CLINTON HEALTH ACCESS INITIATIVE

High-pressure gas cylinders for medical oxygen use in healthcare settings

Oxygen Alliance presentation

23 June 2022

Agenda

- CHAI overview
- General oxygen safety
- Cylinders within the oxygen therapy ecosystem
  - Focus: distribution manifolds
- Procurement considerations
- Oxygen cylinder management
  - Moving within a system
  - Changing and transporting
  - Accessory compatibility
  - Chain of custody
- Cylinder risks & safe practice tips

Our Mission

We are committed to our mission to save lives and reduce the burden of disease in low- and middle-income countries around the world. We aim to sustainably strengthen government and private health systems in countries where we work.

Our Approach

We take on **large, ambitious projects** that will have a **major impact on saving lives**.

We work at the service of and **in partnership with governments**.

We work to help **make health care delivery more efficient and effective**, allowing limited resources to reach more people.

We follow **core values** to carry out our mission.

Our Values

We work with urgency.

We work in cooperation with and at the service of partner governments.

We are a mission-driven organization.

We are frugal.

We operate with humility.

We have an entrepreneurial and action-oriented culture.

We operate based on trust and transparency.

We recognize that our staff is our greatest asset.

We foster diversity and inclusion.

Key Highlights

35+ Countries

Around the world in which CHAI operates.

140+ Global Deals

To lower drug, diagnostic, and other health product prices by 50 to 90%, to accelerate access to developing countries.

84% of Staff

and 44% of CHAI leadership are based in the countries where we operate programs.

20 Years Experience

Founded in 2002 with a focus on HIV/AIDS, our scope has expanded, but our objective remains to save millions of lives.

125+ Countries

Have access to CHAI-negotiated price reductions for key high-quality medicines, diagnostics, vaccines and devices.

A Unique Approach

Ambitious goals that focus on transformational change in global health.

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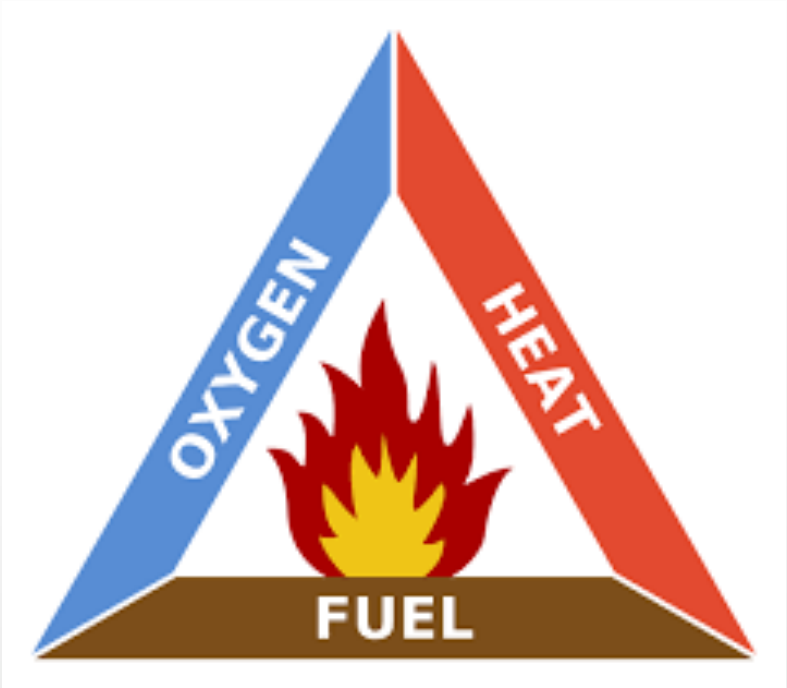
Oxygen risks: the fire triangle

- Oxygen is an '**oxidizing agent**', reacting with most elements
- Oxygen is highly supportive of **combustion** (the reaction with oxygen to release **heat** and light/flame/glow)
- Oxygen **enrichment** is when oxygen content is **greater than that of air, so >21%**

The Fire Triangle



Oxygen-enriched air increases the risk of fire

Basic cylinder caution

Grease or oil will burn in the presence of concentrated oxygen.

- Connections (valves regulators, pipes, and fittings) must always be clean and oil-free:
  - Any device used for oxygen therapy must be clean.
  - Do not touch threads or the inside of any component – hands produce natural oils.
- Ferromagnetic objects cannot be used near to magnetic resonance imaging (MRI) systems.
  - ✗ steel oxygen cylinders and steel trollies cannot be used.
  - ✓ Aluminum alloy products are to be used.
- Smoking or open flames are prohibited within 3m of an oxygen source.

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What is a high-pressure gas cylinder in the context of medical oxygen?

A refillable container-closure system

Made of steel, aluminium, or other material (use-case dependent, e.g., MRIs)

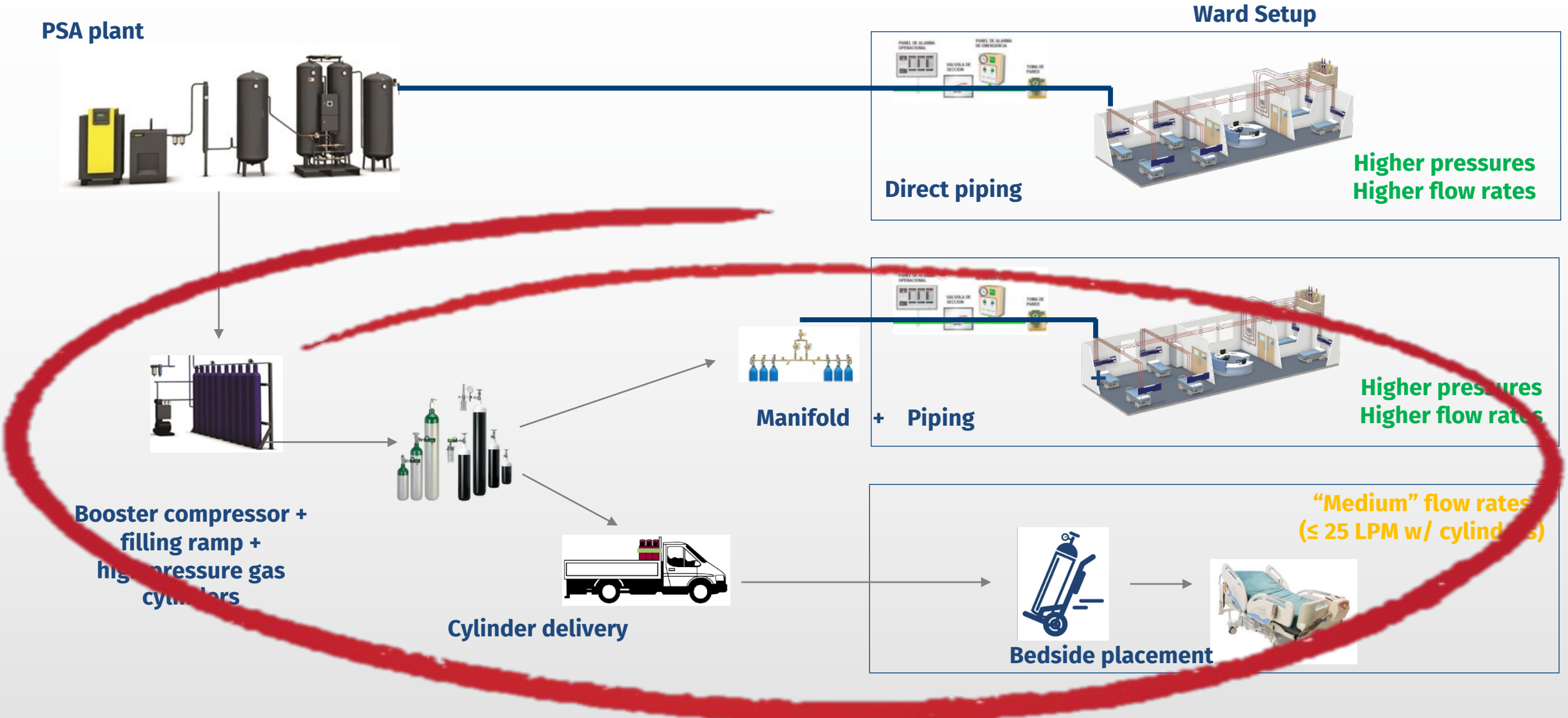
Designed to safely hold compressed medical oxygen at pressure (e.g., 200 bar)

