



Safety requirements - CNG mother daughter systems

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CNG mother daughter system safety requirements

- **Applicable standards**
- **Facility safety requirements (in accordance with standards)**
- **Hazard and risk analyses**
- **Safety management system**
- **Safety systems**
- **Operating procedures**
- **Safety requirements not specified by the standards**

Examples of applicable standards

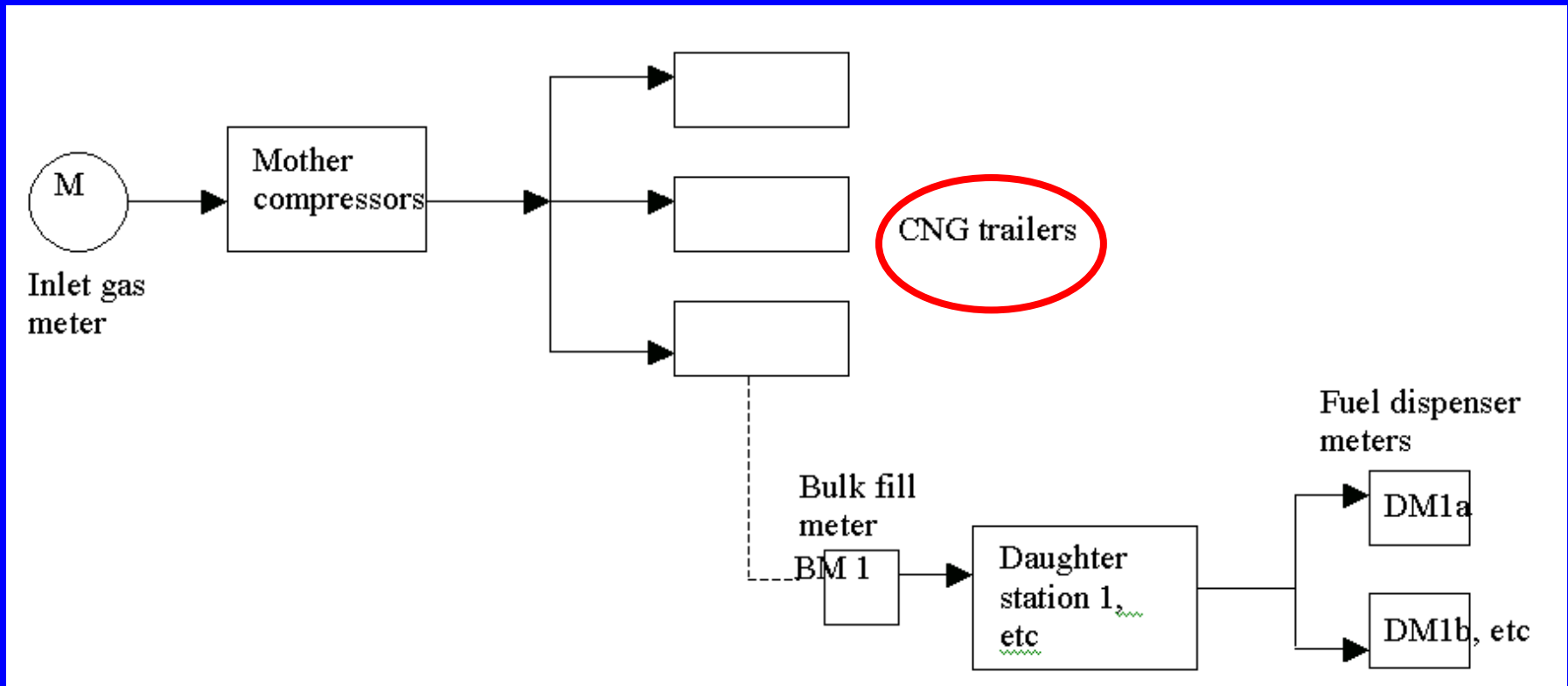
Australia

- AS 5092 (formerly AG 901) – CNG refuelling stations
- AS/NZS 2739 – Natural gas systems for vehicle engines
- AS 2746 – Working areas for gas fuelled vehicles

