Hydrogen Safety Training for Researchers and Technical Personnel

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Project ID # SCS017

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Overview

Timeline

- Start date: **October 2007**
- End date: **Sept. 2013**
- Percent complete: **60%**

Barriers

- **H. Lack of H_2 knowledge**
- **I. Lack of H_2 training facilities**

Budget

- Total project funding
  - DOE: **$550k**
- Funding for FY10:
  - **$50k**
- Funding for FY11:
  - **$150k**

Partners

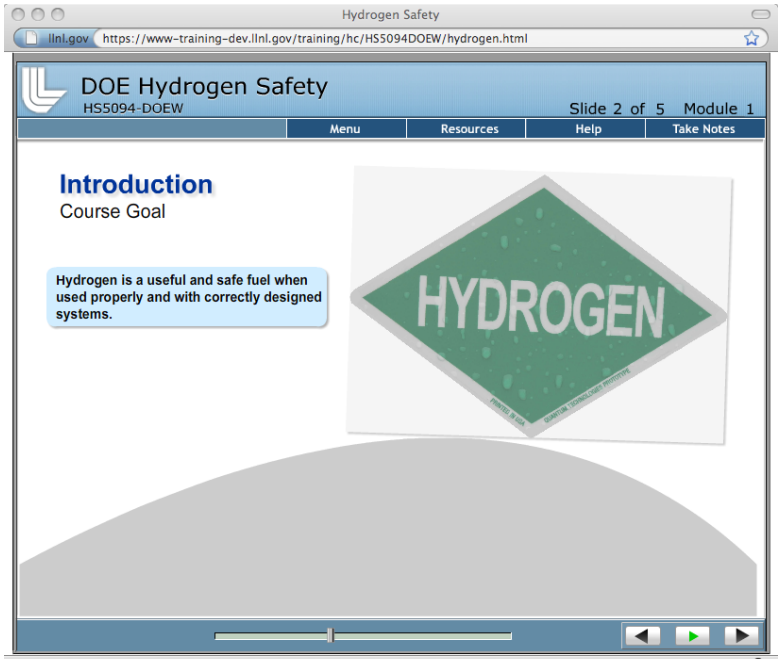
- **Detailed class peer review in collaboration with Hydrogen Safety Panel and Lab Safety Managers**

Relevance: Appropriate H_2 safety instruction is key to avoiding accidents

- ***Laboratory researchers*** ***handling small amount of hydrogen need basic information on pressure, cryogenics, flammability, asphyxiation, and other risks and precautions for using hydrogen***

- ***Technical personnel*** ***in charge of operations need comprehensive instruction on components, system design, assembly, and leak testing***

Approach: minimize risk of accidents & maximize productivity through improved knowledge of H_2 properties and procedures



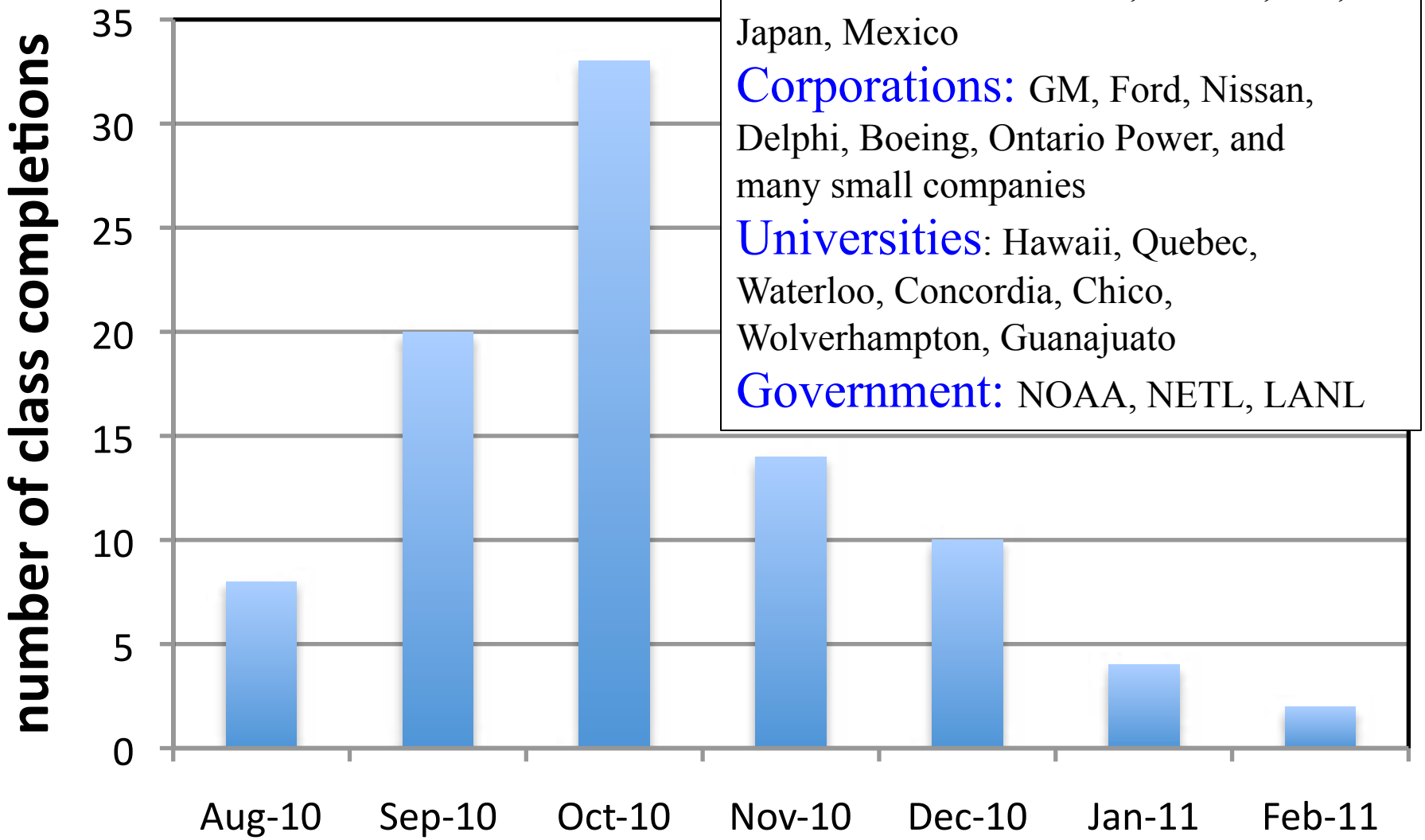
- ***Web-based class*** **(4 hours) developed for laboratory researchers handling hydrogen**