- ✓ Must be used with a pressure regulator – connected directly to the valve or via a distribution manifold – to release the oxygen at a safe working pressure.
- ✓ Inclusive of an O_2-rated context-compatible valve to open / close with a hand-wheel or key

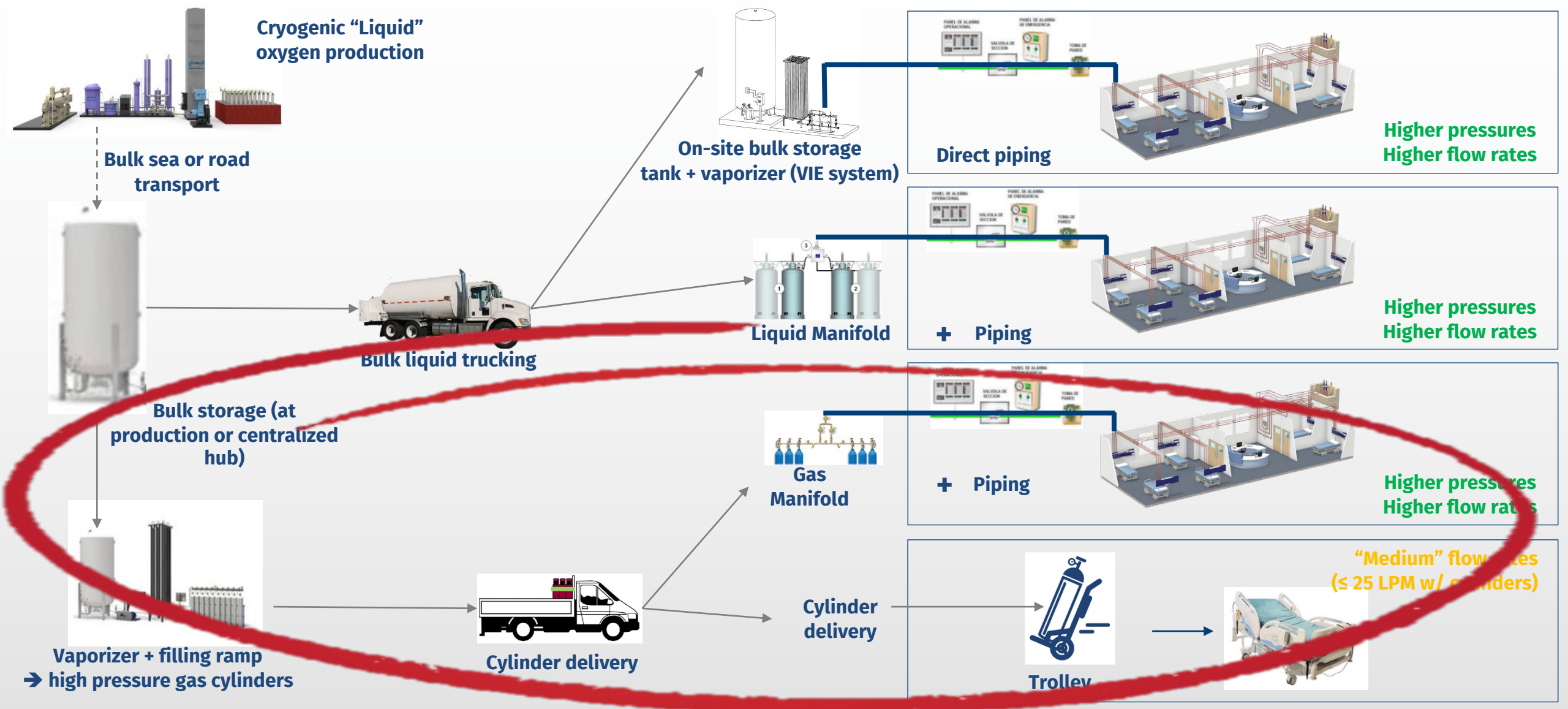
Described by size (in water capacity) and content (denoted by colour)

Classified and regulated as transportable pressure equipment in high-income settings

Where are cylinders found in the healthcare continuum? (1/2)
PSA plant configuration and distribution



