Scuba Learning Module 17

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General

- High pressure air (gas) storage vessel
- Must be regularly inspected and water tested (hydrostatic test), check your local requirements
- In Australia, must be water tested (hydrostatically) annually, check your local requirements
- Markings on cylinder supply information on testing, filling, manufacturing, volume, weight, etc

Take great care with cylinders as they are potential lethal bombs

Types

- Steel alloy:
  - Rounded bottom
  - Long neck
- Aluminium alloy:
  - Flat bottom
  - More buoyant

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Standard cylinder sizes

3200 l	2900 l	2400 l	2100 l	1800 l	1400 l
105 cu ft	95 cu ft	85 cu ft	75 cu ft	65 cu ft	50 cu ft

Usage

- Never fill an out of test cylinder
- Never overfill (check WP) or completely discharge
- Never drop, drag or treat roughly (when transporting protect from rolling and falling)
- Never paint with anything other than air dry paint; heat curing can change the metallic structure and weaken the cylinder wall
- Always open valve carefully
- Wash in fresh water after use
- Always get your scuba air from a reliable fill station

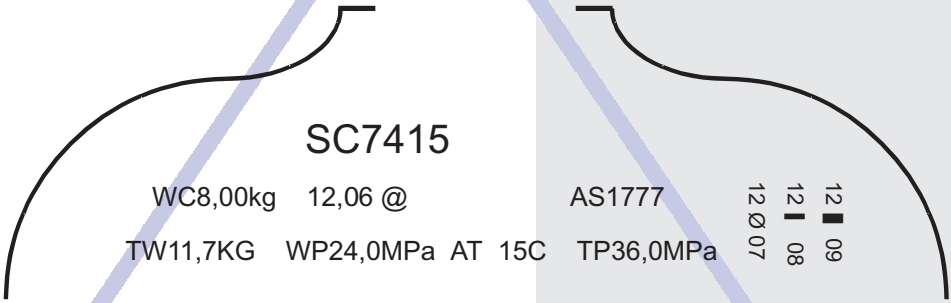
Storage

- Never leave a cylinder standing up unprotected, if knocked over the valve may be damaged or dislodged
- Always store partially full (20–50atm/ 300–750psi)
- Never store empty with valve open; can introduce contaminants including water
- Never store near flammable or corrosive materials

Photo courtesy of Australian Safety Engineers
www.ase.net.au

Manufacturing standard

- Must be manufactured to an acceptable standard:
  - in Australia, see AS2030 and relevant supplements
- Examples of acceptable standards:
  - **AS 1777**–Australian Standard for aluminium cylinders
  - **ASB 113** (or 114)–Australian Standard for steel cylinders
  - **DOT 3AA**–American Department of Transport standard for steel cylinders (old steel)
  - **DOT 3AL**–American Department of Transport standard for aluminium cylinders
  - **HOAL 2** (or 4)–British Home Office standard for aluminium cylinders (old)
  - **BS 5045.1**–British Standard for steel cylinders (modern steel)
  - **BS 5045.3**–British Standard for aluminium cylinders (replaced HOAL 1, 2, 3 & 4)



Serial number

- Usually combination of large letters and numbers (eg. SC7415)
- Unique to each cylinder
- Used to identify for tracing if stolen or recalled

Date of manufacture

- Identifying for recall purposes (eg. 12 ⊗ 06)
- Identifies when first test is due

Working Pressure

- Normal filling pressure at a given ambient temperature, eg WP 24,0 MPa at 15°C
- Conversion of pressure units:

1 atm	= 101 300 Pa	= 1.01 Bar
	= 101 kPa	= 1 kg/cm2
	= 0.1 MPa	= 14.7 psi

- Sometimes WP is not marked–consult manufacturer or test station operator

Test Pressure

- Pressure a cylinder will be subjected to during the hydrostatic (water pressure) test, eg. TP 36,0 MPa
- May be just "T" instead of "TP"
- Sometimes TP is not marked–consult manufacturer or test station operator

In Australia, can only fill to 225 atm (3200psi) with yoke fitting despite higher working pressures, check your local regulations.

