SAND2008-1488P

Pressure Safety Program Overview
Sandia National Laboratories

EPWOG Pressure Safety Task Team Meeting on March 18 and 19, 2008
DOE / NNSA Nevada Operations Office, Las Vegas Nevada

Objective – Provide a brief overview of the elements of the pressure safety program at **S**andia **N**ational **L**aboratories.

Contents – to follow the suggested question and answer format in the proposed agenda.

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Pressure System - Definition

Pressure System - no lower pressure limit, includes vacuum

An integrated array of pressure-containing components typically consisting of pressure vessels, piping, valves, pumps, gauges, etc… which is capable of maintaining fluid (liquid or gas) at a pressure different than atmospheric.

Pressure Safety Program

Goal is to provide a safe pressure environment

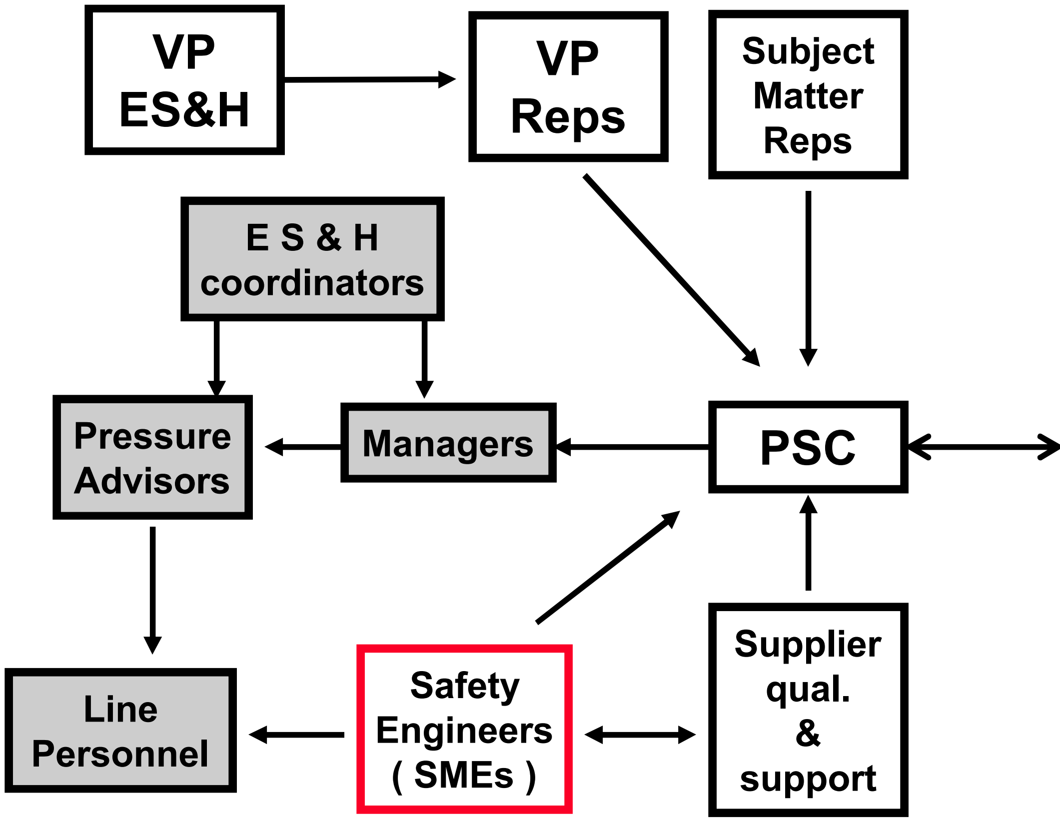
SNL Pressure Safety Program incorporates:

DOE pressure safety requirements (DOE 440.1A and OSHA 10 CFR 851)
+ National Codes for Pressure Vessels, Systems, Hardware (as applicable)
+ SNL Experience

SNL Pressure Safety Program elements:

- Training requirements / qualification process
- Policy & procedures = Pressure Safety Manual and Safe Handling of Cryogenic Liquids
- Provide advice & assistance = Pressure Safety Committee and Pressure Advisor structure
  - misc other consultants (testing / welding / materials / etc.)
- Documentation requirements / accountability of design, operation, and maintenance
- Evaluations / reevaluation criteria must be documented
- Provide hardware control (use safe and rated for the application)
  - participate in selection of JIT suppliers

Pressure Safety Program Structure



Program Ownership

= Safety Engineering

(staffed < 1.2 FTE)

(PSC is advisory)

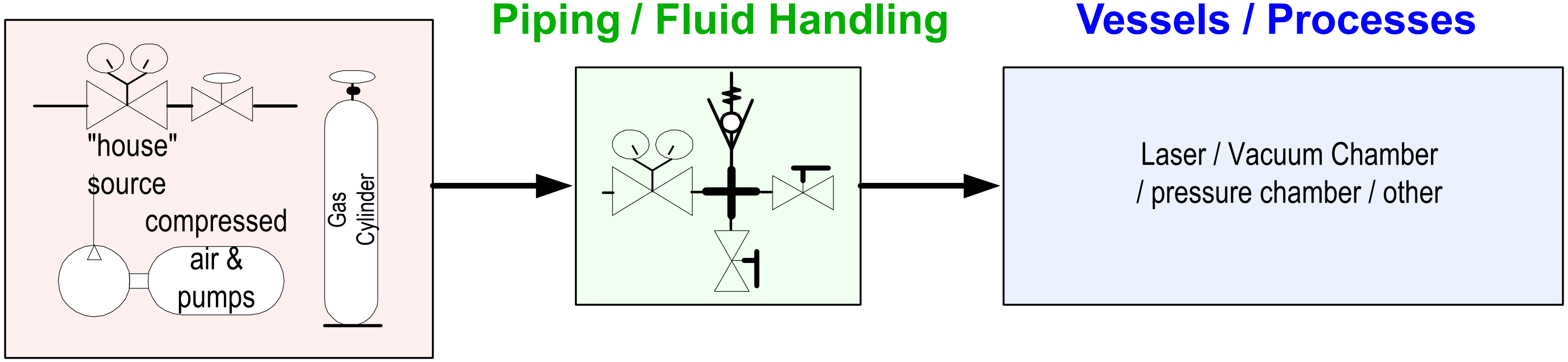
SNL Pressure Safety Program and DOE pressure safety requirements (440.1A)

OSHA 851 Challenges:

1) acknowledging the broad spectrum of applicable Codes

2) flow down of requirements to contractors = follow SNL Manual - or - contractor safety plan reviewed and accepted by SDR (Sandia Designated Representative)

Pressure Sources | **Piping / Fluid Handling** | **Vessels / Processes**



Pressure Sources:
ASME B31.3
DOT
CGA
IFC / IBC

Piping / Fluid Handling:
ANSI / ASME B31.3
ASTM
SAE
API
IFC / IBC

Vessels / Processes:
ASME Section VIII, Division 1
Fire Codes, Building Codes, NFPAs
IFC / IBC (formerly known as UFC & UBC)

Consult your ES&H Support Team
(Safety, I.H., Fire Protection, other?)

SNL does not have the ability to produce code stamped vessels or repairs

R&D systems = "equivalent" safety / "adequate" safety

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Custom Design Concerns

for pressure or vacuum vessels / components

* Consider consequences of failure

Custom designs must include documented justification of ratings based on:

1) calculation of MAWP (appropriate safety factor applied)
   - based on tensile, yield, or buckling strengths (for vacuum)

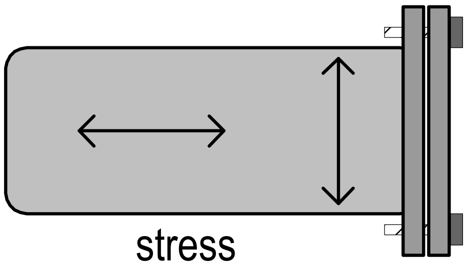
2) failure mechanisms
   - material behavior (brittle vs ductile)

3) temperature, fatigue, corrosion effects, etc.