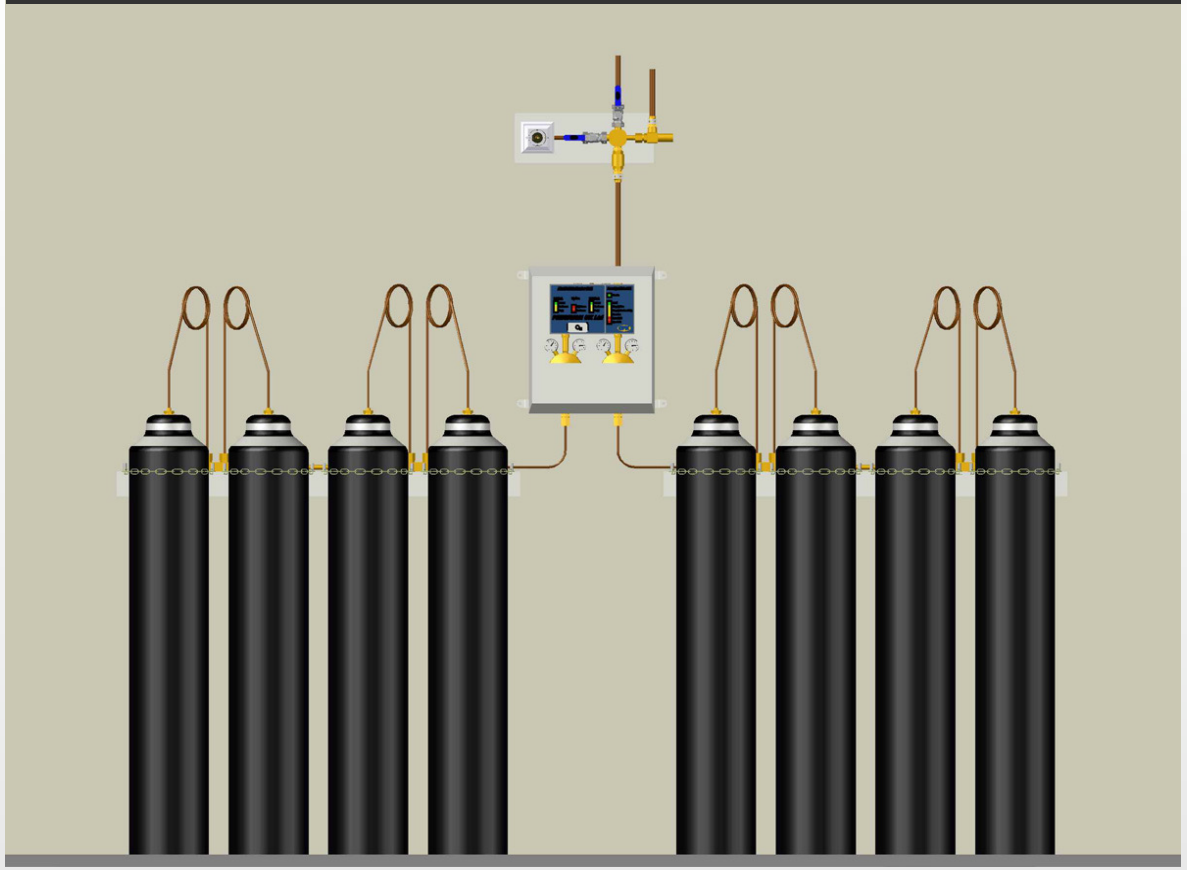
Where are cylinders found in the healthcare continuum? (2/2)
Cryogenic “liquid” plant configuration and distribution



Oxygen distribution manifold overview

- Regulated as medical devices (under EC's MDR).
- Can supply an uninterrupted flow of medical oxygen to the patient's bedside within a facility via a pipeline system.
- Operate from groups of cylinders called "banks":
  A "duty bank" is in operation, the other is a "stand-by bank".
  - The "stand-by" bank comes online when the "duty bank" empties
  - This allows for continuous supply
  - Depleted cylinders are to be replaced as soon as possible.
- Each bank comprises a set number of cylinders (typically largest) inter-connected to a common distribution line.
- The manifold supplies gas at a fixed pressure across all flows within a system by regulating all high-pressure cylinders centrally.
- Manifolds systems are designed based on:
  - use-case (primary source or back-up);
  - ward level demand, which helps to determine total volume to have connected.

Oxygen Manifold



Depleted cylinders on one side of the manifold must always be replaced manually.

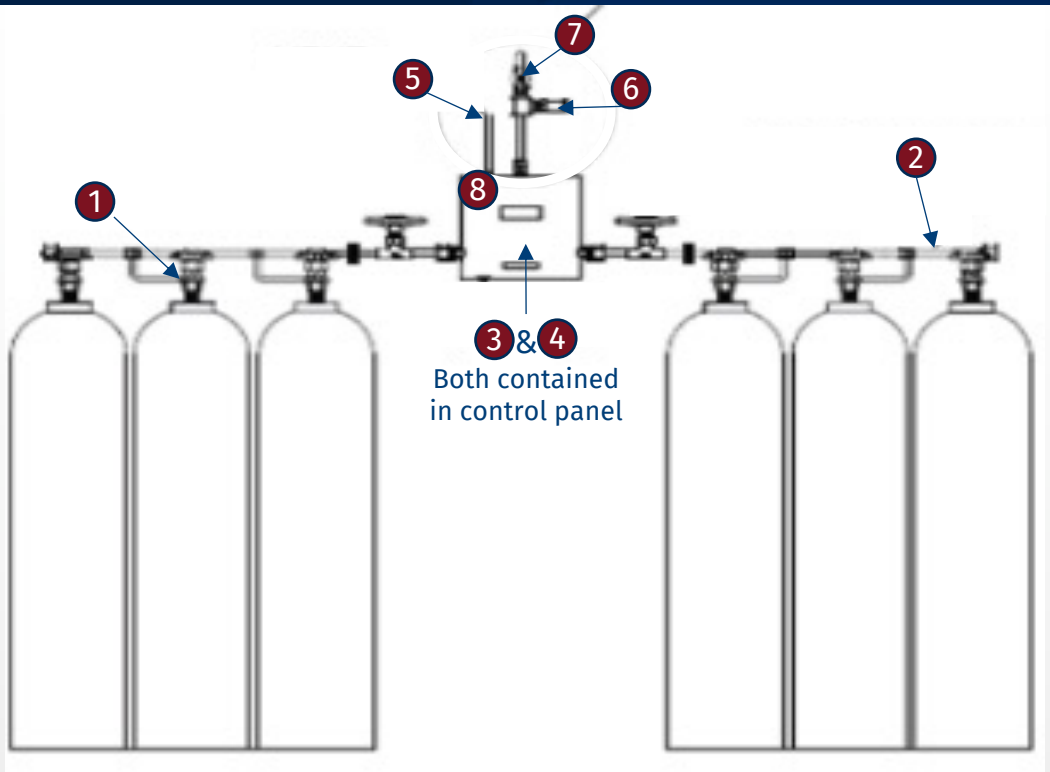
Types of oxygen manifold systems

	Automatic 	Semi-automatic 	Manual 
Description	• **Automatic start-up** when the primary source flow ceases (e.g., PSA plant, VIE system) • Initial start-up trigged by line pressure drop. • **Automatic switch-over** from the "duty" to the "stand-by" cylinder bank when pressure in duty bank drops below a usable level. Achieved by: ▪ using pressure transducers; ▪ solenoid valves; or ▪ a pressure differential change-over. • Fitted with alarms, indicating when system has engaged the "stand-by" bank to prompt replacement of cylinders in the depleted bank. • Display indicates: ▪ which bank is in operation and ▪ Any operating anomalies. • In case of power failure, the system continues to supply gas without interruption.	• Suitable for use as primary supply. • Can be used across a facility if piping permits, or at the ward level. • **Automatic switch-over** from the "duty" to the "stand-by" cylinder bank when the pressure in the duty bank drops below usable. • Fitted with alarms, indicating when system has engaged the "stand-by" bank to prompt replacement of cylinders in the depleted bank. • If used as primary supply, ▪ adequate sourcing and storage of cylinders shall be considered ▪ a secondary / back-up system should be installed to ensure continuity of supply if system malfunctions.	• Suitable for use as primary supply. • Can be used across a facility if piping permits, or at the ward level. • **Manual change-over** from "duty" to the "stand-by" cylinder bank when the pressure in the duty bank drops below usable. • Fitted with alarms, indicating when "duty" bank nearing or completely depleted. • Requires close monitoring and swift action to change banks to ensure continuity of supply. • Shut-off valve is manually controlled. • Changeover lever indicates "duty" bank. • If used as primary supply, ▪ adequate sourcing and storage of cylinders shall be considered ▪ a secondary / back-up system should be installed to ensure continuity of supply if system malfunctions.
Preferred use-case	**Secondary/back-up supply.** **Not suitable for primary supply.**	**Primary supply.** **Ideally for larger demands.**	**Primary supply, ward level.** **Secondary/back-up** to semi-automatic manifold serving as primary.