- ***Hands-on safety class*** **(3 days) developed for technical personnel in charge of designing, assembling, and testing H_2 systems**

Accomplishments: we have produced and peer reviewed a web-based hydrogen safety class for researchers

- Four hours long
- Six modules:
  - Introduction
  - Hydrogen properties
  - Pressure safety
  - Cryogenic safety
  - Emergency response
  - Codes and standards
- End of module quizzes (passing grade 85%)
- Web address: www.h2labsafety.org

We have registered ~100 class completions during the year, but face declining number of monthly completions



Five countries: USA, Canada, UK, Japan, Mexico

Corporations: GM, Ford, Nissan, Delphi, Boeing, Ontario Power, and many small companies

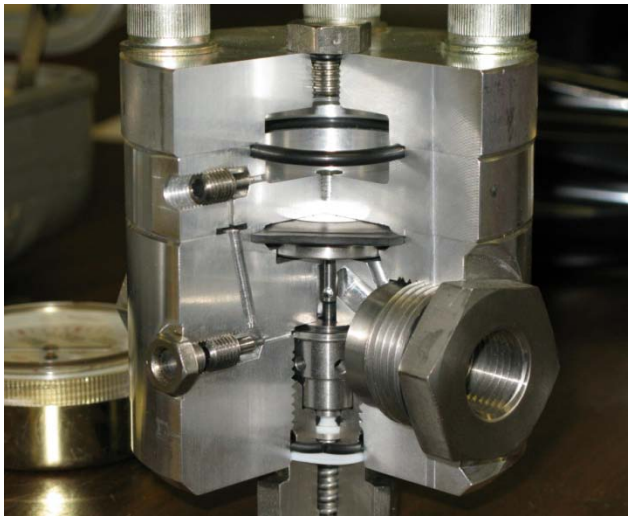
Universities: Hawaii, Quebec, Waterloo, Concordia, Chico, Wolverhampton, Guanajuato

Government: NOAA, NETL, LANL

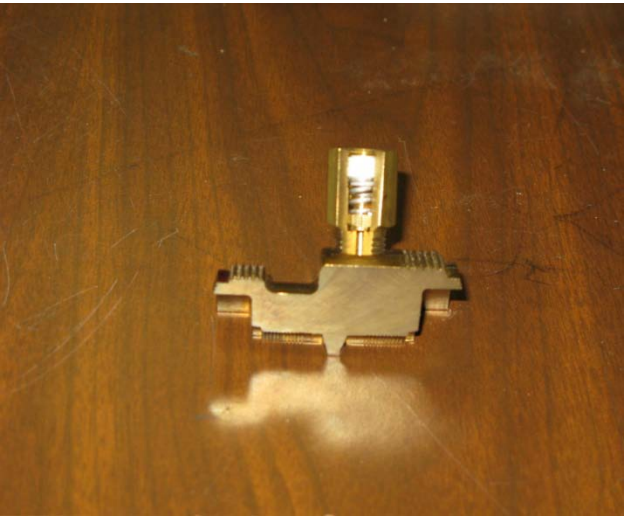
We are developing 3-day hands-on hydrogen safety class

Working board

pressure vessels



regulator



Relief device

pressure gauge

CGA fitting

First day: Classroom discussion on detailed component characteristics

1. Definitions
2. Hazards
3. Personal Protective Equipment (PPE)
4. Gas Cylinders
5. Gas Cylinder Manifold
6. Pressure Reducing Regulators
7. Gauges/Pressure Transducers
8. Regulator Safety Manifold
9. Relief Devices
10. Valves
11. Fittings
12. Tubing and Piping
13. Flash Arrestors
14. Quiz