Do not confuse Test Pressure with Working Pressure when filling a cylinder

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Water Capacity

- Weight of water that will fill an empty cylinder, eg. WC 8,0 kg (8 litres)
- Used as baseline to measure permanent stretch after hydrostatic testing (maximum allowed = 1/5000 of WC)
- Used in conjunction with working pressure to calculate total capacity of cylinder:

  TC = WC x WP

where: **TC** is total capacity of cylinder in litres of air at one atmosphere,
WC is water capacity of cylinder in kilograms, and
WP is working pressure in atmospheres

- Used to calculate air consumption

Tare Weight

- Weight of empty cylinder without valve, eg TW 11,7 kg
- Used as baseline to measure weight loss of cylinder due to corrosion or damage (not to exceed 5% loss)

Test stamps

- Contains month, symbol of test station and year, eg 12 ⊗ 09
- Check local authority for approved test stations.
  - In Australia, refer to the current Standards Australia document MP 48
- Cylinder is in test for the approved time from date of last test stamp (refer to local authority).
  - In Australia, it is 12 months.
- Cylinder may be filled in the thirteenth month at the discretion of the filling station, check local authority

Calculation of air consumption

Air consumed (**AC**) is calculated from:

$$AC = \frac{(P_i - P_f) \times WC}{P \times T}$$

where: P_i is cylinder pressure at start of dive,
P_f is cylinder pressure at end of dive,
WC is water capacity of cylinder in kilograms,
P is ambient pressure in atmospheres absolute, and
T is time in minutes.

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Preparation

- Serial number and owner details are recorded
- Cylinder is drained of air and the valve is removed

Visual inspection

- Cylinder is visually inspected internally and externally for corrosion, damage or faults
- Any corrosion, damage or faults are assessed–if outside tolerance, cylinder **FAILS**

Weight measurement

- Empty cylinder without valve in place is accurately weighed
- Any deviation of more than 5% from original weight **FAILS** the cylinder

Hydrostatic test

- Cylinder is filled with water
- Volume of cylinder is accurately measured
- Pressure of water in cylinder is raised to test pressure for 30 seconds
- Pressure is released and volume of cylinder is accurately re-measured to check for "permanent stretch"
- Any deviation beyond 1/5000 of original water capacity **FAILS** the cylinder

Thread check

- Thread in cylinder neck is tested with a "go-no-go" gauge
- Cylinder **FAILS** if thread check fails

Result

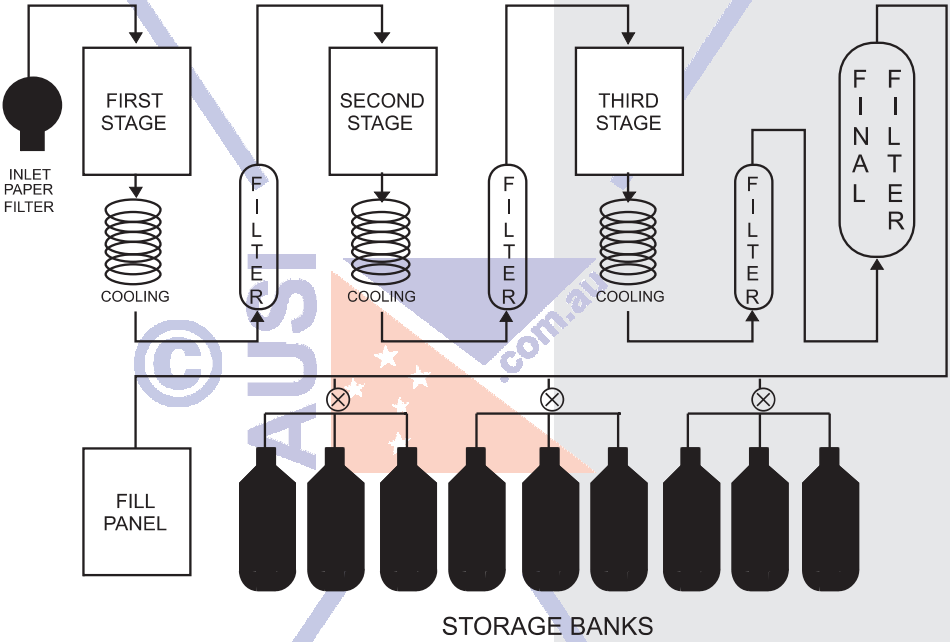
- A **SUCCESSFUL** cylinder will be stamped and a test certificate issued
- A **FAILED** cylinder, for any reason, will be destroyed

