SAND2006-3108C

Pressure Safety Orientation PRS150

Chapter 5) Deterioration, Failures, & Maintenance of Pressure Systems

March, 2006

Deterioration, Failures, & Maintenance of Pressure Systems

Chapter 5 / Objective:

The student will assess the consequences due to system degradation and explain the role leak checking and maintenance schedules play in pressure system operations.

After completing this section you should be able to:

1) List the concepts of why & when to perform system maintenance
2) Identify mechanisms of degradation
3) List common failure mode concerns and consequences
4) Be able to list basic leak detection techniques
5) Identify the requirements and concerns for flexible hoses

* Reminder

The need for system (or vessel) maintenance may call for a system modification, new component selection, or for a procedural change – this responsibility falls to Pressure Installers.

The limitations of pressure operators are repeated here:

- routine operation only (* not qualified to perform repair / maintenance)
- cannot design / install new systems (or re-configure existing systems)
- may include routine cylinder changes, loading samples, etc.

{ hardware training is required, commensurate with responsibilities }

Maintenance & Repair Concepts

*** Always consider potential hazards associated with maintenance & repair**

Pressure systems and components degrade with time and use, corrosion, fatigue, contamination, etc.

Reasons to perform maintenance:

- **bring a system back on-line after a failure**
- **reduce frequency of failures / increased reliability**
  - reliable data / experimental results / scheduling
- **consider the opportunity for improved design (or procedures)**
  - understand the cause(s) of failure
  - new component selection

When to maintain: (when applicable, follow OEM schedules)

- **on demand (system failure)**
- **PM (preventative maintenance)**
  - incorporate failures into PM schedules – record in data package
- **Change in operational parameters / degradation in system performance**
  - changes in pressure (vacuum) / flow / other system readings
- **excursions from designed conditions**

Understanding the cause(s) of a failure and taking corrective action is essential to continued safe operation of the system.

Mechanisms of Degradation

leaks or poor purge

Vessels / Chambers

1) Corrosion – chemical attack
- stress corrosion cracking

2) Materials property degradation
- hydrogen embrittlement
- temperature effects (high or low)
- materials compatibility

3) Fatigue concerns
- brittle-like failures without warning at pressures < MAWP
- repeated pressure, mechanical, or temperature cycles

4) Design & Operational concerns
- poor design (sharp corners, weld joints)
- within design intent (pressure, temp., etc.)
- new (OEM tested)

Systems / Components

1) Particulate contamination
- corrosion by-products, dirt / dust, shreds of Teflon tape, etc.

2) Component lifetime
- related to time, temperature, type of fluids (corrosion), cleanliness, # of cycles
- o-ring compression set
- connectors (repeated make & re-make)
- regulators, valves, etc.

3) Brittle materials – defect intolerant
- glass / quartz, ceramic, etc.
- scratch can initiate catastrophic failure

4) Design & Operational concerns
- rapid pressure transitions
- within ratings (pressure, temp., etc.)
- localized temperature gradients

Bolts & closure hardware: wear & tear / corrosion / galling
(Proper selection and **replacements**)