4) joints and closures
   - weld joint considerations (efficiency factor)
   - analysis of bolt strength (materials / ductile)

5) testing requirements
   - overpressure test, proof test, leak test as needed

6) **F**inite **E**lement **A**nalysis may be needed for complex geometries



stress calculations

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Technical Work Documents (TWDs):

The Principal Documents Related to Pressure Systems are:

1) Data Package – required for all pressure (and vacuum) systems

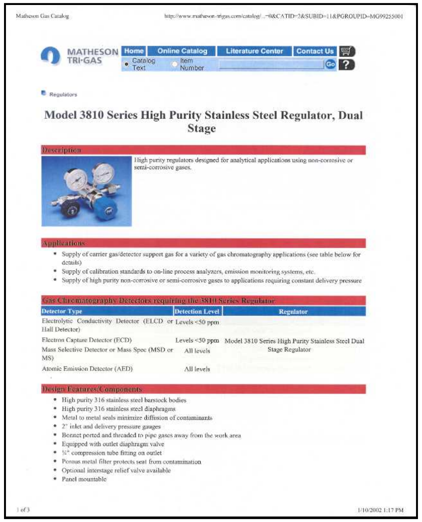
2) Pressure Safety Analysis Report (PSAR)

3) Standard Operating Procedure (SOP or OP) - reference in data package
   - see the SNL ES&H Manual for guidance
   - OPs or SOPs may be required to control specific {higher} hazards
   - WIs (Work Instructions) are specific operational instructions
   - other procedures include OEM manuals, operating instructions, etc.

4) Service Log – to track operation, service, & maintenance intervals; or
   - pressure cycles {vessel fatigue concerns}
   - failures / required repairs
   - parameters listed in PSAR

A “Data Package” is Required for All Pressure Systems

1) Documents compliance with manual - hardware ratings, etc.
2) Is a working document which is kept current
3) Contains all information needed for future evaluations
4) Used as a training tool for operators
5) May refer to start-up, operating, shutdown procedures (checklists, operator aids).
6) Signatures = Installer / Operators / Pressure Advisor / Manager



Matheson Gas Catalog   http://www.matheson-trigas.com/catalog/...=0&CATID=2&SUBID=11&PGROUPID=MG99255001

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Catalog Text Item Number Go

Regulators

Model 3810 Series High Purity Stainless Steel Regulator, Dual Stage

Description

High purity regulators designed for analytical applications using non-corrosive or semi-corrosive gases.

Applications

- Supply of carrier gas/detector support gas for a variety of gas chromatography applications (see table below for details)
- Supply of calibration standards to on-line process analyzers, emission monitoring systems, etc.
- Supply of high purity non-corrosive or semi-corrosive gases to applications requiring constant delivery pressure

Gas Chromatography Detectors requiring the 3810 Series Regulator

Detector Type	Detection Level	Regulator
Electrolytic Conductivity Detector (ELCD or Hall Detector)	Levels <50 ppm	
Electron Capture Detector (ECD)	Levels <50 ppm	Model 3810 Series High Purity Stainless Steel Dual Stage Regulator
Mass Selective Detector or Mass Spec (MSD or MS)	All levels	
Atomic Emission Detector (AED)	All levels	

Design Features/Components

- High purity 316 stainless steel barstock bodies
- High purity 316 stainless steel diaphragms
- Metal to metal seals minimize diffusion of contaminants
- 2" inlet and delivery pressure gauges
- Bonnet ported and threaded to pipe gases away from the work area
- Equipped with outlet diaphragm valve
- ½" compression tube fitting on outlet
- Porous metal filter protects seat from contamination
- Optional interstage relief valve available
- Panel mountable

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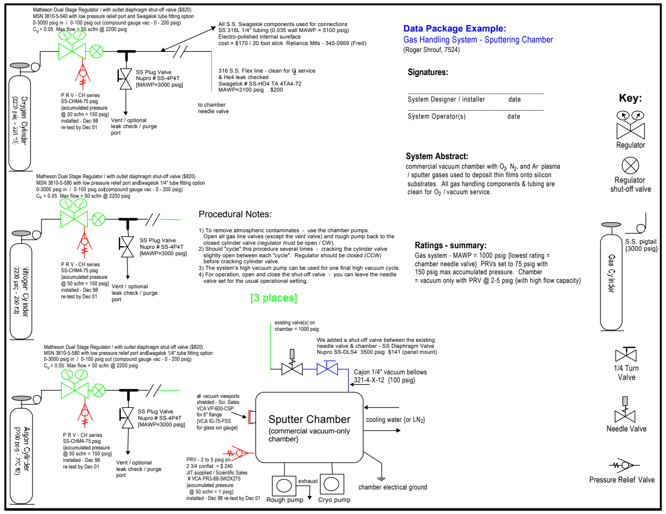

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Data Packages (or PSARs) are required

As a minimum, the Data Package should contain -

1) System description {abstract} and ownership information
2) Consideration of hazards
3) MAWP of components / system {based on lowest rated component}
4) Overpressure protection information
   - set pressure $\leq$ MAWP / flow capacity considerations / recall & maintenance
5) Drawings
   - can share software with SMEs (Subject Matter Experts)
   { Microsoft Visio / Technical Edition }
6) Materials and process data;
   - factors of safety and how determined
   - temperature considerations
7) Evaluation information
   - overpressure test, NDE, relief valve intervals, etc.
8) Identification of Isolation (LOTO)
   - how / where to safely shut-down / isolate & apply LOTO (if applicable)

* OEM manuals can be considered part of the system data package – must document areas not covered.

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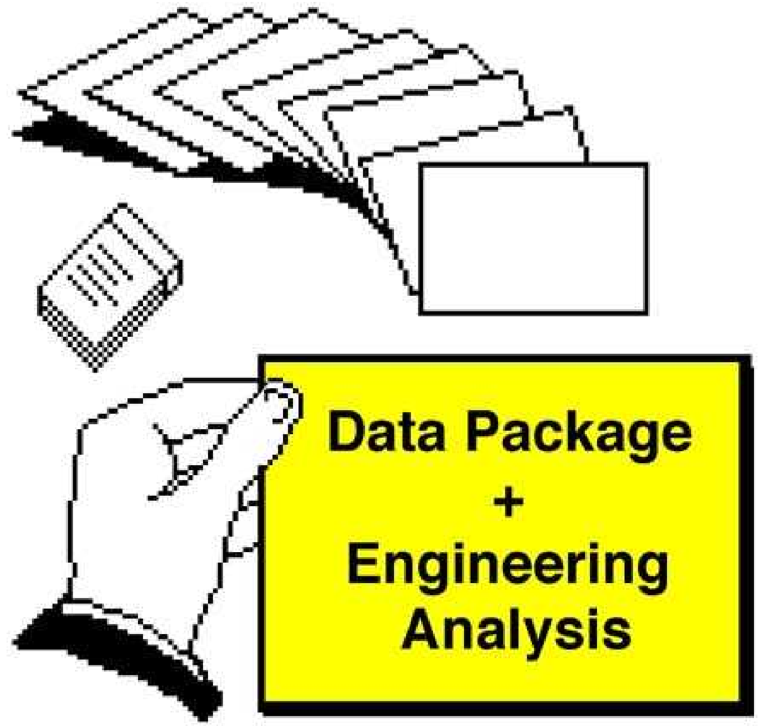
PSARs Address Pressure Systems with High Hazard Potential

PSAR = Pressure Safety Analysis Report



The mounting design and thickness of this custom-designed and fabricated viewport is added to the standard data package information to complete a PSAR.

Pressure Safety Program Homepage

Pressure Safety Committee Responsibilities:

1) Administer Program

2) Formulate Policy

3) Author the Pressure Safety and Cryo Safety Manuals
   Our manuals are outside the firewall at http://www.sandia.gov/

4) Recommend Testing Facilities

5) Establish Training Requirements

6) Serve as Advisory Group (interpretation of requirements)

7) Maintain PSC Homepage http://psi.sandia.gov (inside the firewall)
   - Pressure Safety Manual / Cryogen Safety / PSC Charter
   - Points of Contact (Index of assistance personnel)
   - Pressure Advisor Listing
   - Application Notes / course materials
   - Bulletins / News Notes / link to SNL Lessons Learned
   - Guidance on documentation

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Pressure Safety Manual (MN471000)

1) Purpose - Contains requirements and guidance

2) Scope - SNL Employees & Contractors who Design, Install, or Work with Pressure Systems Shall Meet Requirements Set Forth

851 / Flow down of requirements = contractors must follow:
- the SNL Manual(s) or
- a safety plan (reviewed and accepted)

Building Systems are managed by Facilities (air / nitrogen / etc.)