Components of distribution manifolds

The following list of components apply to all types of distribution manifolds:

1. Cylinder connection
   - flexible copper pigtails, *spec connection, e.g., pin-index, bullnose*
   - Safety check valves (non-return)
2. High-pressure header, comprising:
   - bank valves
   - bank regulators & gauges, *indicating cylinder content status*
3. Lever to control / indicate "duty" bank
   specify control vs. duty depending on auto or semi/manual
4. Line outlet pressure regulator and gauge (2-stage)
   2nd in two-stage (one 'multistage' regulator unacceptable)
5. Exhaust line
   Exhaust line diameter > main line diameter
6. Line pressure release valve & test point valve
   Point to test for purity and to exhaust gas for maintenance
7. Lockable line isolation valve
8. Alarm panel with visual & audible alarm
   ideally to be in nursing station or where someone will see/hear 24/7, connected to pressure switch



The following apply to semi- and fully automated distribution manifolds:

- Pressure sensors (solenoid valves where applicable)
- Pressure differential change-over switch

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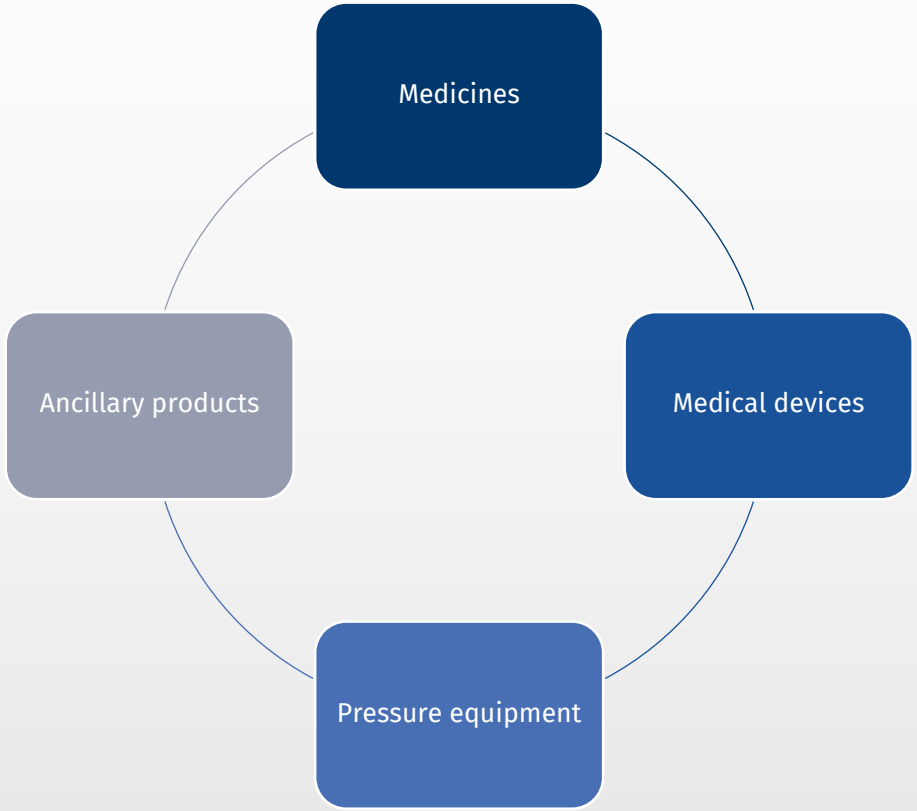
Patient & end user safety are paramount, putting impetus on quality

Goods within the oxygen ecosystem must be procured with care.



The "what" for any of these procurements must be clearly delineated:

- ❑ Detailed, targeted product specifications:
  - Performance criteria
  - Measurement criteria
  - Environmental parameters
- ❑ Standards requirements
- ❑ Regulatory requirements
- ❑ Warranty: details and clear expectations
  (NOT to be conflated with maintenance)

Documentation and evidence of the above shall be submitted in any procurement in order to complete a dossier.

- ➢ A technical team shall ensure dossier completion; that product under procurement "passes" technically prior to final quality review.
- ➢ There must be consistency in technical and quality requirements to increase assurance of safety and positive patient outcomes.

Adequate training, service and maintenance are mandatory, and installation (where applicable) shall be carried out by qualified personnel.

Procuring cylinders: rarely 'equal', & compatibility is complex

Key stakeholder engagement required when buying cylinders

To frame any procurement, cylinders:

- Are a "C/C" system,
- Should be considered as a regulated product:
  - in EU under Transportable Pressure Equipment Directive (TPED), cylinders & valves require a "π" mark stamped on their shoulder.
  - In the USA, under the Code of Federal Regulations (USA) of the Department of Transportation (DOT), they require a "DOT3AA" stamp.
- Adherence to ISO 9809-1 *(or equivalent)*, tying to ~5 standards…
- Must consider national needs (MoH standards, national regulations, etc.), inclusive of physical attributes & safety requirements.

+

Procurement planning must also cover:

- Who will be the ultimate owner?
- Where and how will the cylinders be used?
- Where/by whom will the cylinders be filled?
- Who will manage the cylinders if not in a closed system (e.g. remain at facility with a PSA plant)?

Consider gas supplier requirements (operational & safety directives), inclusive of validation and verification processes.

How does this translate? **Assurance of compatibility!**

The onus is on the buyer to determine and address potential use-case(s), then to:

- Ensure translation of requirements, including standards.
- Demonstrate that what is being procured is equal to or better than requirements of key stakeholders.