Singapore:

- TR 10 – CNG vehicle workshop and personnel requirements
- TR 11 – CNG vehicle component and installation requirements
- TR 12 – CNG refuelling stations

Schematic of mother - daughter system

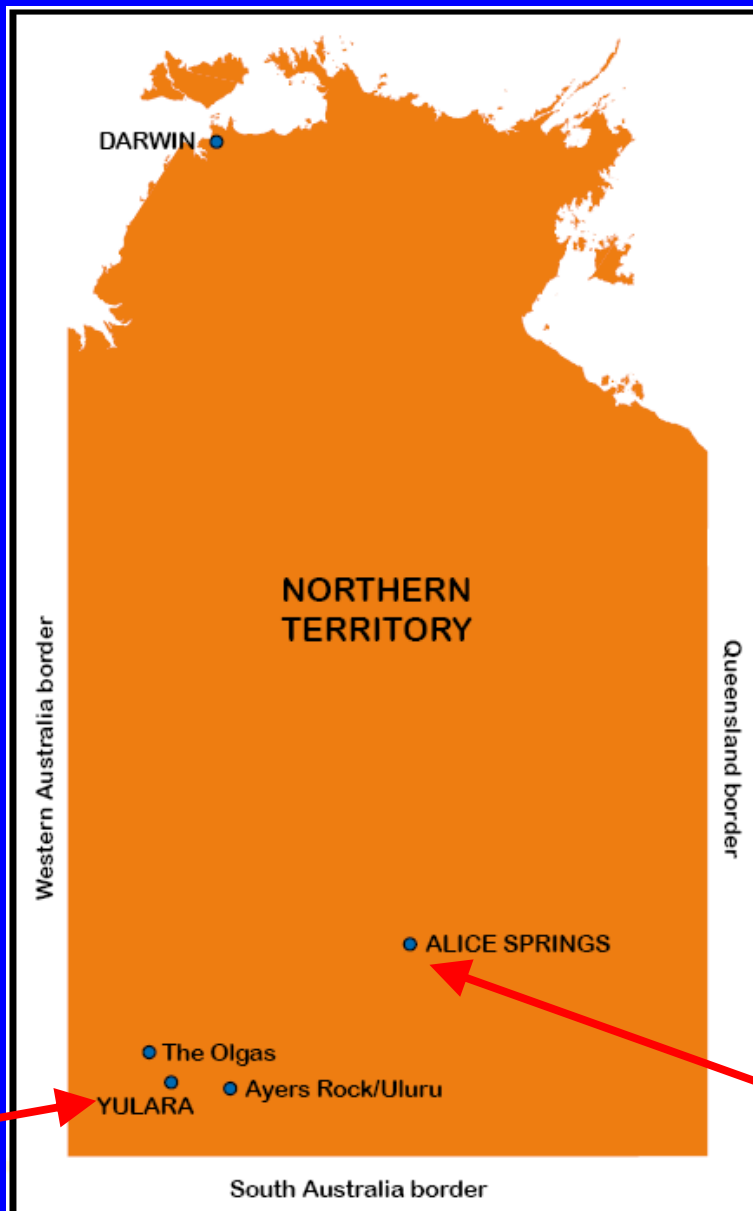


Energy Developments Limited – Alice Springs mother station and CNG truck/trailer (desert road train)



On-board CNG storage is by **composite CNG cylinders**, not tubes

Energy Developments Limited – Alice Springs mother station and power station at Yulara (880 km round trip)



4.5 MW power station

250 TJ p.a.

Mother station

Energy Developments Limited – Alice Springs mother station fuel transfer points



IEV Group – Indonesian mother station and CNG trailer



CNG trailers at mother station

IEV Group – Indonesian mother fuel transfer points



Filling poles

IEV Group – Indonesian mother fuel transfer point



CNG Dispenser

IEV Group – Indonesian customer fuel transfer points



Trailers connected discharge poles

IEV Group – Indonesian CNG customer fuel transfer points



Discharge station at customer's site

**Lincoln Composites “Titan” all - composite bulk storage containers
(four times more weight efficient than steel cylinders)**