Laboratory Systems are managed by the line orgs (? many thousands ?)

3) Manual / Program Ownership = Safety Engineering
- Pressure Safety Manual
- Safety Handling of Cryogenic liquids

Appendix F / Assistance Index (lists PSC members)
- materials consultants
- testing
- cryogen safety
- Drawing Review / drafting & design services
- Code applications
- welding safety

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Personnel Involved with Pressure Systems should be:
- identified according to job task
- aware of system hazards, requirements, and available assistance

Pressure Operator	=	PRS150 (≈ 2500 trained)	+			Hardware Training ?	+	OJT
Pressure Installer	=	PRS150	+	PRS250 (≈ 1200 trained)	+	Hardware Training	+	OJT
Pressure Advisor	=	PRS150	+	PRS250	+	Hardware Training	+	PRS160 (≈ 100 PAs)

NOTE: add PRS115 (≈ 1100 trained) for any cryogenic applications

Training organized according to level of responsibility
(not pressure range)

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Description of Pressure Safety Courses

Live-taught classes (follow-up lab visits with SMEs encouraged)
- completion requirements = written test + class participation
- web-based refreshers under development

PRS 150 Pressure Safety Orientation ≈ 4.5 hours
- basic program information and roles / responsibilities
- reminders (gas laws, units, etc.)
- basic manifold requirements (function and failure modes of regulators, valves, etc.)
- gas specific concerns for asphyxiation hazards, toxics, pyrophorics, corrosives, etc.
- gas cylinders (cylinder storage and handling issues)
- maintenance concerns and common failures modes (lessons learned, LOTO, etc.)

PRS 250 Advanced Pressure Safety ≈ 3.5 hours
- detailed discussion of documentation requirements (tools for documentation)
- relief valve flow capacity calculations
- vacuum concerns
- pressure testing and evaluation / reevaluation criteria

PRS 115 Cryogen Safety ≈ 2 hours
- fluid properties
- hazard identification (emphasis on overpressure and asphyxiation / other hazards…)
- PPE requirements
- use of Dewars / cold traps / etc.

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Pressure Operator Responsibilities & Limitations

Responsibilities:

1) Hazards Awareness

2) Verify Assembly - proper rating, valve placement, sufficient relief

3) Use of available assistance in ascertaining safety
   - Pressure Advisor, Pressure Installer, PSM, Appendix F, or SMEs

4) Review the contents of applicable pressure system documentation
   - data package, procedures, OEM instructions, etc.

Limitations:

1) Limitations placed on pressure operators:
   - routine operation only (* not qualified to perform repair / maintenance)
   - can not design / install new systems (or re-configure existing systems)
   - may include routine cylinder changes, loading samples, etc.
   { hardware training is required, commensurate with responsibilities }

Pressure Installer Responsibilities

1) Design, installation, modification, operation, and maintenance of pressure systems (without supervision)

2) Selection / procurement of pressure hardware

3) Provide guidance to other personnel involved with the system (pressure operators, etc.)

* Applications involving cryogenic fluids require PRS115, Cryogen Safety

Note – SNL bears the responsibility for system design. Suppliers and sub contractors (such as Albuquerque Valve & Fitting, Trigas, or Henderson Construction) provide guidance only.

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PRESSURE INSTALLER QUALIFICATION FORM

Pressure System Title/Type Application________
Designee______
(print name)

The responsibilities and functions of a Pressure Installer (PI) are listed in the *Pressure Safety Manual* (MN471000), Chapter 2.

PERFORMANCE EVALUATION

The above named Pressure Installer has successfully completed the Pressure Safety Training course(s) applicable to the applications listed above. (Course certificates are on file.)

Date	**Course**
_________	PRS115, Cryogen Safety (as applicable)
_________	PRS150, Pressure Safety Orientation (required)
_________	PRS250, Advanced Pressure Safety (required)
_________	Commercial Hardware Training (or equivalent)
_________	Organizational, instructional, and practical application phases of on-the-job training

The designee has also demonstrated the skills and abilities to perform the duties of PI for the system/type operation listed above.

Comments ____

____

____

QUALIFICATION RECOMMENDED

Trainer ______________________________	Date ____________________
Pressure Advisor ______________________	Date ____________________

QUALIFICATION APPROVED

Manager ______________________________	Date ____________________

Guidance for the qualification of Pressure Installers:
The PI shall meet the following requirements:
1.Be recommended by manager based on job tasks.
2.Complete classroom training as stated above.
3.Complete local and on-the-job training as specified by the organization.
The manager and Pressure Advisor shall sign the **Pressure Installer Qualification Form.**

(Keep in organization files)

Qualification forms (optional)

1) matches personnel to their application(s)

2) documents training (including OJT)

3) Qualification approved

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Guidelines for Pressure Testing

Typical OEM Testing (Original Equipment Manufacturer)

- vessels, systems, or components are typically subject to testing by the OEM
- examples include ASME vessels / overpressure test as per code (additional info / radiography or other NDE, leak test, etc.)
- systems (gas panels, etc.) are leak tested as per OEM spec
- components (PRVs, flex lines, etc) are functional tested

Custom designs – SNL should specify the required testing

- custom designed vessels or components / applicable testing to be determined
- documentation of test / acceptance criteria
- follow the guidance in applicable codes (or the SNL Pressure Safety Manual Chapters 3 & 6)

Evaluations & re-evaluations

- establish intervals and criteria
- follow applicable code or industry standard practices

The Overpressure Test - is performed under controlled conditions where the pressure is taken above the MAWP

1) Validates structural integrity
2) Indicates an absence of critical flaws
3) Completion / validation of the design cycle
4) May be used for re-inspection

Re-inspection issues - establishes potential for flaw growth

- some designs may call for an initial overpressure test only (air receiver tank)
- repeated overpressure testing may be applicable in some cases (DOT gas cylinder)

NDE is typically performed during an overpressure test

An overpressure test alone does not establish an MAWP

- design calculations are required
- the overpressure test parameters are a function of the design

ASME Pressure Vessel Code hydro = 1.3 x MAWP (pneumatic = 1.1)

DOT = 5/3 x MAWP (depends on the design specification)

Note - an "overpressure" test is NOT performed on piping systems

Systems assembled from OEM rated components such as tubing, valves, etc. are "pressure / leak" tested as per ASME Piping Code (acceptance criteria TBD)

hydro = 1.5 x Design (Operating) pressure (pneumatic = 1.1)

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The "Proof" Test is different from an Overpressure Test

A "Proof" test:

- is done when the **design parameters are unknown**
  (no design calculations – Material strength? / MAWP? / burst pressure? / safety factor?)
- the **component / vessel is taken to failure** (burst / yield) and a failure point is determined
- an acceptable **safety factor is applied** to establish MAWP for "like" components / vessels
- safety is an issue during a proof test (shielding / remote / etc.)
- follow the guidance in ASME Code

Note: performing an "overpressure test" at some % above MAWP (without knowing the predicted burst pressure / safety factor / etc.) will not ascertain any valuable information

Concepts of Evaluation
(and Maintenance)

*** Proper isolation of hazards - LOTO may be required?**

1) Program established "up front" and documented in Data Package

- system dependent and evolves with system use

2) Criteria: (use applicable Code or OEM guidance)

a) system modified / repairs

b) degradation:

- Corrosion or harsh environment
- Change in material properties
  (hydrogen embrittlement is an example)
- Mechanical fatigue
- Component limitations