The following excerpt, from our adapted specifications, will illustrate how specificity of 'ask' can vary…

We will provide an Excel file for you!

	edical use.
	(for example):
	9.43 L, "E" - 4.68 L, "D" - 2.32 L
	150 bar
	fy standard:
	50/CGA 870 valve)
	/8 inch BSP(F)/BS 341 valve *or* CGA 540 *or* DIN 9 *or* NF 'F' *or* NEN Ri2)
	ve assembly material: brass
Technical	Valve handle/key operated, supplied with tools.
	Material: CGA approved seamless steel/aluminum alloy/carbon fibre/other composite body
	Colour coding: according to ISO/ANSI/CGA/NFPA
	Supplied with valve stem cap / safety cap / valve guard
	Stamped onto shoulder:
	· Nominal and test pressures · Cylinder capacity (water litres)
	· Weight (kg) · Date of manufacture
	· Serial number · Company and country of origin
	· transport rating (DOT3AA or UN stamp) · inspection agency stamp (matching regulatory)
	Environmental:
	· Suitable for continuous operation in ambient temperature of at least 5–45 °C, relative humidity of at least 15–90% non condensing
	· Capable of being stored in ambient temperature of at least 5–50 °C, relative humidity of at least 15–95% non condensing
Warranty	5 years recommended
QMS	ISO 9001 (General QMS)
Regulatory	CE indicated by pi, "π" (Cylinders fall under TPED) or US DOT
	· applies to BOTH cylinders and valves
Product performance standards *Where testing indicated, must be done by an accredited laboratory - documentation of which to be included prior to shipment*	ISO 10297: Gas cylinders – Cylinder valves – Specification and type testing
	ISO 14246: Gas cylinders – Cylinder valves – Manufacturing tests and examinations
	ISO 7866: Gas cylinders – Refillable seamless aluminium alloy gas cylinders – Design, construction and testing
	ISO 9809-1: Gas cylinders – Refillable seamless steel gas cylinders – Design, construction and testing
	ISO 13769: Gas cylinders — Stamp marking
	ISO 13341: Gas cylinders – Fitting of valves to gas cylinders
	ISO 15996: Gas cylinders – Residual pressure valves – Specification and type testing of cylinder valves incorporating residual pressure devices
	ISO 11363-1: Gas cylinders — 17E and 25E taper threads for connection of valves to gas cylinders
	ISO 15001: Anaesthetic and respiratory equipment – Compatibility with oxygen

Physical attributes:
- Valve type and thread
- Valve protection (guard/cap)
- Colour
- Size

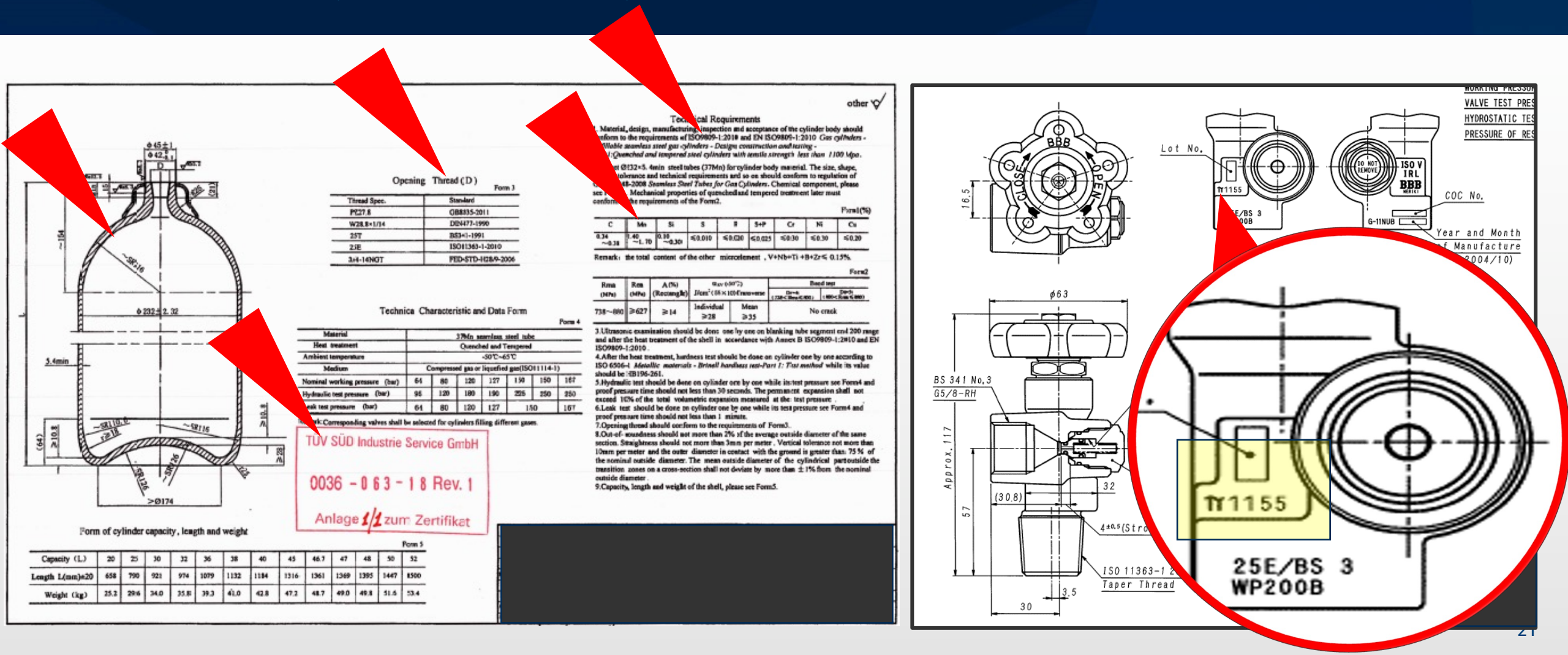
Safety:
- Transport rating

Quality
- Inspection stamp (either π or DOT3AA)
- Cleaning
- QMS ISO 9001 – scope clearly defined