Mobile CNG refuelling station, Japan

Mother and daughter requirements according to Singapore TR 12

- **All safety requirements of conventional (online) stations apply, in particular:**
 - **On site notices**
 - **Fire protection equipment**
 - **Emergency shut down buttons**
- **Mobile storage (trailer) parking bay**
- **Security fencing**
- **Risk assessment**

Mother and daughter on-site notices (1)

- **Fuel transfer procedure in the fuel transfer areas**
- **No Smoking, Flammable Gas and No Naked Flames in areas adjacent to compressor and CNG fuel storage**
- **Stop Engine, No Smoking, Flammable Gas, No Naked Flames and No Electrical Appliances adjacent to fuel transfer areas**
- **Emergency Shut Down next to the Emergency Shut Down buttons**
- **Signs and notices must be made to recognised standards with letters of minimum height 50 mm**

Mother and daughter on-site notices (2)

- **Fire extinguisher signs above the fire extinguishers**
- **Emergency procedure including evacuation routes in the fuel transfer area**
- **Emergency contact name and numbers (internal and external) in the fuel transfer area**

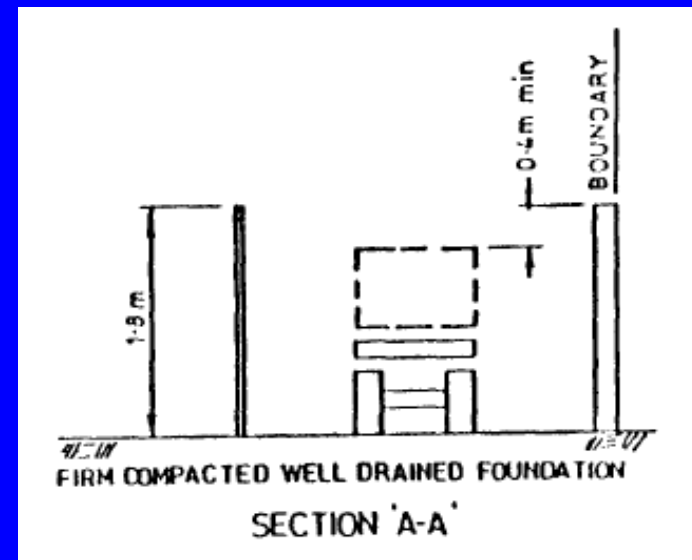
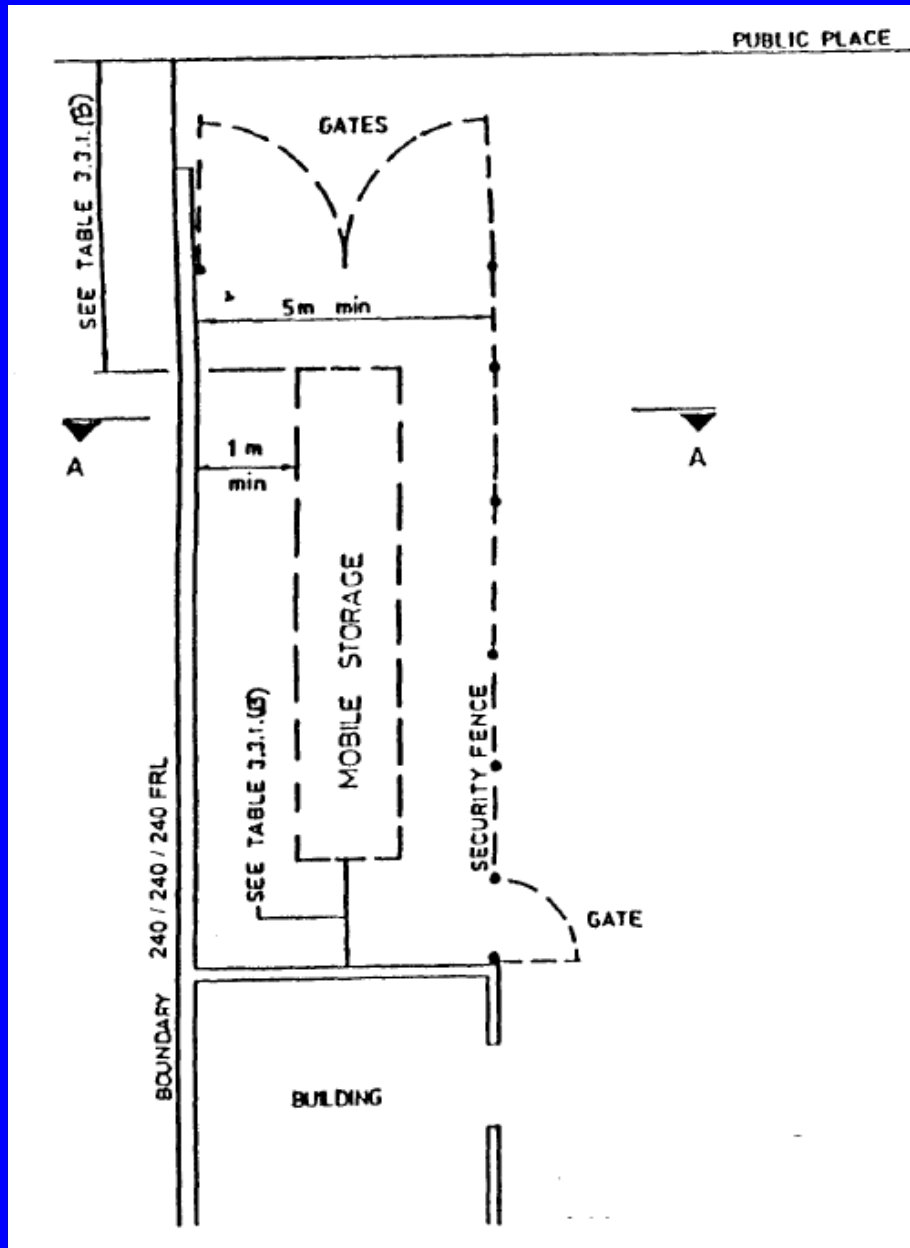
Mother and daughter fire protection