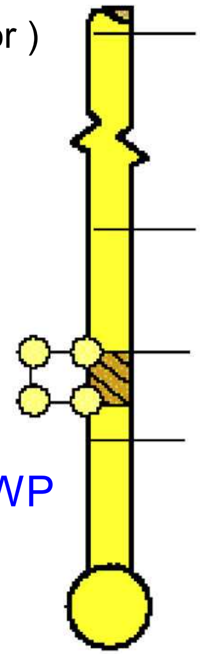
3) Use assistance available (SNL Pressure Safety Manual)

- guidance (checklists) in Pressure Safety Manual
- assistance personnel in Appendix F (various NDE available)

Pressure Safety Practices

Key relationships in the proper design of a pressure system

Material design factor (safety factor)
- based on design and material allowable stress value



Predicted failure
(burst or yield)

Overpressure Test [1]

Opening Range of Relief Device

MAWP Maximum Allowable Working Pressure

Operating Pressure < MAWP [2]
(Design Pressure)

operating pressure < relief device < MAWP

[1] Details on overpressure testing are covered in PRS250 – operators must not conduct overpressure tests

[2] can operate up to MAWP

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Typical Pressure Safety Manifold
- a low pressure system using a high pressure source

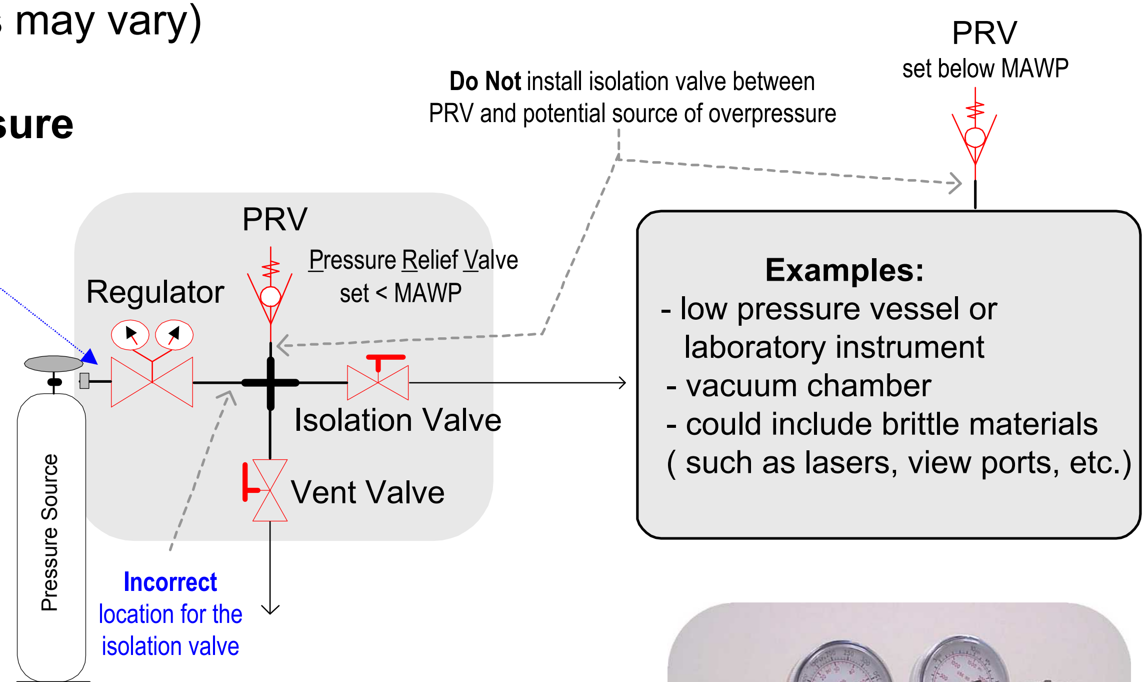
Manifold Functions: (designs may vary)

1) Regulate / reduce high pressure

2) Overpressure protection

3) Isolate / shut-off

4) Vent system pressure
- do not crack fittings under pressure
- vent to a safe location / away from operator, etc.



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Pressure Safety Manifold Variations
Purge Concerns:

Purge: the removal or replacement of residual gases within a system by using flow, pressure, or vacuum.

1) to remove chemical hazard gases prior to breaking any system connections
   - prevent exposure to hazardous gases during cylinder changes, maintenance, etc.

2) to maintain gas purity
   - don't pay high dollars for high purity gas - used on a low purity system
   - purge should be adequate to maintain gas purity to the point of use

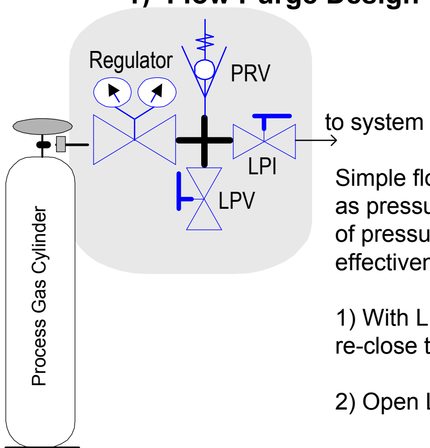
3) to reduce reaction by-products
   - corrosives, toxics, pyrophorics, others - react with water, oxygen, hydrocarbon, etc.)
   - chemical reactions can cause PRVs to stick closed
   - or particulate contamination that can cause regulators to "creep", valves to leak, etc..
   - specific examples:
     - fluorine {F_2} reacts with water to form hydrofluoric acid {HF}
     - silane {SiH4} reacts with residual oxygen to form SiO_2 (particulate)

4) Cycle purge - best technique to provide a high quality purge
   - alternate cycles of vacuum & pressure (purges "dead-leg" spaces)
   - rough vacuum (50 to 100 torr is adequate) – clean source (venturi pump)
   - clean, dry, inert gas { N_2 ? } typically used at 20 to 90 psig
   - residual N_2 - but other contaminates are removed

Note that systems must be leak-free

* Application Note 3

1) Flow Purge Design



Simple flow purge is not as effective as pressure cycles. Repetitive cycles of pressure / vent increase the purge effectiveness.

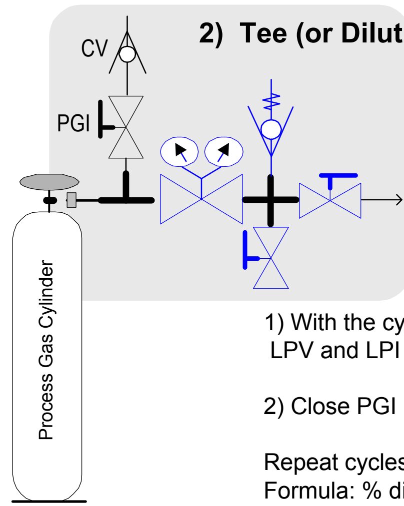
1) With LPI and LPV closed, crack and re-close the cylinder valve

2) Open LPV (repeat cycles)

* A "clean" vacuum pump could be used to pump from the system back through the piping components to the closed cylinder valve to further enhance purge effectiveness.

PRV = pressure relief valve
LPI = low pressure isolation
LPV = low pressure vent

2) Tee (or Dilution) Purge Design



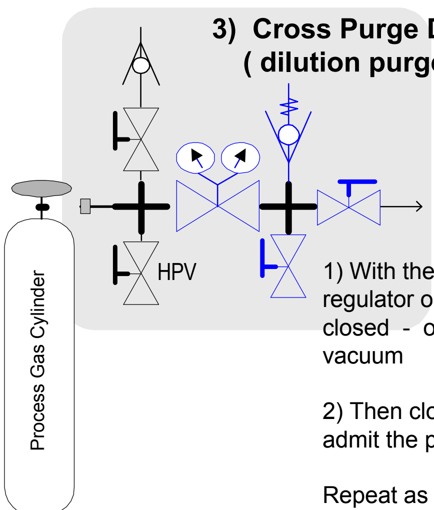
1) With the cylinder valve closed, the regulator open, LPV and LPI both closed - open PGI

2) Close PGI - and then open LPV

Repeat cycles as needed
Formula: % dilution = {15 / {15 + Z}]^{N} x initial %
where N = number of cycles
and Z = purge gas pressure

CV = check valve
PGI = purge gas in

3) Cross Purge Design (dilution purge + vacuum)



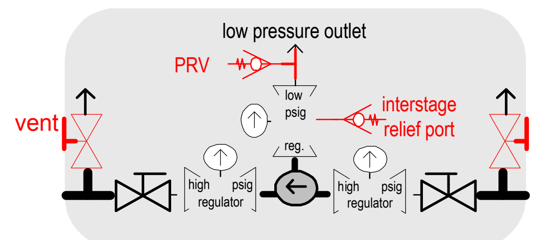
1) With the cylinder valve closed, the regulator open, LPV and LPI and PGI all closed - open HPV to a clean source of vacuum

2) Then close HPV - and open PGI to admit the purge gas.