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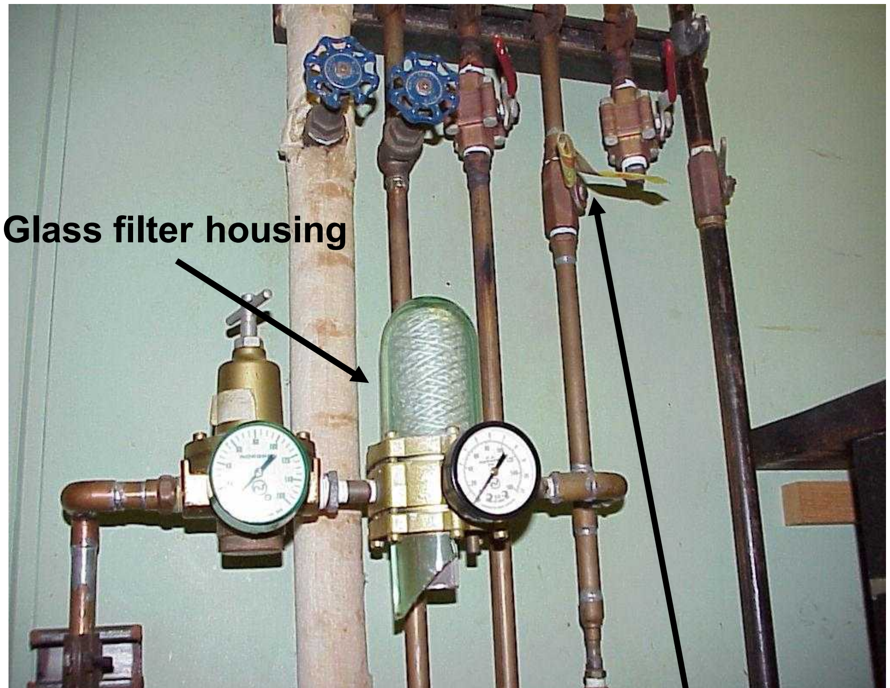
Pressure System Deterioration Points Out the Need for Proper Design and Factor of Safety



4 failures noted in this incident:

1) a crack developed in the glass filter housing

2) the 1/4 turn valve leaked through and failed to isolate the air pressure

3) design problems: no vent valve except the “drain” on the filter housing

4) no shielding on a brittle material component

* Result was the filter housing shattered as the operator opened the drain valve on the bottom of the filter housing

Failure Mode Concerns
Protection of personnel and property

* Important to identify potential hazards in Primary Hazard Screen (PHS)

1) **Consequences of Leakage** (leak test before hazardous operations)
   - release of hazardous substance {toxic / flammable / asphyxiant}
   - asphyxiation hazard associated with "House" inert systems
   - exposure to toxic / corrosive gases
   - other hazards / cooling water / disruption of schedule

High pressure (velocity) jets from leakage or rupture can be a hazard

2) **Consequences of Rupture - Brittle or Ductile?**
   - brittle failures = flying fragments
   - ductile failures = blast effects

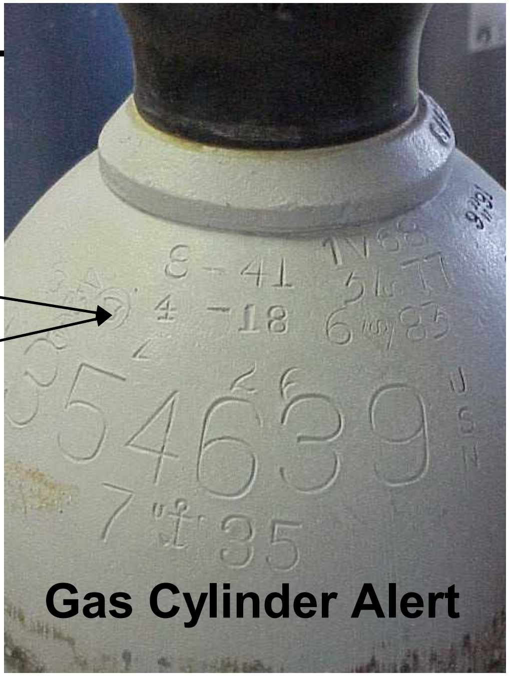
3) **Risk of failures is increased:**
   - operation outside of design parameters
   - during pressure or temperature transitions
   - after repairs or modifications (or new system?)

Understanding the cause(s) of a failure is essential to continued safe operation of the system.

Causes of Pressure System Failures / Accidents

1) Engineering / design based failures

- poor design of overpressure protection (PRV sizing, etc.)
- poor selection of materials of construction (strength, compatibilities, etc.)
- poor selection of components (quality, ratings, etc.)
- poor construction (sharp corners, weld quality, etc.)