- **Fire extinguishers** of powder type and 9 kg size within 4 m of every truck/trailer in the fuel transfer area
- **Fire hydrant** on site for emergency services
- **No fuel transfer** to be conducted indoors

CNG truck/trailer parking bays

- **Parking bays must have well compacted, well drained surfaces**
- **Where no security fencing is provided for the mother or daughter site, the parking bay must have its own security fencing of 1.8 m minimum height, 1 m clearance around the truck/trailer**
- **Outward opening gate/door to be provided**

Mobile CNG gas storage (recommended by AS 5092)



CNG facility risk assessments

- **Qualitative risk analysis**
- **Hazard identification and classification**
- **HAZOP studies**
- **Quantitative risk assessment (QRA)**
- **Gas jet fire (thermal radiation) and explosion effects**
- **Radiation flux contours**

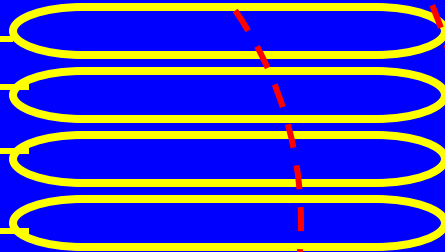
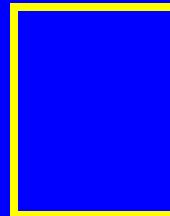
Outcomes of a CNG refuelling station risk assessment

- **Potential risks are identified**
- **Likely impacts of the operation of the facility**
- **Feasible hazard scenarios that could impact on-site and surrounding persons and assets**
- **Probability of injury, fatality and property damage (at levels specified by standards and regulations) are estimated**

QRA results (example)