Repeat as needed.
* Note - a clean (non-oil back streaming) source of vacuum is needed, such as a venturi pump with a capability of 50 to 100 torr base vacuum

HPV = high pressure vent (vacuum)

Commercial Gas Panel Designs

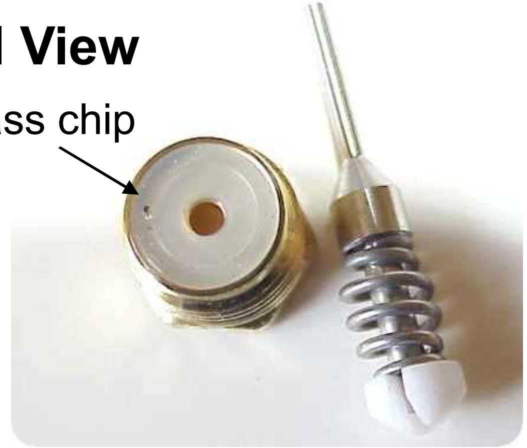


Auto - switchover panel without pressure relief, vent, or purge capability

Various suppliers provide pre-assembled gas panels with a variety of purge levels to choose from - ranging from simple manual flow purge designs with Swagelok and pipe thread connections to fully automated UHP cycle purge designs with VCR and orbital welded connections.

Safety concern with commercial designs - as sold, these panels may not include all the safety features required by SNL such as pressure relief or vent valves. **The SNL requestor is responsible for the system design and may need to modify / add to the suppliers' design to meet SNL requirements.**

Regulators – Primary Failure Modes & Internal View



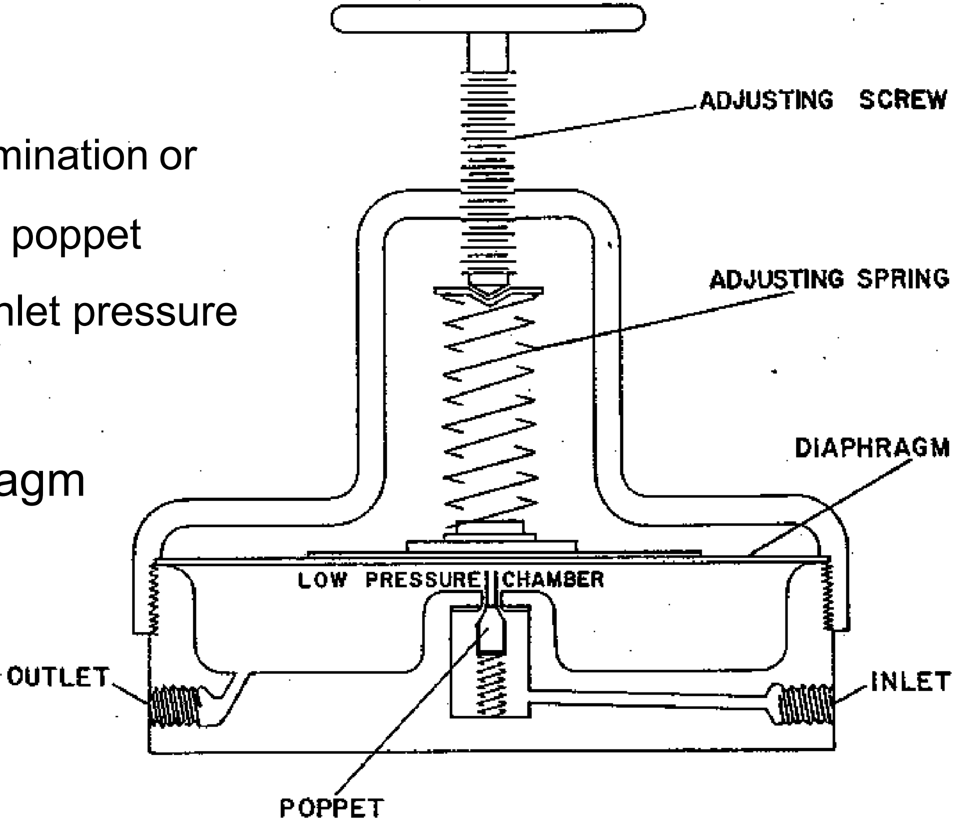
* Regulators only reduce pressure - they are not pressure limiting devices - and DO NOT provide sufficient overpressure protection

1) outlet pressure “creep”

- most noticeable at no / low flow conditions
- leakage at the poppet seat
- often caused by: particulate contamination or pressure surges that can deep-seat poppet
- set point can change with decaying inlet pressure

2) diaphragm leakage or failure

- uneven forces across the diaphragm
- often caused by fatigue or materials compatibility problem



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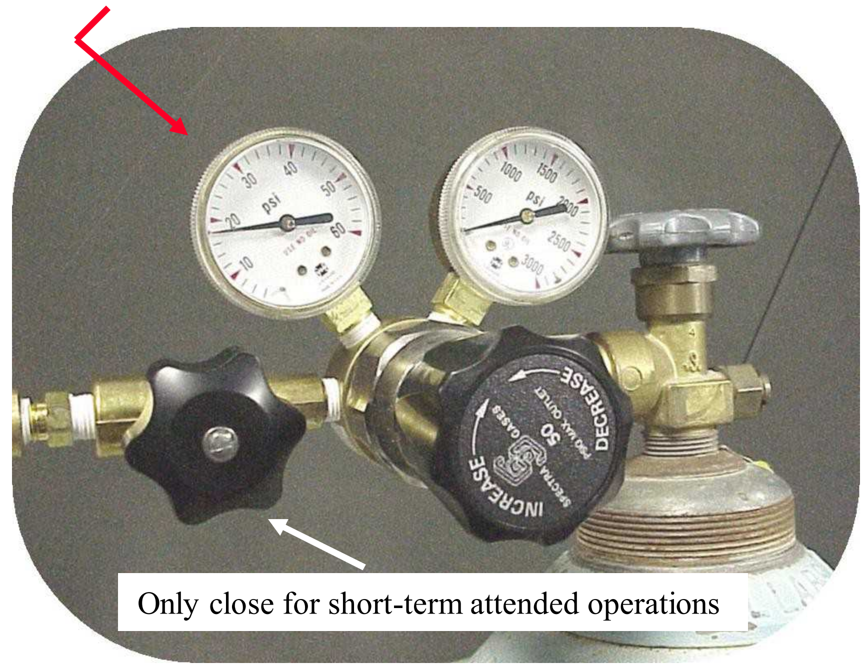
Regulator Selection Notes continued

In this design, the PRV protects both the downstream system - and the regulator outlet valve, diaphragm, & outlet gauge.

As purchased from some suppliers, the regulator's outlet valve, diaphragm, & outlet gauge could see overpressure with creep.



PRVs on regulators are intended to protect the outlet side of the regulator (diaphragm)

– and not intended to protect downstream equipment

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Correct Use of Pressure Relieving Devices

Pressure Relief Valves (PRVs) or Rupture Disks

1) MAWP compatible (set pressure and flow capacity)

- "accumulated pressure" < MAWP

2) Correct placement within the system

- Do not isolate the pressure relief device

3) Orient and control relief device discharge

- vent into exhaust, scrubber, outside ?