Airdive Hydrostatic test panel
Photo courtesy Airdive Equipment P/L
www.airdive.com.au

Function

- Compression of atmospheric air
- Drying and filtration of atmospheric air
- Storage of compressed atmospheric air (optional)

Block diagram



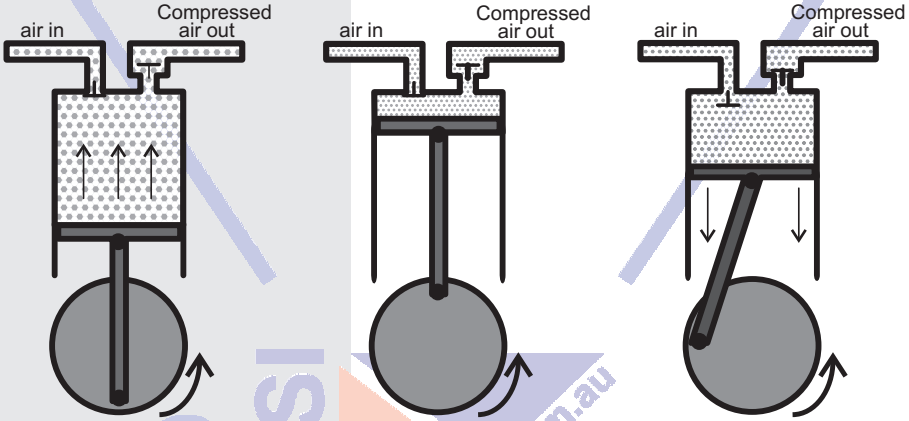
General features

- Compressor is powered by a V-belt connected to either:
  - Electric motor
  - Internal combustion engine (ie. petrol or diesel)
- Can be portable or fixed
- Compression rates vary, for example:
  - Small portable ≈ 4-6 cu.ft./min
  - Large fixed ≈ 15-25 cu.ft./min

Typical portable compressor

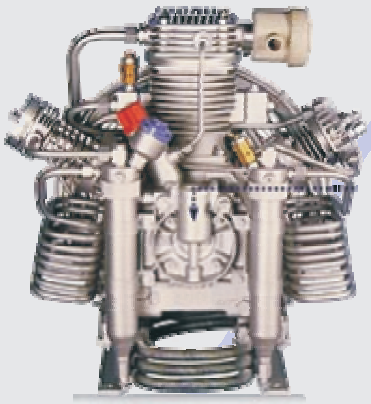
Compression cycle

- Compressed air is achieved over two to four stages of compression via pistons moving in a cylinder



Single stage ≈ 7:1 compression ratio

- One-way valves in the cylinder control air flow in and out
- On down stroke of piston
  - Air is drawn into cylinder at inlet pressure
  - Inlet valve is open and outlet valve is closed
- On up stroke of piston
  - Volume of cylinder is reduced
  - Pressure of air is increased
  - Temperature of air is increased
  - Inlet valve is closed and outlet valve is open
- Each stage supplies a compression ratio of approximately 7:1 as shown below:



Bauer compressor block
Photo courtesy of Australian Safety Engineers
www.ase.net.au

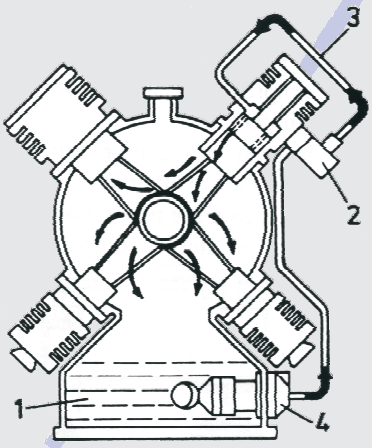
	Inlet pressure	Outlet pressure
First stage	1 atm	7 atm
Second stage	7 atm	50 atm
Third stage	50 atm	350 atm