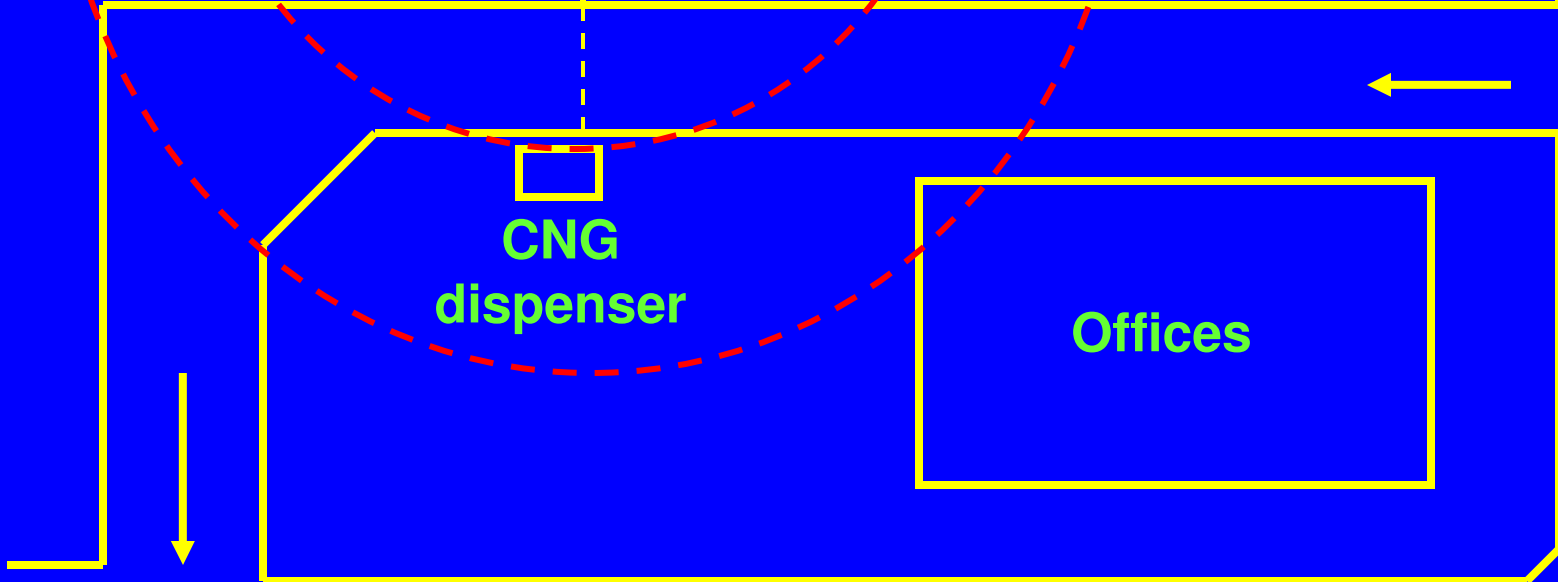
Risk of injury 1.3×10^{-8}

Compressor



CNG storage

Risk of fatality 9.1×10^{-7}



CNG dispenser

Offices

--- Risk contour

● A potential leak point

Fuel transfer points (1)

- **Fuel transfer hose to be fitted with fuel connectors and safety breakaway coupling**
- **Fuel transfer hose must be of the approved design**
- **Hose isolating valves to be provided, readily accessible to operator**
- **Fill pressure gauge**
- **Automatic pressure control valve to prevent fill overpressure**
- **Safety relief valve set at no higher than 110% of maximum truck/trailer's rated pressure**

IEV Group – Indonesian customer fuel transfer points



Discharge station at customer's site

Fuel transfer points (2)

- Hose assembly rest position and support such that hose will **not touch or drag** on the ground or other equipment at all times
- Provision for safe disposal of vent gas from relief valves and fuel transfer connectors
- If vent hose is routed back to compressor inlet, non return valve must be fitted to prevent back flow to fuel transfer connector
- Means for preventing fuel transfer hose operation by unauthorised persons when facility is not attended
- Adequate lighting for night time operation