* increased importance for "house" inert gases (asphyxiation hazard)

4) Retest or replace as required by the application (new PRVs tested by OEM)

- "functional" test for cracking and re-seal (minimize 1st pop effect)

  * repaired valves require re-test (will not maintain ASME rating)

- establish appropriate re-test or replacement schedule / dependent on:

  - relationship to MAWP and characteristics of the components being protected
  - correct selection of valve / corrosive or otherwise harsh application
  - does the valve actuate during normal operations? (example = cryo Dewars)

Pressure Relief Valves (PRVs) -
Require Periodic Evaluations for Continued Use

Evaluation - includes inspection, testing (cracking pressure measured / valve actuated), or replacement of PRVs at the intervals incorporated into the system Data Package.

Type of System Where Valve is Used	Evaluation Interval	Responsible Organization
Inert Gas, Dry Air	• Inspect annually (operate manually, if possible) • Test and tag every 3 years • or replace ?	• Line • Designated Test Station* • Line
High Pressure (greater than 3,000 psi)	• Inspect annually (operate valve manually if possible) • Test and tag every 2 years • or replace ?	• Line • Designated Test Station* • Line
Corrosive, Glutinous or Other Potentially Damaging Internal Gas or Fluid	• Inspect every 6 months • Test and tag every year • or replace ?	• Line • Designated Test Station* • Line
Harsh External Environment	• Inspect every 6 months • Test and tag every year • or replace ?	• Line • Designated Test Station* • Line

or alternate testing?

Guidance only! – user must select an appropriate interval

Regulator / PRV Sizing

Introduction of Flow Formula

Calculating PRV “**accumulated pressure**”

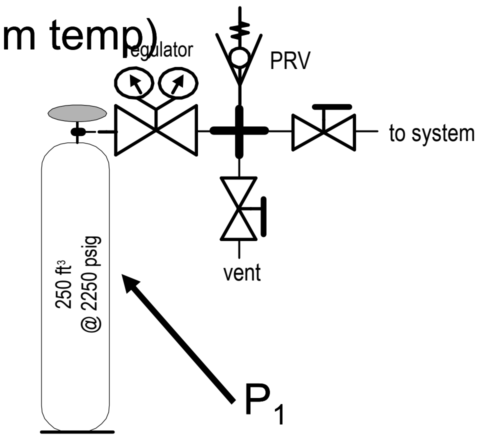
Step 1 = calculate flow through regulator

Step 2 = reference the PRV flow charts

Assumptions: (conservative approach = regulator fails full open)

Cylinder volume >> system volume & the cylinder is full (and at room temp)

For PRV sizing, always calculate for air (S_g = 1)



Most often applicable: Choked flow from the regulator where the inlet pressure is twice (or more) the outlet pressure

$$Q = 0.471 \times N_2 \times C_v \times P_1 \times \sqrt{\frac{1}{S_g \times T_1}}$$

* referenced from Swagelok Valve Sizing Technical Bulletin
- also listed in other suppliers notes / TESCOM, other

$$Q = 0.471 \times 22.67 \times C_v \times P_1 \times \sqrt{\frac{1}{1 \times 532}}$$

Simplified with combined constants and given values

$$Q = 0.4629 \times C_v \times P_1$$

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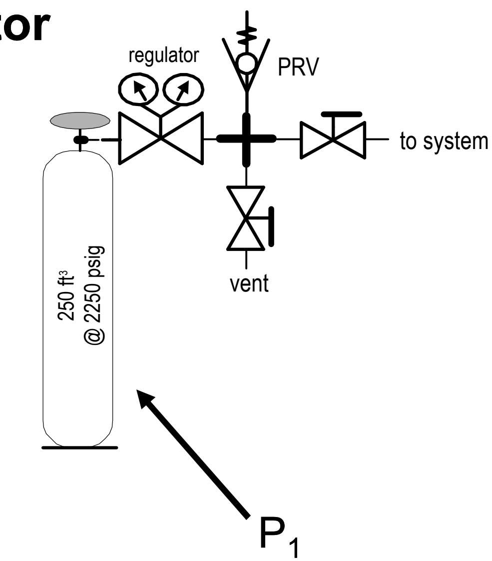
Regulator / PRV Sizing

System design vs evaluation of existing system

PRV sizing info
PRVs vs Burst disks

Step 1) Determine the maximum flow from the regulator

$$Q = 0.4629 \times C_v \times P_1$$



Example:

Q max = 52 scfm for a regulator with Cv = 0.05
and 2262.2 psia cylinder pressure

*** Common mistakes:**

1) Do not evaluate sizing by comparing the C_v of the regulator with the C_v of the PRV
2) Do not use the maximum "normal operational flow" from the regulator data sheet
   - the normal or "operational" flow for the above 0.05 Cv regulator = 10 scfm (not 52!)

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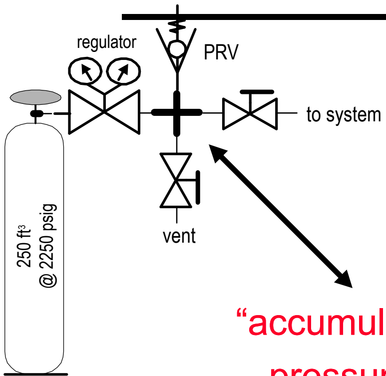
Regulator / PRV Sizing continued

*** Common mistake**

Do not "calculate" flow through the PRV (use the flow charts)



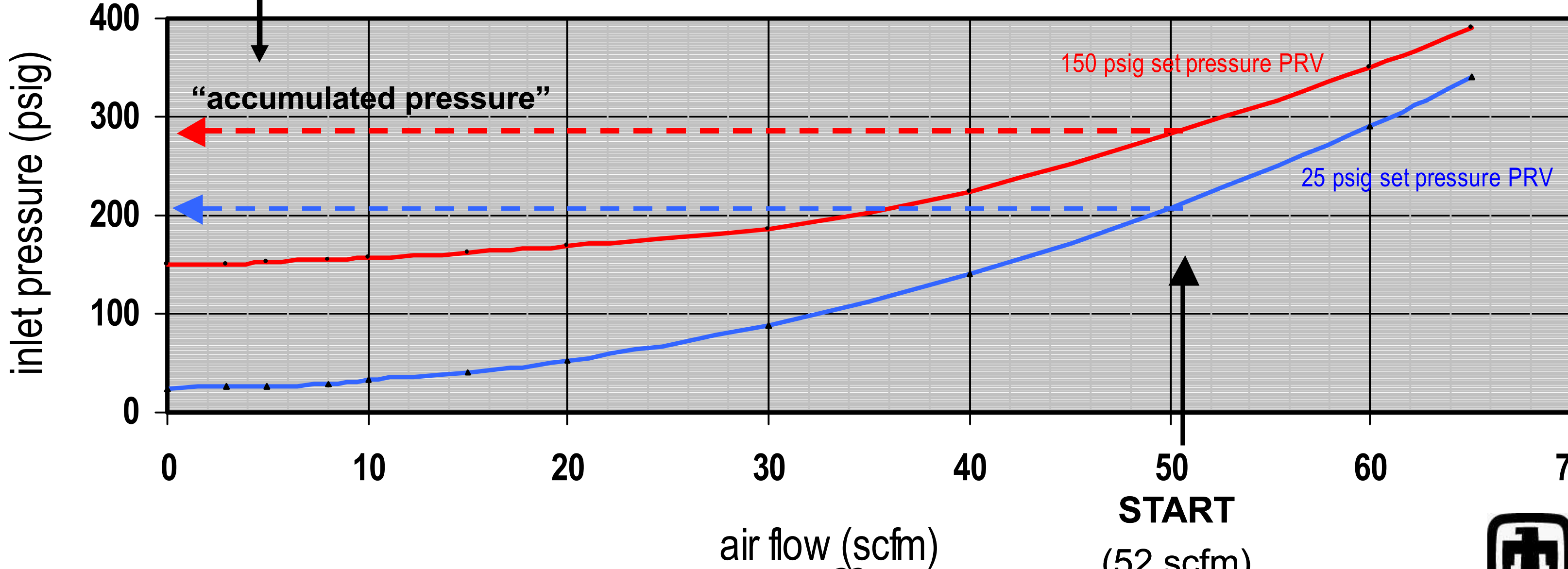
Step 2) Use the PRV flow charts to determine "accumulated pressure"

- find intersection of max flow line & set pressure flow curve
- for a set pressure of 25 psig, accumulated pressure = 208 psig !
- for a set pressure of 150 psig, accumulated pressure = 284 psig !