Lubrication

- Lubrication oil is required between the piston and the cylinder
- Oil must be capable of handling high pressure, high partial pressure of oxygen and high temperature without "flashing"
- Correct oil is either mineral or synthetic (not hydrocarbon based or vegetable oil)

Cooling

- Cooling is essential so that compressed air is at ambient temperature
- Compressor running too hot can cause "flashing" of oil in heads (producing carbon monoxide) and overheating of cylinders during filling
- Cooling is achieved by:
  - Vanes on compressor cylinders
  - Coils between stages
  - Volume expansion in filters
  - Main fan which moves air past compressor to achieve cooling



1. Oil sump
2. Oil pressure regulator
3. Oil supply line to cylinder
4. Oil pump

Bauer Verticus filling station
Photo courtesy of Australian Safety Engineers
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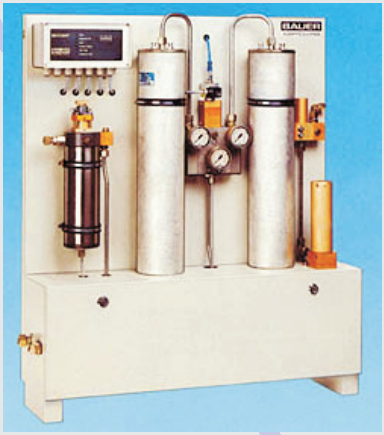

Bauer Seccant filtration system
Photo courtesy of Australian Safety Engineers
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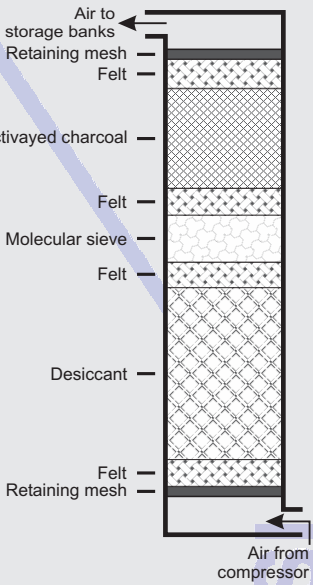
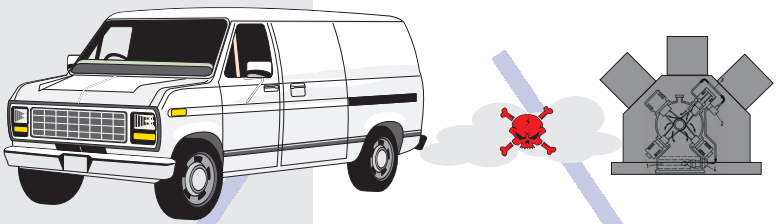


A typical filter tower

Filtrates

Filters remove contaminants, such as dust, water, oil, oil vapour and odour:

- Air intake (paper) filter removes dust
- Filters at end of each stage remove oil and water vapour and droplets using gas expansion for temperature drop and centrifugal force
- Each filter has pressure relief valve and drain cock
- The final filter is usually a chemical tower consisting of:
  - Desiccant for drying air, eg. activated alumina
  - Molecular sieve for removing small particles
  - Activated charcoal to deodorise
  - Air flows upwards through the filter to prevent filtrates from becoming wet
- Other filtrates include:
  - Hopcalite to convert CO to CO_2
  - Soda lime to absorb CO_2



Avoid sources of carbon monoxide when filling cylinders as most compressors will not filter carbon monoxide, a special catalyst (Hopcalite) is required

Air purity (from AS 2299)

Compressed air for use by scuba divers shall contain:

- Odour: no objectionable or nauseous odour
- O_2: 20–22% by volume
- CO: ≤ 11 mg/m3 at 15°C & 100 kPa
- CO_2: ≤ 900 mg/m3 at 15°C & 100 kPa
- Water: ≤ 100 mg/m3 at 15°C & 100 kPa
- Oil: ≤ 1 mg/m3 at 15°C & 100 kPa