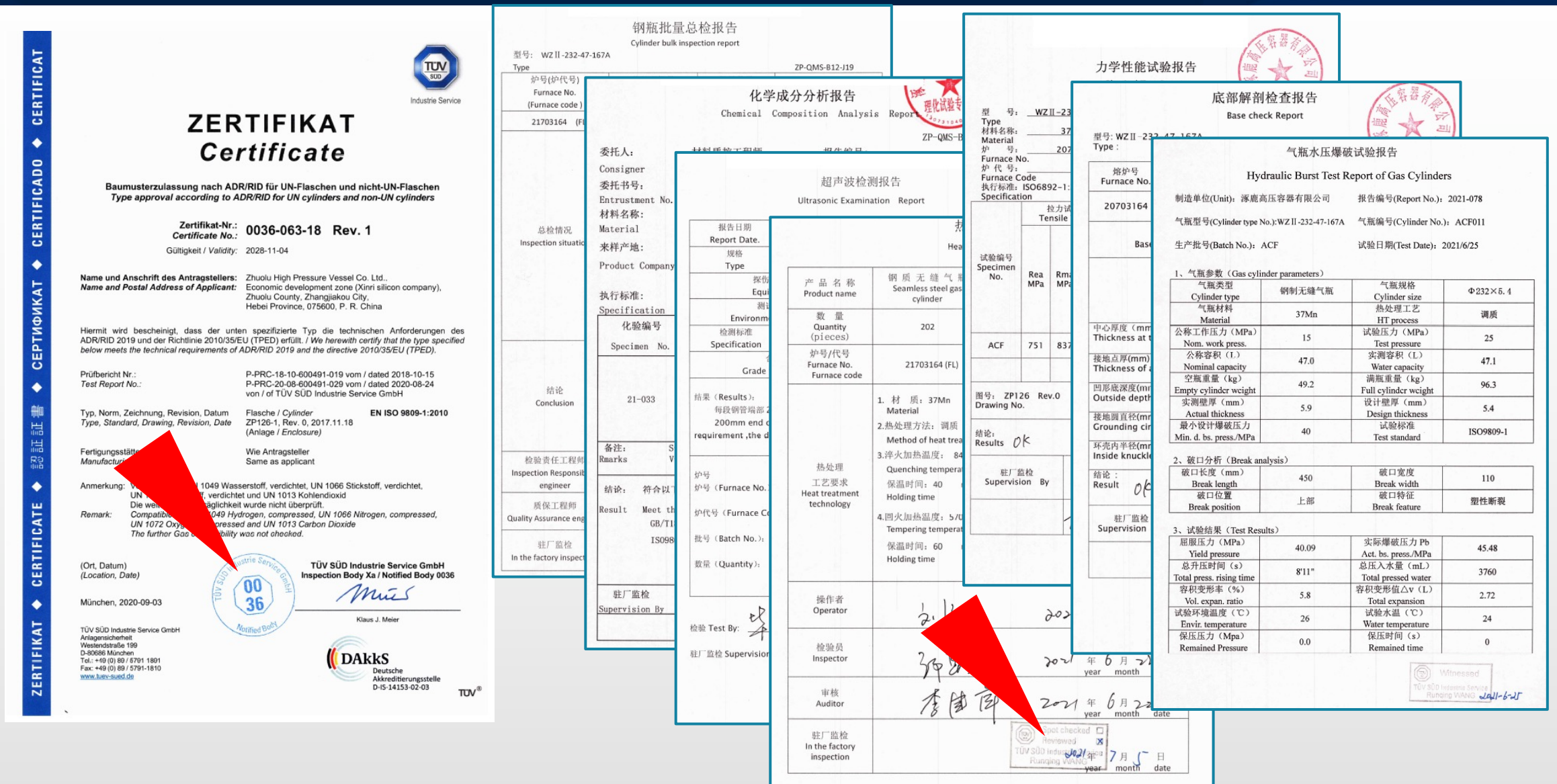
Technical
- ISO 9809-1
  Gas cylinders – refillable seamless steel – General design, construction, and testing
- ISO 11363-1
  Gas cylinders – 17E and 25E taper threads

Design and regulatory requirements a prerequisite

Some of the key considerations for cylinder shells and valves



Batch test documentation and certification specific to cylinders procured



ZERTIFIKAT ◆ CERTIFICATE ◆ 認証証書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

TÜV SÜD Industrie Service

ZERTIFIKAT
Certificate

Baumusterzulassung nach ADR/RID für UN-Flaschen und nicht-UN-Flaschen
Type approval according to ADR/RID for UN cylinders and non-UN cylinders

Zertifikat-Nr.: / ***Certificate No.:*** **0036-063-18 Rev. 1**
Gültigkeit / *Validity:* 2028-11-04

Name und Anschrift des Antragstellers: / ***Name and Postal Address of Applicant:*** Zhuolu High Pressure Vessel Co. Ltd., Economic development zone (Xinri silicon company), Zhuolu County, Zhangjiakou City, Hebei Province, 075600, P. R. China

Hiermit wird bescheinigt, dass der unten spezifizierte Typ die technischen Anforderungen des ADR/RID 2019 und der Richtlinie 2010/35/EU (TPED) erfüllt. / *We herewith certify that the type specified below meets the technical requirements of ADR/RID 2019 and the directive 2010/35/EU (TPED).*

Prüfbericht Nr.: / *Test Report No.:* P-PRC-18-10-600491-019 vom / dated 2018-10-15; P-PRC-20-08-600491-029 vom / dated 2020-08-24 von / of TÜV SÜD Industrie Service GmbH

Typ, Norm, Zeichnung, Revision, Datum / *Type, Standard, Drawing, Revision, Date* Flasche / *Cylinder* ZP126-1, Rev. 0, 2017.11.18 (Anlage / *Enclosure*) **EN ISO 9809-1:2010**

Fertigungsstätte / *Manufacturing* Wie Antragsteller / Same as applicant

Anmerkung: / *Remark:* UN 1049 Wasserstoff, verdichtet, UN 1066 Stickstoff, verdichtet, UN 1049 Hydrogen, compressed, UN 1066 Nitrogen, compressed, UN 1072 Oxygen, compressed and UN 1013 Carbon Dioxide, verdichtet und UN 1013 Kohlendioxid. Die weitere Verwendbarkeit wurde nicht überprüft. / *The further Gas suitability was not checked.*

(Ort, Datum) / *(Location, Date)* München, 2020-09-03

TÜV SÜD Industrie Service GmbH
Inspection Body Xa / Notified Body 0036

Klaus J. Meier

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DAkkS Deutsche Akkreditierungsstelle D-IS-14153-02-03

钢瓶批量总检报告
Cylinder bulk inspection report

化学成分分析报告
Chemical Composition Analysis Report

超声波检测报告
Ultrasonic Examination Report

力学性能试验报告

底部解剖检查报告
Base check Report

气瓶水压爆破试验报告
Hydraulic Burst Test Report of Gas Cylinders

制造单位(Unit)：涿鹿高压容器有限公司　报告编号(Report No.)：2021-078
气瓶型号(Cylinder type No.):WZⅡ-232-47-167A　气瓶编号(Cylinder No.)：ACF011
生产批号(Batch No.)：ACF　试验日期(Test Date)：2021/6/25

1、气瓶参数（Gas cylinder parameters）

气瓶类型 Cylinder type	钢制无缝气瓶	气瓶规格 Cylinder size	Φ232×6.4
气瓶材料 Material	37Mn	热处理工艺 HT process	调质
公称工作压力（MPa） Nom. work press.	15	试验压力（MPa） Test pressure	25
公称容积（L） Nominal capacity	47.0	实测容积（L） Water capacity	47.1
空瓶重量（kg） Empty cylinder weight	49.2	满瓶重量（kg） Full cylinder weight	96.3
实测壁厚（mm） Actual thickness	5.9	设计壁厚（mm） Design thickness	5.4
最小设计爆破压力 Min. d. bs. press./MPa	40	试验标准 Test standard	ISO9809-1

2、破口分析（Break analysis）

破口长度（mm） Break length	450	破口宽度 Break width	110
破口位置 Break position	上部	破口特征 Break feature	塑性断裂

3、试验结果（Test Results）

屈服压力（MPa） Yield pressure	40.09	实际爆破压力 Pb Act. bs. press./MPa	45.48
总升压时间（s） Total press. rising time	8'11"	总压入水量（mL） Total pressed water	3760
容积变形率（%） Vol. expan. ratio	5.8	容积变形值△v（L） Total expansion	2.72
试验环境温度（℃） Envir. temperature	26	试验水温（℃） Water temperature	24
保压压力（Mpa） Remained Pressure	0.0	保压时间（s） Remained time	0