"accumulated pressure"

Example PRV Flow vs Pressure Chart

{this represents typical PRV flow characteristics}



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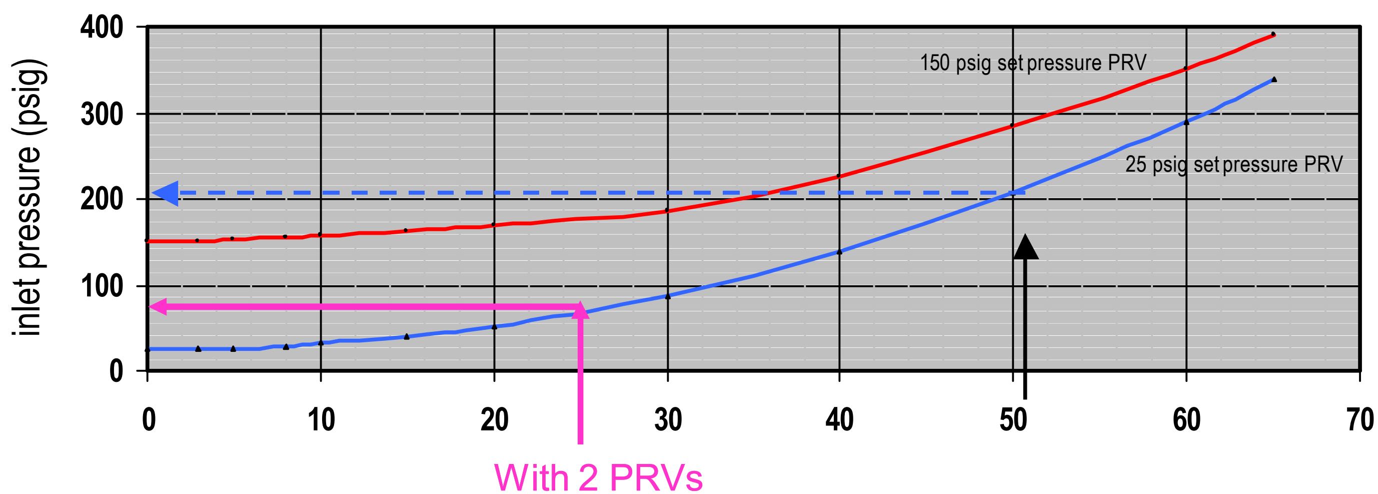
Regulator / PRV Sizing continued (Design recommendations & modifications)

3) If accumulated pressure is within system MAWP, design is adequate

4) If accumulated pressure > MAWP, there are several options:

a) Lower the maximum flow through the regulator / stay on the flatter portion of the PRV curve
- select a lower Cv regulator
- install a flow limitation (excess flow valve or Restrictive Flow Orifice)

b) select a higher flow PRV (or multiple PRVs or combine a PRV and Rupture disk)
- example: 2 PRVs would limit the accumulated pressure to around 70 psig



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Regulator / PRV Sizing continued

Manifold Design Options

Flow capacity concerns = data package
- regulator flow calculations
  - RFO / excess flow valve data
- accumulated pressure at the PRV

2) Higher flow PRV
Or
Multiple PRVs
Or
Combine PRV & rupture disk

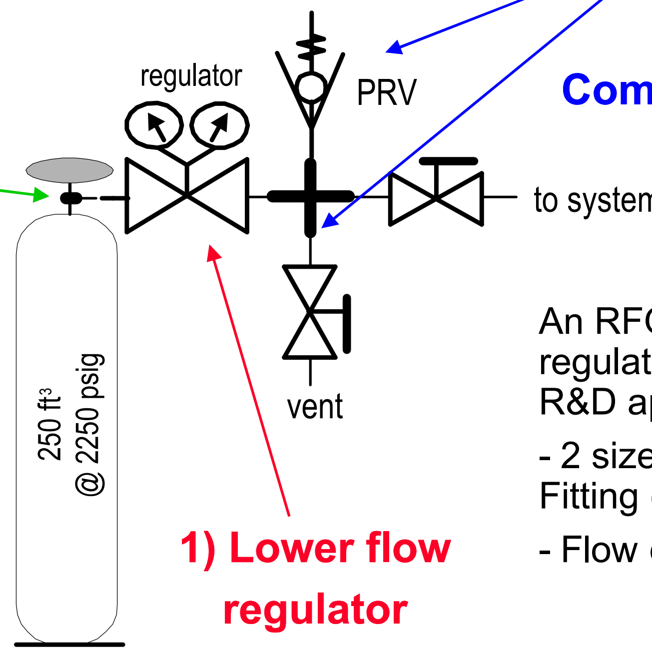
Dual benefit of limiting accidental releases of hazardous gases

3) RFO

This is frequently the best option

4) System automation?

Pressure transducer with auto shut-down



1) Lower flow regulator

An RFO on the up-stream side of the regulator is frequently recommended for R&D applications.

- 2 sizes available JIT from Alb Valve & Fitting (SS-4A-RFO-010 or -020) $36
- Flow data on the “Homepage”

Note – placing a flow restriction (RFO or excess flow valve) downstream of the regulator can cause accumulated pressure on the outlet side of the regulator & lead to gauge or diaphragm failure

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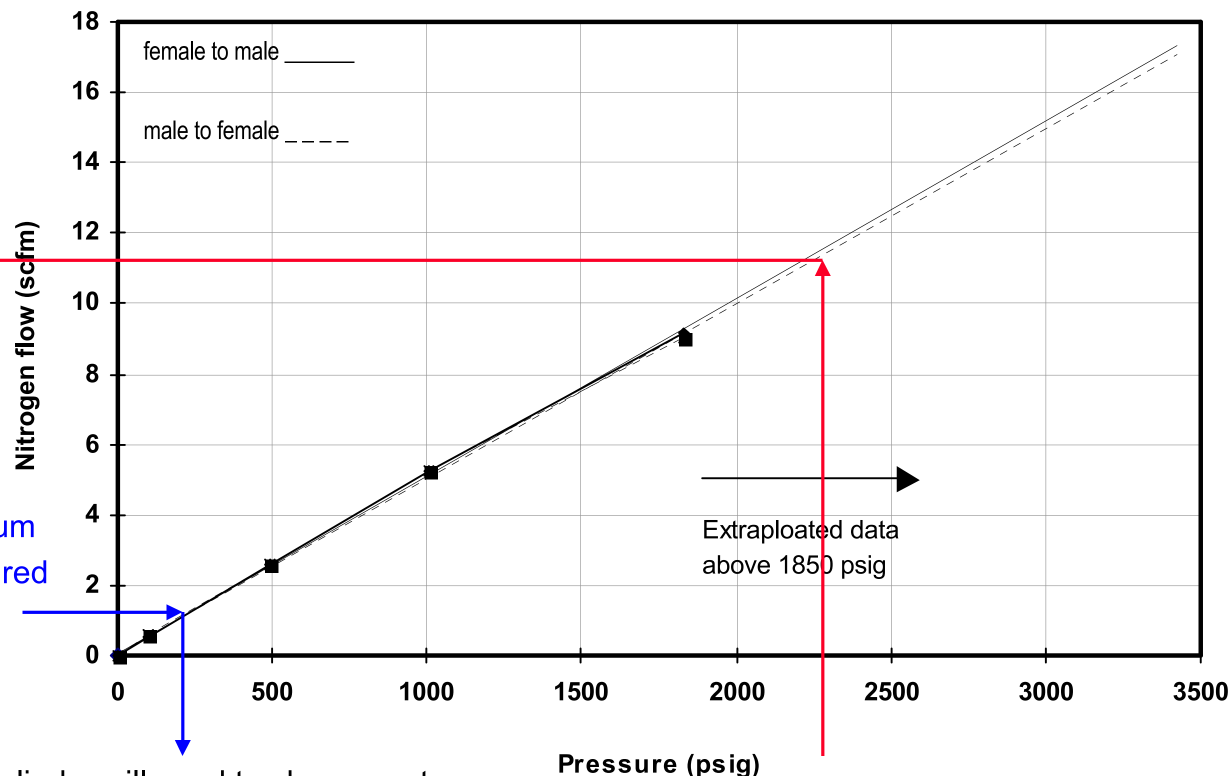
Regulator / PRV Sizing continued