CNG trucks/trailers requirements according to Singapore TR 11 (1)

- **Installation workshop and personnel in compliance with TR 10**
- **Overpressure protection (including in fire)**
- **Fire protection design and fire fighting equipment**
- **Orientation of pressure relief devices or pressure relief valve discharges**
- **CNG storage system information plate**
- **Signs and notices**

CNG truck/trailer – CNG storage system information plate

- **Durable information plate to be installed near the on - board CNG storage system, containing:**
 - **“CNG Fuel Storage Unit”**
 - **The rated working pressure in MPa**
 - **The cylinder/tube identification numbers**
 - **The stamped date of the next cylinder/tube periodic recertification**
 - **When a cylinder/tube is changed or recertified, the information plate must be accordingly updated**

CNG trucks/trailers – safety requirements (2)

- **Ignition cut - off during fuel transfer (battery master shut off switch may be considered)**
- **Mounting attachments for CNG fuel storage system**
- **Vehicle axle mass limits**

CNG trucks/trailers – Cylinder/tube attachment strength requirement (TR 11)

Acceleration direction	Design factor
Longitudinal	10 g
Lateral	5 g
Vertical	4.5 g

“g” = gravitational acceleration, 9.81 m/s²

Safety management system (TR 12)

A Safety Management System (SMS) must be established including the following elements:

- **The site safety management policy**
- **The emergency procedures**
- **Staff response training and refresher training**
- **Documentation of all above activities to be retained on site by the operator**

Safety management training material (TR 12)

The safety management training material must contain:

- **Basic but adequate information on the functions of the major components**
- **How they affect the safety of the site**
- **All aspect of the facility operation and emergencies**

Emergency procedures (1)

The emergency procedures must cover action to be taken in the event of gas leaks, accidents, equipment failure, or other abnormal occurrences – including acts of arson and terrorism.

The procedures must contain at least the following (and any other as appropriate):

- List of contacts, emergency services and their phone numbers**
- Chain of command**
- Duty list**
- Cooperation with relevant authorities**

Emergency procedures (2)

- **On-site staff response**
- **Debriefing and reporting**
- **Contractors and**
- **Site plan, evacuation routes and mustering stations**

Operation and work procedures

- **Truck/trailer fuel transfer procedure**
- **Security of equipment**
- **Inspection and maintenance program**
- **Work procedures**
- **Standing rules for work on site**
- **Authorisation for work**
- **Emergency plan and drills (including joint exercises with emergency services)**

Other safety requirements (1)

Many of the safety requirements to deal with the safety issues below may be included in the facility design or operation, or both:

- **Automatic compressor shut - down in the event of transfer hose or connector failure**
- **Daughter station storage cylinder safety**
- **Inadvertent connector separation during fuel transfer**
- **Inability to disconnect fuel transfer connector at end of fuel transfer**
- **Fuel leakage from hose or truck connector after disconnection**

Other safety requirements (2)

- **If cylinders are enclosed, adequate ventilation must be provided**
- **Composite cylinders operating temperature must be kept within the limit set by the cylinder standard or the cylinder manufacturer**
- **Truck/trailer collision, gas leak and fire**

Compressor shut - down in the event of transfer hose failure

- Compressor outlet pressure sensing and PLC (programmable logic controller) to shut down compressor
- Excess flow valve on compressor outlet – are they available in the size and at the pressure rating needed?
- Emergency shut down (ESD) buttons needed at fuel transfer points within safe reach by operators

Emergency shut down (ESD) button



Daughter CNG cylinder safety

- The large number of fill cycles and depth of daily pressure excursions may limit service life of daughter CNG cylinders
- Example of failure of buffer cylinders at a slow fill station in the US points to the need to correctly select storage cylinder design for large cycle operations with large pressure cycles
- Suitable cylinders may need to have significantly higher static pressure rating than the nominal fuel storage pressure, or a design with high cycle life (like CNG vehicle cylinders)