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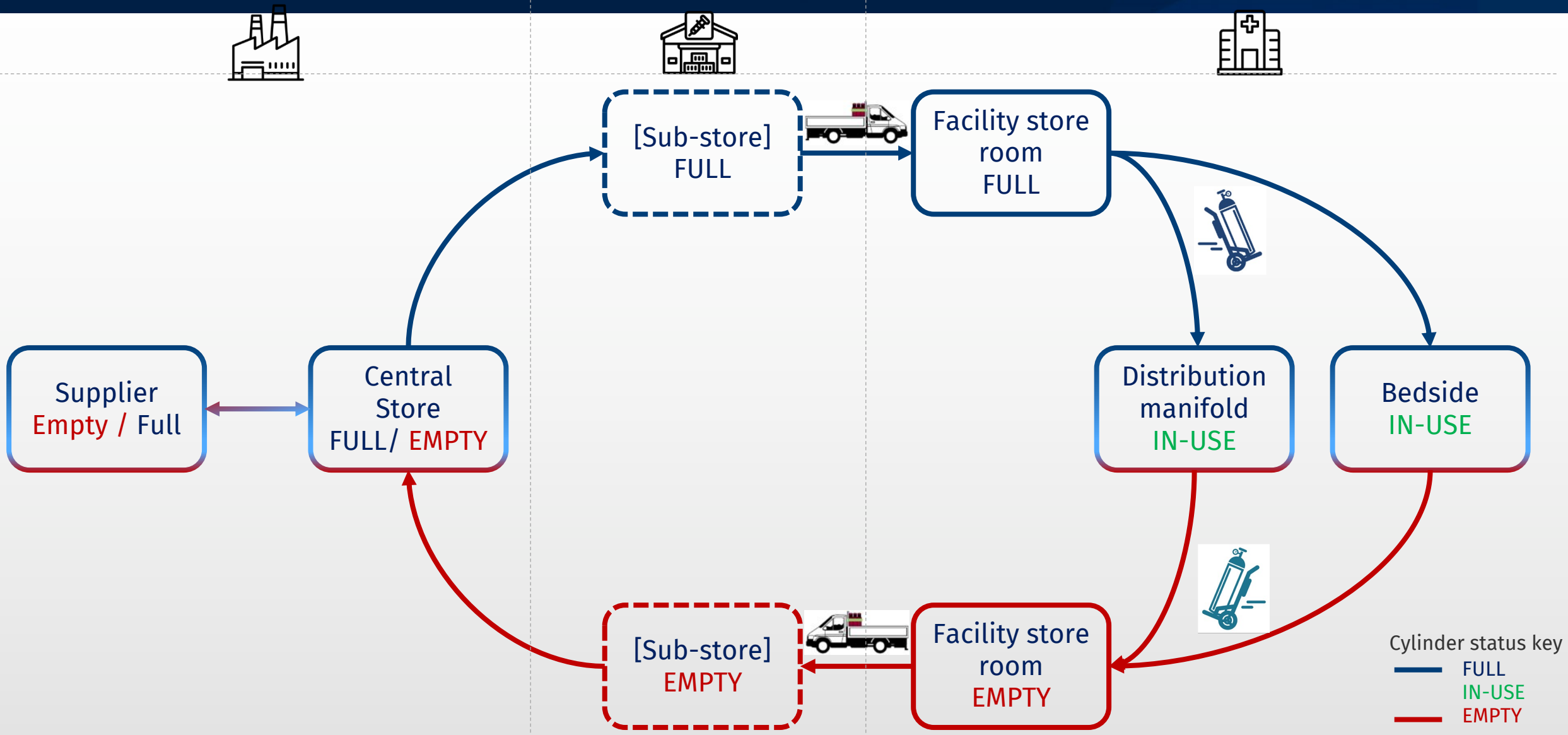
Oxygen cylinder management: moving within a health system



Oxygen cylinder management: Changing and storing

Changing a cylinder

- The **valve must be closed**, and the **pressure must be released** completely before disconnecting the regulator.
- Be sure that the *new* cylinder contains the right gas.
- Connecting a regulator:
  - First **inspect the valve**: it must not be visibly damaged, and it must be free of dirt, dust, and grease.
  - If the regulator has an **O-ring**, check if it is correctly in place and not damaged.
  - Do not use too much force when connecting a regulator. **Tighten by hand** only – the regulator will tighten itself further under pressure.
  - Never use a longer lever or a hammer to tighten a regulator.
  - **Do not use PTFE/Teflon** tape on the high-pressure side.
- **Open the valve slowly**.
- **Check for leaks** around the regulator. Listen to hissing sounds. After closing the cylinder valve, the pressure shown on the pressure gauge should remain stable.

Transport & Storage

- Gas cylinders should only be transported with their **protective cap/guard** in place.
- Use a **cylinder trolley** where available.
- Large cylinders should **stand upright** and against a wall fixed with a chain or stored in a metal rack.
- Small cylinders should lie horizontal in a shelf.
- Different gases should be **stored separately** from one another.
- **Empty cylinders should be separated from full cylinders**. Empty cylinders should be clearly labelled so there is no mistake in inventory when taking stock.

Cylinder and accessory compatibility

Not all regulators will work with this valve type, modifications for incorrect type are not possible.

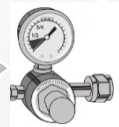
Ensuring the right products are bought from go will enable utility of products

Information required in cylinder & accessory procurements

Cascade of requirements for components to ensure compatibility

❶ Cylinder

Primary outlets*:
- Bullnose (5/8 inch BSP (F)/BS 341 valve / CGA 540 / DIN 9 / NF 'F' / NEN Ri2)
- Pin-index (ISO 407/BS 850/CGA 870 valve)



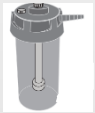
❷ Regulator

Inlet*: to match cylinder
Outlet*: connection standard DISS, male (confirm)

❸ Flowmeter

Inlet*:
- If for cylinder use: DISS, female
- If for terminal unit / wall outlet use: choose from 6+ adapters

Outlet: DISS, male with attached "Christmas tree" adapter



❹ Humidifier

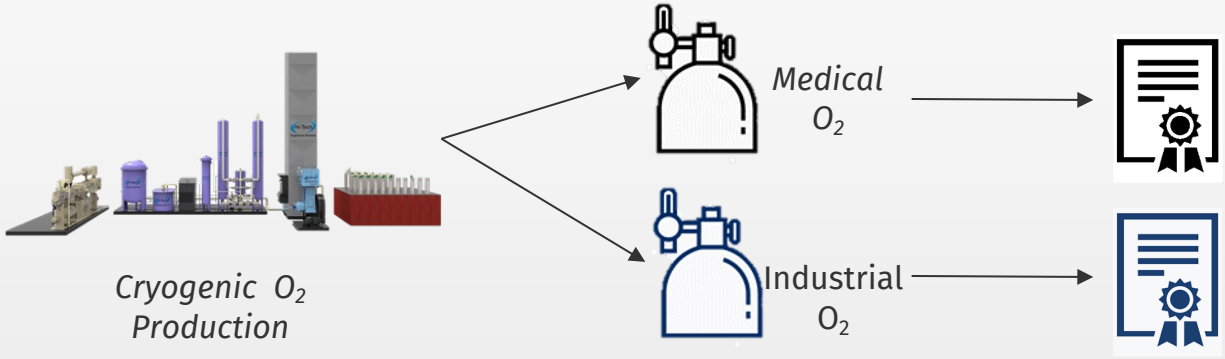
Typically universal
- DISS female inlet
- Barbed outlet

Upstream components will govern connections required for downstream accessories to be compatible.