Manifold Design Options – Example RFO Selection

RFO Flow Data / diameter = 0.020 inch
(part # SS-4-A-RFO-020)



Read the graph for max flow for the PRV
(rather than calculate for the regulator failure)

Read the graph for minimum cylinder pressure for required system flow.
Example = 3 scfm helium
(or 1.1 scfm nitrogen)

cylinder will need to change out at around 200 psig

$$Q_{sg} = Q_{nitrogen} \times \sqrt{\frac{1}{S_G}}$$

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Rupture Disks {sometimes called burst disks}

* a diaphragm-type component designed to rupture at a set pressure and protect a system from accidental over pressure

1) Harsh applications where PRV would fail
   - temperature dependent
2) Also good for UHV applications
   - all SS / welded
3) High flow capacity
4) Complete loss of system fluid
5) Fatigue / replacement interval
   - system pressure << burst pressure
   - reverse buckling style vs tension loaded
   - corrosive or other effects ?

Rupture Disks	vs	Relief Valves
do not re-close		opens and closes
higher flow capacity		lower flow capacity
	Set Pressure	
Less accurate		more accurate
No 1^{st} pop effect		1^{st} pop effect
Lower limits ?		lower set pressures
	Operating Pressure (O.P.)	
Burst psi >> OP		set psi near OP
	Maintenance	
replacement may be many years		more frequent test or replacements

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Vacuum System Applications
Special Concerns:

1) Vacuum Chambers

*** approved supplier vs SNL design**

- vacuum only or vacuum & pressure design
- approved supplier designs are accepted for use
- other designs: subject to testing

* **or**

- design / buckling strength analysis (PSAR)

adequate safety factor, safe materials, and
safe failure mode

Until a molecule, propelled by random collisions, enters the pumping mechanism of a pump, it *cannot* be removed from the chamber. The pump does not reach out, grab a molecule from the chamber, and suck it in. Grasping that basic fact makes all other aspects of vacuum easy to understand. So, the first principle of vacuum technology is:

Vacuum Doesn't Suck!

Buckling failure

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Vacuum System Applications Special Concerns: (continued)

Accidental overpressure concerns for: chambers, viewports, thin-wall bellows, feedthroughs, pumps, etc.

2) Protect from accidental overpressure from all pressure sources:
- vacuum only systems are not rated for internal pressure
  - * special concerns: viewports, feedthroughs, thin-walled bellows, etc.
- backfill or process gases
- chemical reactions
- cryogenics: cold traps / pumps / etc.
- cooling water and / or heat sources (steam)
- vacuum pumps: inlet vs exhaust / 3-phase motors

3) Relief Devices - ALARA (As Low As Reasonably Achievable)
- PRVs and rupture disks
  - * special sizing concerns
- gravity or vacuum closure hardware
- volume limitation
- do not depend on gauge readings (direct reading vs T.C. gauge)

4) Shield brittle materials (or require PPE)
- watch out for: scratches, thermal gradients (lasers), and pressure transitions (roughing or backfilling)

5) Pump concerns
- compatible with gas(es) pumped (oxygen, corrosive, etc.)
- hazardous residues (repair or salvage)

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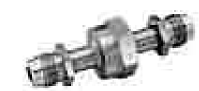
Vacuum PRVs & Rupture Disks

Get product details from the Homepage – under data Package Guidance

Rupture Disks for Vacuum Applications

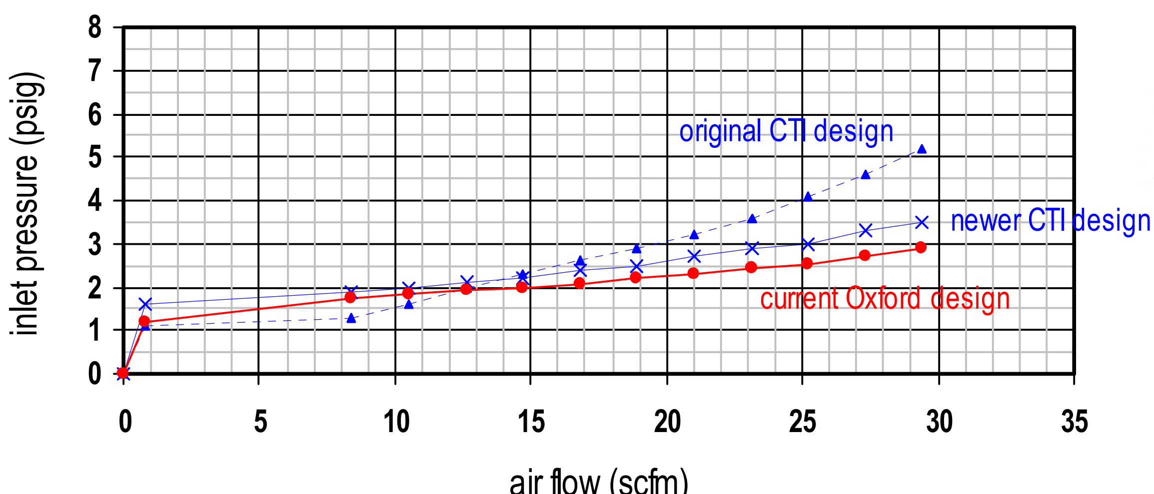
- burst pressure as low as possible
  (BS&B disk at 7 psig = TQA5-01889 on 1.33 mini conflat flange)
  * burst pressure can vary with rate of pressure rise or temp.
- all Stainless Steel / UHV compatible
- various standard vacuum connections



JIT from Alb Valve & Fitting
CW Series check / relief valve
Part # = 6L-CW4VR4
(1/4 male VCR connection)

PRV requirements for vacuum applications

- very low set pressure (from 2 to 5 psig are available)
- high flow capacity (minimal "accumulated" pressure)
- good leak integrity with standard vacuum connections



JIT from Scientific Sales
Part # = SSA-PRV-275

Special Pressure Safety Components

1) **Excess Flow Valves** – automatically closes when flow exceeds “trip point”
   - limit potential accidental release
     (hazardous gases, large volume inerts / house gases, etc.)
   - can reduce hose whipping hazards
   -or for PRV flow capacity consideration
   - **does not provide overpressure protection**

JIT Alb Valve
SS-XSF4M4-1

2) **RFOs (Restrictive Flow Orifice)**
   - to provide flow restriction / limitation
   - can be built into the cylinder valve or other
   - may affect normal flow / purge requirements

3) **System Automation** – reduce human error / repetitive operations
   - pneumatic (or solenoid?) valves with micro-processor controller
   - auto valves on the gas cylinder / or on system
   - remote actuation for high hazard applications
   - excess flow switches to prevent accidental releases
   - pressure sensors for high or low pressure set points
     - interface to gas detection, exhaust, remote emergency off, etc.

Hazard Mitigation (& good *pressure safety practices)*

PPE for appropriate activities (consult ES&H support team)

safety glasses / face shield, gloves, safety shoes, hearing protection, respiratory protection, fire extinguishers, etc.

Considerations for flex hoses (can present a whipping hazard)

- to accommodate relative motion / vibration isolation (not just for convenience)

What happens upon loss of utilities

- electrical power, cooling water, pneumatic air supply, etc.

Special considerations for "House" systems (large volume inert gas sources)

- large volume = asphyxiation hazard (Consult ES&H Support Team for hazards / monitoring)
  - accidental releases or normal operations (dry boxes, temp chambers venting into lab)
  - House nitrogen (gas phase) / use flow restriction (RFO or excess flow valve)
    also tie vents / PRVs etc. into exhaust (See the Homepage - Application Note 4)

Do Not leave liquid nitrogen valves open and unattended

Failures & Maintenance for Flexible Hoses

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

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

* 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

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

Solid tubing “pigtail” may be safer alternative

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