Slow fill station buffer tank explosion, USA 2001



Review by CNG facility or cylinder expert at facility design stage would have prevented this (flat bottom) buffer cylinder failure

Inadvertent separation of fuel transfer connector or safety breakaway coupling during fuel transfer (1)

- **Refuelling connectors have been known in the US and Australia to have inadvertently separated during refuelling**
- **Resulting hose whip can cause serious operator injury or property damage**
- **Mother daughter fuel transfer may be vulnerable to inadvertent connector separation**
- **An exclusionary zone can be imposed, or restraint used, to prevent persons from being hit by hose whip**

Inadvertent separation of fuel transfer connector or safety breakaway coupling during fuel transfer (2)

- **Inspection of transfer connectors (for damage or contamination) prior to every connection must be part of the operating procedure**
- **Connectors must be protected from contamination (dirt, grit, etc) and damage (collision and impact)**

Safety exclusion zone – Sydney bus refuelling station



Inability to disconnect fuel transfer connector at end of fuel transfer

- Defect in non return valves on fuel transfer lines may prevent connector disconnection at the end of fuel transfer
- Quick action (quarter - turn) **isolation valves** on truck and on mother outlet and daughter inlet lines will enable connector depressurisation
- The **isolation valves** must be located within safe reach of operator

Fuel leakage from mother/daughter or truck connector after disconnection

- **Defect or damage** in self sealing valve in truck connector and mother daughter connector may allow fuel to leak after disconnection at the end of fuel transfer
- **Fuel contamination** may cause connector self sealing valve not to seat (close) properly
- **Quick action (“quarter – turn”)** **isolation valves** on truck, and on mother outlet and daughter inlet lines, will stop this leak
- The isolation valves must be located within safe reach of operator
- Adequate and effective **fuel filtration** (mesh size selection and maintenance) must be provided on mother inlet and outlet, and truck transfer lines

CNG truck/trailer leak and fire (1)

- **Good components and workmanship will minimise risk of gas leak**
- **Locations of gas components must minimise likelihood of damage in feasible collisions in traffic and during site manoeuvres**
- **Major gas leaks may cause truck fire**
- **CNG truck/trailer electrics (non flameproof or non intrinsic) should not be exposed to feasible gas leak paths**
- **Most truck fires have origins other than gas (e.g. brake or deflated inside tyre or dual wheels)**
- **CNG trucks/trailers can be exposed to fires on other vehicles in traffic**