Gas Cylinder Alert

2) Operational / maintenance based failures

- poor procedures (use checklists for critical steps in assembly) / valve sequencing / pressure surges
- evaluations and maintenance neglected
- shelf life for corrosive gas cylinders

3) Survey of Pressure Vessel Failures (ASME / Industrial Vessels)

- most caused by excursion from designed conditions (pressure, temp., etc.)
- most incidences occur within the first few years of operation
- cracks = #1 failure mode (cracking at welds)
  - component failures (25% due to fatigue / 30 % due to corrosion 20 % pre-existing from OEM suppliers)

Causes of Pressure System Accidents
* SNL Experiences

Well defined procedures (w / checklists) vs "skill of the craft"

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1) Manifold design – regulate / over pressure protection / isolate / vent

- Do not crack fittings under pressure
- Wear PPE when appropriate (eyes, face, skin, respiratory, etc.)
- Instrumentation in appropriate locations
- Operator errors / understanding of system
- Installation vs in-use

2) Flexible Tubing: ratings (pressure & temperature) / compatible materials

- "soft plastic" lines (tygon) vs harder "plastic" lines (Teflon / PFA)
- Swagelok fittings with inserts for secure connections

Portable Eyewash **100 psig**

SCBA used to pressurize a portable eyewash. No safety manifold – hose exploded into brittle-like fragments.

Causes of Pressure System Accidents

* SNL Experiences continued

check valve – in corrosive service

3) Maintenance / replacement intervals

- application dependent (corrosive, other?)
- components: PRVs, check valves, flex lines, regulators, pneumatics, gas cylinders (cylinder valves), other ?

4) Accidents related to "purge" of hazardous gases

- cracking fittings / opening chamber when the purge was not effective. Watch carefully: (wear PPE?)
- line tracing
- turning wrong valve / loosening wrong fitting
- filters (clogging) restricting purge
- RFOs, needle valves or MFCs (plugged)
  - valves not open (manual or automatic) or regulators not "open"
  - instrumentation to confirm successful purge operations (purge sequentially and watch for pressure transitions)

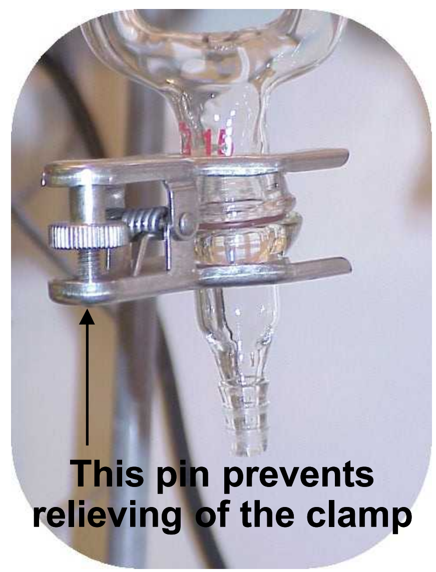
RFO = Restrictive Flow Orifice
MFC = Mass Flow Controller

Causes of Pressure System Accidents

* SNL Experiences continued

5) Pressure excursions / unexpected reactions and brittle materials

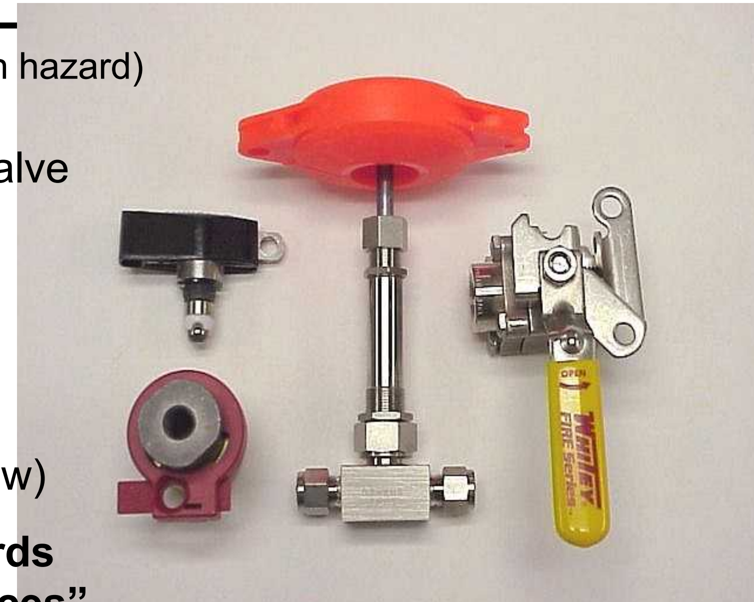
- know (or calculate) pressure ratings
- proper overpressure protection is important
  PRVs, burst disks - other relief / vent ports
- defect intolerant - scratches or chips invalidate the ratings – do not use
- shield components (or wear PPE)