➢ All items marked with an "*" must be confirmed to order

Oxygen cylinder management: Chain of custody

Chain of custody (CoC) - Getting tanks filled/ swapped with a reputable supplier, along with rigid maintenance of components, can ensure a dependable chain of custody.



Although from the same "production line", GMP is different for industrial than it is for medical, thus a different CoC and certification process is necessary.

Certification is done by authorized/certified 3rd party to ensure continued good manufacturing processes (cGMP). The following is tested/checked:

- That oxygen adheres to an indicated pharmacopoeia.
- That impurities remain below thresholds indicated in pharmacopoeia.
- That C/Cs used for medical oxygen are for this product line and used uniquely for the storage and distribution of medical oxygen.

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Risk points: patient delivery, filling, and transport

	Oxygen distribution	Cylinder filling	Cylinder delivery
Risk	• Gas Leakage, O_2 enriched environment • Injuries caused by falling cylinders • Improper O_2 administration can be harmful to patients (e.g., retinopathy, etc.)	Gas wastage, fire, or explosion, product contamination during fill, due to: • Improper evacuation prior to filling • Incidents during depressurization (venting following fill) due to damaged O-rings, valves opened too quickly or in wrong order • Addition of cylinders to filling rack whilst filling is ongoing • Connection tightening during filling	Injury to transporter, and surrounding persons, which can occur when transporting cylinders within or between buildings or to an external location
Mitigation	• Timely inspection of cylinders, valves, manifolds, pipeline. • Cylinders should be moved in trolleys and strapped down when in use. • Provider capacity building	• Use a vacuum pump on each cylinder prior to filling • Check O-ring before every fill • Open and close valves with caution • <u>Always fill cylinders in batches, in a methodical manner.</u> • Continuous trainings of production and filling unit operators • Leak checks prior to every fill	• Use of cylinder trolleys, ensure cylinders are properly chained into trolleys. • Transports with an open back utility truck rated for payload, separated from the cabin. • Pallets on truck with ability to secure cylinders in an upright position for transport

Oxygen cylinder do’s and don’ts

Do’s

- ✓ Ensure a regulator is fitted before use
- ✓ Ensure cylinder is firmly secured
- ✓ Ensure connections are suitable
- ✓ Ensure connections are hand-tight
- ✓ Ensure cylinders are stored and used away from sources of ignition (no smoking!)
- ✓ Store full and empty cylinders separately
- ✓ Ensure valve guards or caps are fitted when cylinders are not in use
- ✓ Use mechanical assistance when handling cylinders (e.g. trollies)

Don’ts

- ✗ Repaint a cylinder
- ✗ Change the markings on a cylinder
- ✗ Use oil or lubricants on cylinder valve
- ✗ Tamper with the gas cylinder test tag
- ✗ Tamper with or remove the barcode from a cylinder (if applicable)
- ✗ Roll cylinders along the ground
- ✗ Attempt to fight a fire involving a gas cylinder
- ✗ Transport gas cylinders in the passenger compartment of a vehicle
- ✗ Use a cylinder that shows evidence of damage or corrosion
- ✗ Fill cylinders with any material

Thank you.

Oxygen cylinder use: Roles & Responsibilities (~illustrative)

Level	Roles & Responsibilities in healthcare continuum use	
MOH	• Leadership, oversight and guidance	
Gas supplier	• Provision of medical grade oxygen in cylinders as per PO • Provision of Certificate of Analysis "CofA" with each batch	• Management of orders • Delivery of filled/collection of empty cylinders (if in scope of work)
Central store (public or private)	• Start- and end-point for cylinder management & distribution: ▪ Places orders to and receives cylinders from supplier ▪ Receives orders from facilities, dispatches into network ▪ Point of dispatch to either sub-store or facility	• Dispatches cylinders to LSP • Centralized store for empties to be returned to gas supplier • Manages all documentation (CofA, orders, etc.) • M&E to track and manage performance
Health Facilities	**Pharmacist** • Manages stock of facility oxygen cylinders (full/empty) • Submits orders to central store • Provides empty cylinders to delivery team • Signs the delivery note/voucher and retains a copy • Manages all necessary documents (incl. stock cards for oxygen)	**Ward responsible** • Submits anticipated daily consumption as an order to pharmacy **Porter** • Moves full cylinders to point-of-use (to distribution manifold or bedside in ward) • Makes connection (to manifold header or to pressure regulation/flowmeter) • Returns empty cylinder to pharmacy
LSP	• Develops route plans and delivery schedule based on demand • Loading and offloading of cylinders to/from delivery truck • Follows scheduled route for delivery of full cylinders • Maintains vehicle log sheet	• Collects empty cylinders (full-out/full-on-return), note empties on delivery document • Obtains and retains a copy of signed delivery note as proof of delivery • Compiles post delivery reports
TWG	• Develop oxygen supply 'roadmap' • Develop / advocate / coordinate with all entities on training	• Review distribution system performance • Recommend appropriate action/refinement of distribution system • Presentation of findings to MOH

Operations: changing a cylinder bank

When a bank of cylinders has depleted, replace all empty cylinders as soon as practical

Carry out these steps in order:

1. Close all individual cylinder valves
   Use valve key or spindle, turn clock-wise ↻
2. Close the header valve on the depleted cylinder bank
   Turn clock-wise ↻
3. From each cylinder, slowly loosen and remove the pigtail connection.
   Remove empty cylinders and ensure that they are returned to filling point.
4. Put full replacement cylinders near to their connection point and secure into place using chains / brackets.
   In the absence of a valve cap or seal, with the valve outlet pointed away from any personnel, open each full replacement cylinder valve slightly to blow out any dirt or contaminants which may be in the cylinder valve.
5. Connect pigtails to cylinder valves and tighten securely.
6. Open each cylinder valve slowly until fully open.
   Turn spindle or key counter-clockwise ↺
7. Check that all cylinder/pigtail connections are leak-free using a mild (oil-free) soapy solution. Formation of bubbles indicates a leak; repair/replacement will be necessary.

The manifold reserve bank is now replenished and is ready for use.

Note:

There is a non-return valve at each cylinder connection point, serving to reduce the variable pressures between the gas cylinders; thus, all cylinders on a given bank will reach the same pressure shortly after operations if not already the same.