender.
c. Construction.

Notwithstanding UI's internal quality control processes, contractors and their consultants shall implement their own robust quality assurance and control procedures to ensure compliance with requirements of this standard.

14.3 Construction Compliance

Consultants and contractors are expected to include check sheets for each system component detailing each item that needs to be checked, tested and verified during the installation process. Such check sheets shall be completed and verified by the project consultant/contractors, including the identification of any defects and the closing out of such defects.

14.4 Acceptance

The University will only accept projects as complete when all of the above have been carried out, submitted and verified.

The above standards are not an exhaustive list of the relevant requirements. The consultant/contractor shall incorporate all relevant standards and Authorities requirements into project specific design, documentation and installation.

Consideration shall be given by the consultant/contractor to the original standard of performance relevant to the construction date of the individual Lab Gas services.

15 Document Amendment History

Revision	Amendment	Commencing
001	First Issue	2026

16 Reference Documents

AS2896 - Medical gas systems - Installation and testing of non-flammable medical gas pipeline systems
Santa Clara County Toxic Gas Ordinance
CGA G-13 Guideline for Silane and Silane Mixtures
USYD Safety Health and Wellbeing – Working with Gases
AS60079.10.1 Explosive atmospheres
ISO 8573.1 Compressed Air
BCGA Guideline Note II - best practice for the safe storage of gas cylinders in the workplace
CCPS Centre for Chemical Process Safety
OREDA – Offshore and onshore reliability data handbook
AS4024 Safety of machinery
IEC/ AS61508/61511 Safety Automation

17 Appendix A – Pipe Spec Tables

Pipe Spec Tables.xlsx

GAS TYPE	AS 4343 TABLE 3.2 SERVICE CONDITIONS	PURITY			AS 4041 - PIPING CLASSES / DESIGN PRESSURE LIMITS		
		≥5.0	3.5 < P < 5.0	≤3.0	Class 1	Class 2A	Class 3
Highly Toxic	LG - Lethal Gas	SS DC	SS DC	SS DC	No design pressure limit.	Prohibited.	
Toxic	VHG - Very Harmful Gas	SS W	SS W	SS W	No design pressure limit.	104 bar (1508 psi) max. design pressure	20 bar (290 psi) max. design pressure
Corrosive	VHG - Very Harmful Gas	SS DC	SS DC	SS DC	No design pressure limit.	104 bar (1508 psi) max. design pressure	20 bar (290 psi) max. design pressure
Flammable	VHG - Very Harmful Gas	SS W	SS W	SS W	No design pressure limit.	104 bar (1508 psi) max. design pressure	20 bar (290 psi) max. design pressure
Oxidiser[1]	VHG - Very Harmful Gas	SS W or SS HP	SS HP	CP LG or SS LP	No design pressure limit.	104 bar (1508 psi) max. design pressure	20 bar (290 psi) max. design pressure
Inert	NHG - Non-Harmful Gas	SS W or SS HP	SS HP	CP LG or SS LP	No design pressure limit.		

NOTES:
1. All tubing, valves and instruments to be Cleaned for Oxygen design (CFOS)
2. For temperature limits for each pipe class refer to Table 1.4 in AS4041. In general laboratory gas is used at ambient temperature which does not contribute to piping class determination
3. The piping class designation as determined in Table 1.4 of AS4041 refers to a pre-engineered set of rules and data that define how a particular piping system must be designed, fabricated, inspected, and tested for a given pressure/temperature and fluid service.