Control of Hazardous Energy

Lockout / Tagout (LOTO)

SNL References:
- ES&H Manual Chapter 4C
- LOTO Homepage



Isolation & Verification Techniques (dependent on hazard)

1) disconnect pressure source
2) Valving / consider the effects of leakage through a valve
  - valve designed to provide shut-off
    (not a regulator backed out, metering valve, etc.)
  - closed valve with downstream vent
  - double block and bleed
  - double block and purge / evacuate
3) Vent, purge & verify (instrumentation = pressure / flow)

COHE (LOTO) - to protect personnel from the hazards related to the unexpected start-up of “energy sources”
(This includes pressure “sources” that present a hazard)

Evaluate each application in order to assure worker protection and LOTO requirements met.

COHE (LOTO) considerations:

- maintenance / service personnel must be trained and qualified
  - seek assistance when questions arise as to when / how to lock out

LOTO vs “Administrative” controls

- Administrative = to control access / use
- LOTO = to protect from hazards

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Leak Detection Concepts

Leakage can represent safety, purity, & cost concerns

1) release of hazardous gases (flammable, toxic, etc.)

- leak check prior to admitting hazardous gases

- leakage may be a precursor to catastrophic failure

2) Leak detection techniques:

- visual signs of leakage

- leak-check hole (VCR, DISS, other connections)

- pressure decay / not an over pressure test

- or vacuum decay (use compound gauges)

- leak detection fluid (Swagelok = SNOOP)

- fluid must be compatible with system fluids

- "Sniffers" (point source leak detectors)

- tuned for specific gas(es) / cross sensitivity

- Helium leak detection (helium = safe & highly sensitive)

- outboard or inboard (* add % helium to purge gas)
- RGAs (Residual Gas Analyzer) / detection with mass spectrometer

- acoustic emissions

Portable Leak Detector

Sniffer

All systems leak - it's a matter of degree and what level of leakage is of concern for the system.

Maintenance of Pressure Systems

SNL Facilities Equipment vs Line Organization Equipment

Line owned and maintained ←

Line organizations maintain their own systems and must not maintain or modify Facilities-owned equipment

Facilities Organization is responsible for maintaining building and permanently installed pressure systems (examples include house nitrogen gas or liquid, house air, etc.)

→ Facilities Owned and maintained

Pressure Relief Valves (PRVs):
require periodic evaluations for continued use

Evaluation - includes inspection, testing, or replacement of PRVs at the intervals incorporated into the system Data Package.

For this valve:
nominal set pressure = 100 psig
1st pop pressure = 180 psig

Failures & Maintenance for Flexible Hoses

Use for vibration isolation, alignment, etc. (not just for convenience)