Start up

- Ensure you are trained in the correct use of the compressor before attempting to use it
- Read the operators instruction manual
- Ensure air inlet is upwind, at least one to two metres (3' to 6') off ground and free of potential contaminants (eg smoke, exhaust etc)
- Ensure compressor is correct orientation and horizontal
- Check filter run time, fuel and oil levels
- Check tension on belt
- Set valves correctly
- Run up to pressure
- Ensure blow off valves work

Shut down

- Open valves (drain cocks)
- Turn off
- Fill in logbook
- Report any abnormalities

Maintenance

- Chemical filters need to be changed after a certain number of running hours (consult manual)
- Oil levels need to be checked regularly
- Air purity should be monitored and tested regularly

When using an internal combustion engine to power a compressor, if the power unit shuts down unexpectedly, check oil levels to avoid permanent damage

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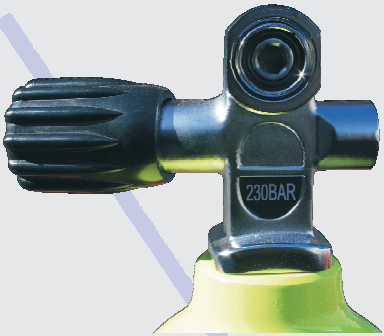

Typical K-valve

Typical DIN-valve
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Charging a scuba cylinder

Valves

Types

- Yoke (J and K valve) < 225 atm (3200 psi)
- DIN valve > 225 atm (3200 psi)

Burst disc

- Safety blow off valve, incorporated in cylinder valve:
  - Thin pressure-calibrated copper disc that ruptures if over pressurised

Storage banks

- Allow for more efficient filling of cylinders
- Compressor can be run to fill the storage banks prior to being needed
- Cylinders are filled by decanting from storage banks starting with the highest pressure storage cylinder and working to lowest, while compressor continues to run
- In between fills, the compressor tops up storage banks again

Filling cylinders

Whether filling a cylinder from storage banks or directly from a compressor:

- Check cylinders to ensure the following:
  - In-test
  - Fill pressure
  - No external damage (dings, gouges, fire etc)
  - Not painted with non-air drying paint
  - Not completely empty
  - O-ring is intact
  - No "F" mark on cylinder neck (indicates fracture)
- J-valve open, if applicable
- Begin filling cylinders
- Fill as slowly as possible
- Never overfill cylinders
- Drain filters as per manufacturers recommendations

Odour

- Bleed blow-off valves
- Change main filter

Leaking

- Check valve O-ring, replace if necessary
- If leak is between valve and cylinder **do not** fill, change main cylinder/valve O-ring (qualified technician only)

Blown burst disk

- Get qualified technician to replace

Can't get air into cylinder

- Check valve function
  - If J-valve, check position of reserve lever
- Check and replace valve seat (qualified technician only)

Overfilled cylinder

- Bleed off to correct fill pressure

Last fill was contaminated

- Drain contents before filling
- If it still smells or tastes, get qualified technician to clean cylinder

Logbook

- Fill in operation times
- Record filter changes
- Record all maintenance

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1. How often do cylinders have to be hydrostatically tested:
   a) In Australia?
   b) In your country?

2. What do the following cylinder markings mean and what is their purpose?
   a) AS 1777
   b) A2679
   c) WP 24,0 MPa at 15°C
   d) TP 36,0 MPa
   e) WC 11,4Kg.
   f) TW 10,5Kg.
   g) 7@95

3. List five reasons a cylinder could fail test.

4. What is the function of a compressor?

5. What type of oils must not be used in an air compressor?

6. List four methods of cooling air during a compression cycle.

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7. What are three types of filters used in a compressor system?

8. What is the function of the following filtrates:
   a) Activated alumina:
   b) Activated charcoal:
   c) Molecular sieve:
   d) Hopcalite:

9. What are the nine checks to be made before starting up a compressor?

10. List three areas of a compressor system that need regular maintenance.

11. What is the maximum allowable pressure for a yoke type valve?

12. List seven things to check before filling a cylinder.

13. What must be done before filling via J valve?

14. List five potential problems when filling cylinders.

15. List three areas to record in the compressors's maintenance logbook.

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