Table 1: Gas Type vs Purity Selection and AS 4041 Piping Classes

PIPING SPECIFICATION		TUBE SPECIFICATION	SURFACE FINISH / CLEANLINESS (INTERNAL)	PERMITTED JOINING METHODS	PERMITTED VALVE TYPES	PRESSURE TESTING REQUIREMENTS	PERMITTED LEAK RATE	MINIMUM REQUIRED CERTIFICATIONS
SS WELDED		ASTM A 316 L - Composition ASTM 269 / 270 - Dimension, Ovality and Wall Thickness Refer to Table 3 for pressure rating as a function of tube outer diameter OR calculate as per Clause 3.14 of AS 4041.	<15 µin Ra EP	Orbital welding VCR[1]	Diaphragm Bellows	PT HLT	<1 x 10-9 std cc/s (SEMI F1-96)	Refer to Welding Qualifications described in AS 4041 Table 1.5, Item No. 3 for the applicable Piping Class.
SS D.C.	Inner tubing		<15 µin Ra EP	Orbital welding	Diaphragm (only in ventilated enclosure)	PT HLT	<1 x 10-9 std cc/s (SEMI F1-96)	
	Outer tubing		Mill	Orbital welding VCR	N/A	PT HLT	Evacuation to <10 mbar <1.0 x 10-9 std cc/s	
SS HP			<15 µin Ra EP	Double ferrule compression	Diaphragm Ball Globe	PT	<1.0 x 10-4 std cc/s	No special certification required for gas fitting in lab gas installations.
SS LP			Mill	Double ferrule compression	Any	PT	<5.0 x 10-4 std cc/s	No special certification required for gas fitting in lab gas installations.
CPLB LG		AS1571 seamless copper tube Refer to Table 4 for pressure rating as a function of tube outer diameter OR calculate as per Clause 3.14 of AS 4041.	Refrigeration / Medical Grade	Braze with inert purge Double ferrule compression	Any	PT	<5.0 x 10-4 std cc/s	Refer to Brazing Qualifications described in AS 4041 Table 1.5, Item No. 3 for the applicable Piping Class. No special certification required for gas fitting in lab gas installations.

NOTES:
1. No mechanical joints permitted in ceiling spaces - fully welded only.

Table 2: Pipe Specification Requirements

TUBE OUTER DIAMETER (inch)	DESIGN PRESSURE (MPa)[1,2] WALL THICKNESS (mm)		
	0.90	1.60	2.00
1/8	75.1		
1/4	40.4	80.9	
3/8	25.7	49.2	64.4
1/2	18.8	35.3	45.6
3/4	12.3	22.6	28.8
1	9.1	16.6	21.1
1 1/2	6.0	10.8	13.7
2	4.5	8.1	10.1
2 1/2	3.6	6.4	8.1
3		5.3	6.7
4		4.0	5.0
6		2.6	3.3
8		2.0	2.5

NOTES:
1. Ratings apply to seamless tube at ambient temperature, up to 50°C.
2. Design pressures calculated as per AS 4041 for the given wall thickness.

Table 3: Design Pressure vs. Tube Outer Diameter - Stainless Steel Tubing

TUBE OUTER DIAMETER (inch)	WALL THICKNESS (mm)	DESIGN PRESSURE (MPa)[1]
1/4	0.71	9.18
3/8	0.91	7.72
1/2	0.91	5.66
3/4	1.02	4.15
1	1.22	3.71
1 1/2	1.22	2.44
2	1.22	1.81
2 5/8	1.22	1.38
3	1.63	1.61
4	1.63	1.20

NOTES:
1. Ratings apply to Copper tube to AS1571 at ambient

Table 4: Design Pressure vs. Tube Outer Diameter - Copper Tubing to AS1571

TERM	DESCRIPTION
SS W	Stainless steel welded
SS DC	Stainless steel, double contained
SS HP	Stainless steel high purity
SS LP	Stainless steel low purity
CP LG	Copper lab grade
Ra	Roughness Average measured as per ASME B46.1
EP	Electropolished
PT	Pneumatic pressure test
HLT	Helium leak test
O.D.	Outer diameter

Table 5: Legend

TERM	DESCRIPTION
ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A270	Standard Specification for Seamless and Welded Austenitic and Ferritic/Austenitic Stainless Steel Sanitary Tubing
AS1571	Copper - Seamless tubes for airconditioning and refrigeration
AS 1796	Certification of welders and welding supervisors
AS 3992	Pressure equipment—Welding and brazing qualification
AS 4343	Pressure equipment—Hazard levels
AS 4041	Pressure piping
SEMI F1-96	Specification for Leak Integrity of High-Purity Gas Piping Systems and Components
ASME B46.1	Surface Texture (Roughness, Waviness, Lay)

Table 6: Relevant standards