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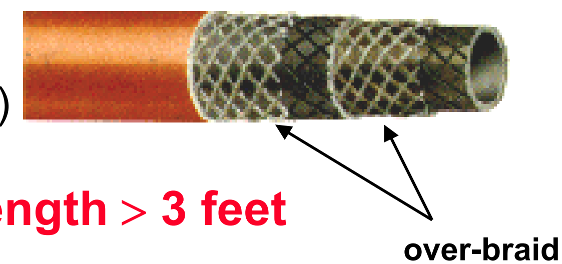
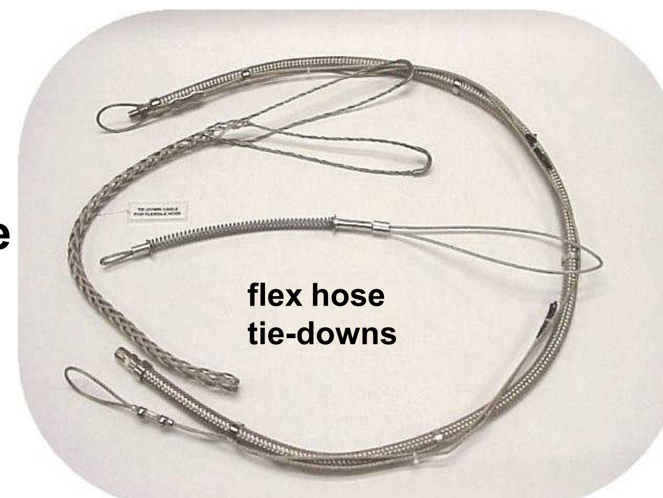
1) Hose whipping hazards – inspect & replace leaking or damaged hoses
- leakage may indicate imminent catastrophic failure
- over braid supplies the pressure integrity of the assembly
- materials compatibility with system fluids (corrosive, other?)
- "vacuum flex lines have minimal pressure ratings



2) * Tie-down required if: operated > 150 psig AND length > 3 feet
- Matheson Tri-Gas / "Lifeline" or "Smarthose" hose
- Excess flow valve may also address whipping hazard

3) Do not use Teflon-lined flex hoses for high pressure oxygen applications

4) Solid tubing "pigtail" may be safer alternative



Flexible hose hazards
- often fail at the connections
- tie-downs must also be secure

Maintenance Guide for Seals, Filters, and Regulators

Intervals (if used) can be time and application dependent

1) Seals & soft-seat materials (o-rings, gaskets, valve seats or packing, etc.)
- o-rings & gaskets eventually take a "compression set" and begin to leak
- some soft-seat material may swell upon exposure to specific gases (proper selection)
- replace on time or use (number of make & re-makes) interval

2) Filters & Purifiers
- may load up or become all reacted
- replace on time or use intervals (or when pressure drop increases, flow decreases, etc.)

3) Bolts / closure hardware (failures from high torque, fatigue, corrosion, etc.)
- use torque wrench & bolt lubricant / establish replacement intervals

4) Regulators are typically replaced – not repaired
- replacement interval (if used) is based on the application / cleanliness, etc.
- do not make your own repairs (unless specifically training and use OEM tools and parts)

5) Vacuum Pump Maintenance
- identify potential hazardous residues prior to shipping a pump out for repair
- hazard info also used at the end of useful lifetime of the pump (haz waste?)

Summary of Chapter Objectives

1) Maintenance concepts (repair, preventative maintenance, reliability) and take the appropriate corrective actions (system modifications)

- maintenance performed upon failures, excursions from designed conditions, or schedules dependent on time, application specifics

2) Mechanisms of degradation include:

- corrosion or materials degradation (such as fatigue or hydrogen embrittlement)
- particulate contamination
- lifetime limitations (time, temperature, etc.)
- rapid pressure transitions or localized temperature gradients

3) Failure mode concerns include hazardous releases and potential brittle or ductile rupture failures (consider hazards to personnel and property)

- risk is increased when outside of designed parameters, during pressure / temperature transitions, or after repairs / modifications

4) Leak checking (visual signs, pressure decay, leak detection fluids, Sniffers, helium leak detection (outboard or inboard), and acoustic

- what level of leakage is of concern for the specific system?

5) Flexible hoses can present a whipping hazard

- secured (> 150 psig and > 3 feet in length)
- replace if damaged (over braid supplies the pressure rating)
- Teflon / oxygen concerns