Tyre problems – dual tyres catching fire

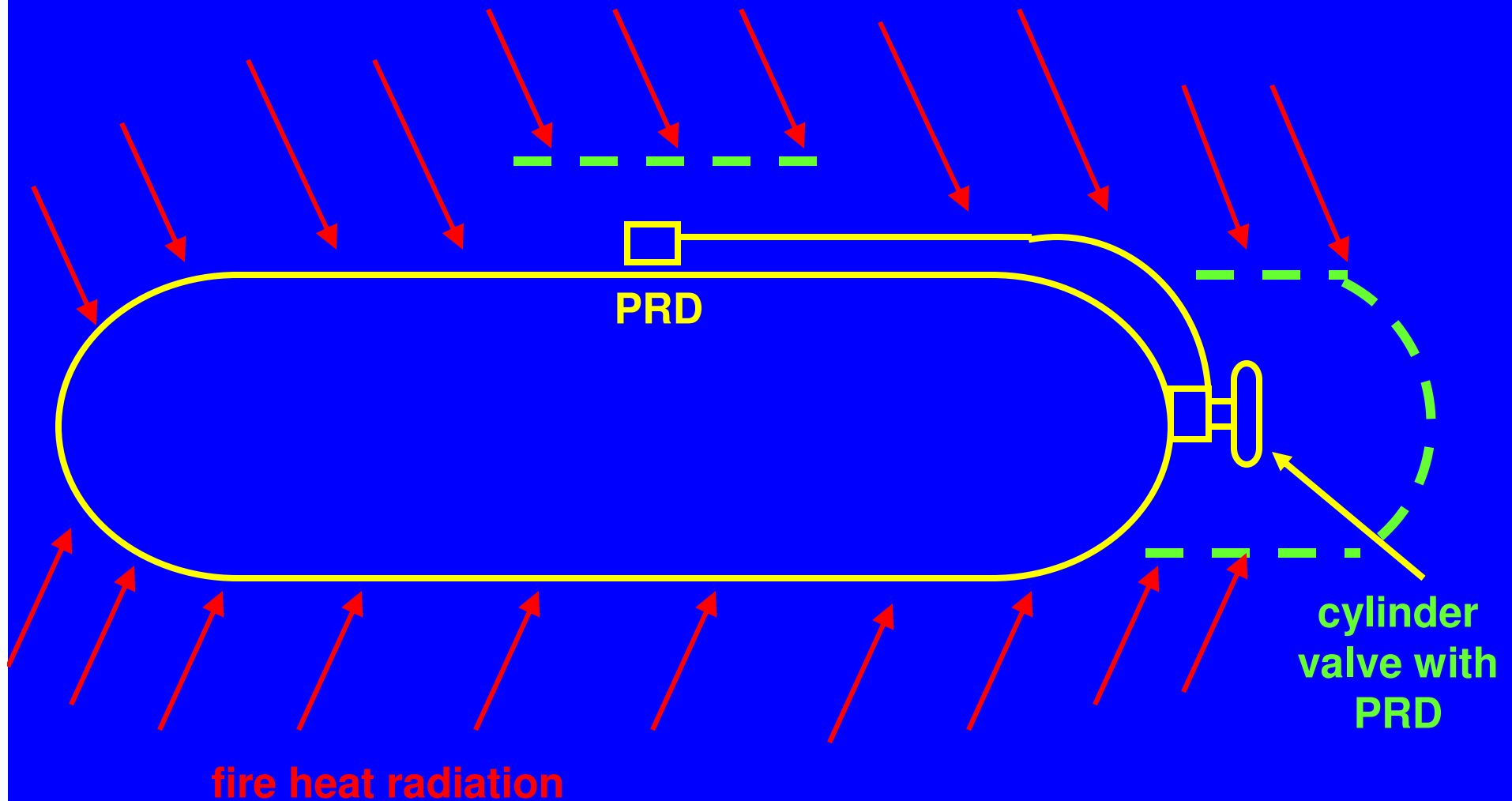


(Undetected flat tyres of dual wheels overheat and ignite from running friction)

CNG truck/trailer leak and fire (2)

- Adequate fire protection design of gas storage cylinders or pressure vessels is required
- If CNG cylinders are used, pressure relief devices (PRDs) must be positioned to be exposed to fire – no less exposure than the cylinders
- PRD discharge jets may create large, intense jet flames that can cause injury, death or damage to persons and other assets
- The ideal PRD discharge direction is vertically upward

Avoid shielding or insulating PRDs



— — — shield or insulation (e.g. vehicle bulkhead or cargo)

CNG bus cylinder PRDs pointed vertically upward (MARTA, Atlanta, Georgia, 2002)



CNG trailer/truck leak and fire (3)

- **Fire extinguishers of suitable type (e.g. dry powder) and size (e.g. 9 kg) must be provided at ground fuel transfer points and on trucks (e.g. 6 kg)**
- **Fire extinguishers should be located at no more than 4 m from each truck/trailer during fuel transfer**
- **Ground based operators and truck operators should be given suitable fire fighting training and periodic refresher training**
- **Truck/trailer and ground facility emergency programs must include fire fighting**

CNG trailer/truck leak and fire (4)

- Emergency services must be trained in CNG safety and fire fighting technique
- Efforts must be made to put out truck fires while it is still safe to do so
- Rapid evacuation to an **adequate distance** must be conducted in the case of fire on trucks/trailers with fully wrapped composite cylinders

CNG mother daughter system safety requirements

- Summary of topics covered

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- **Facility safety systems**
- **Safety requirements not specified by the standards**