First day: Classroom discussion on detailed component characteristics

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14. Quiz

Example: class materials for pressure reducing regulators

Pressure Reducing Regulators

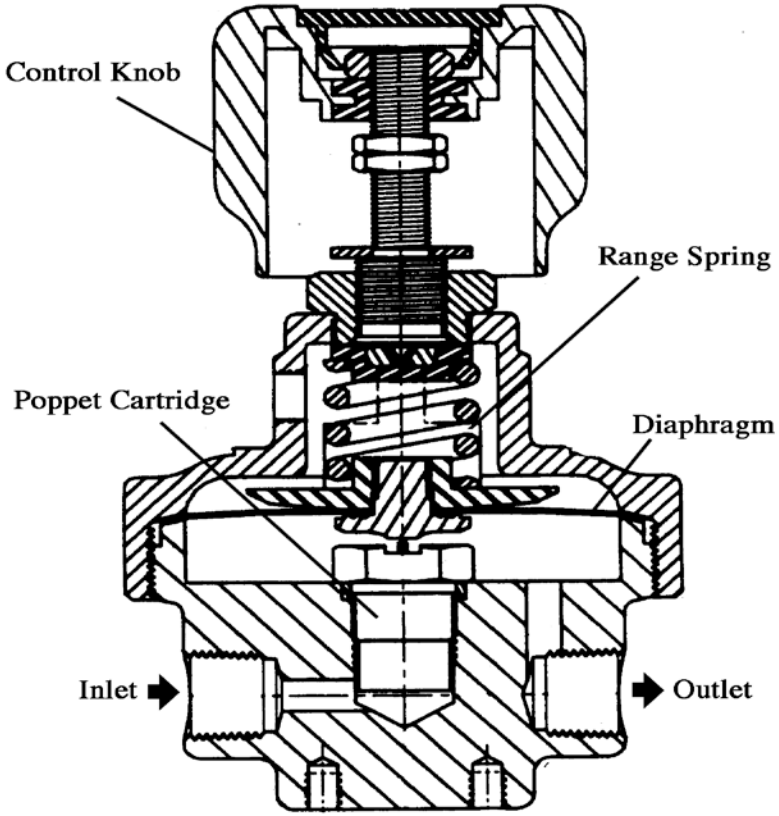
- Regulator Types
  - Single stage
  - Two-stage
  - Back pressure
  - Dome loaded

Pressure Reducing Regulators

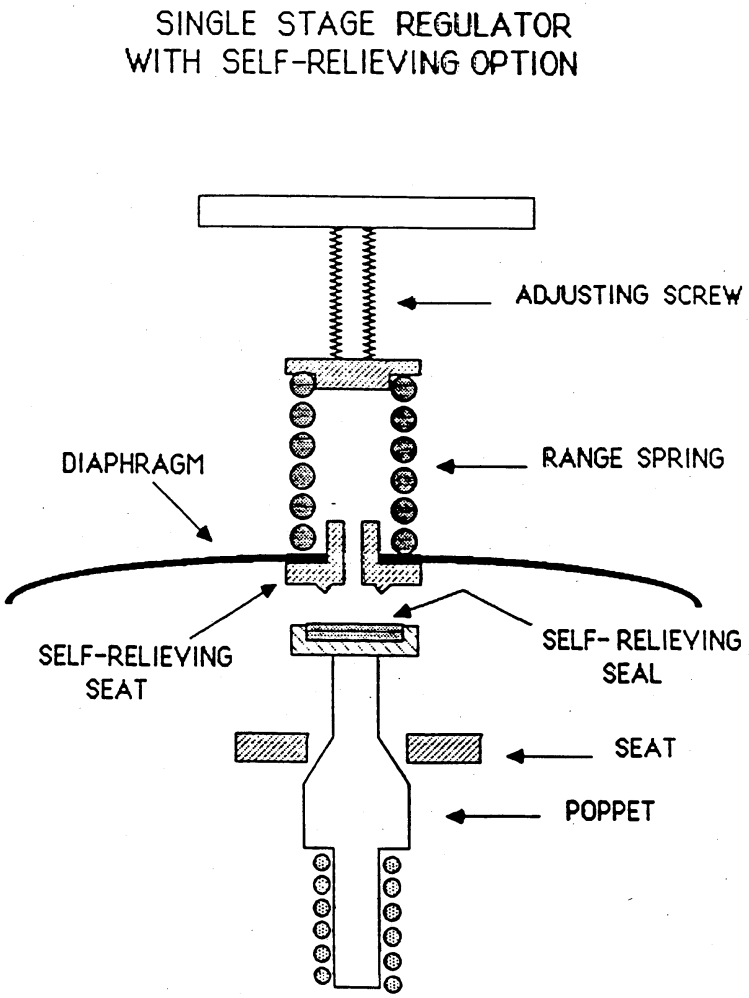
- Single Stage Regulator

  Two Typical Applications:

  - High Pressure
    - Manifold Regulator
    - High Flows
  - Low Pressure
    - Line Station Regulator
    - Low Flows



Pressure Reducing Regulators

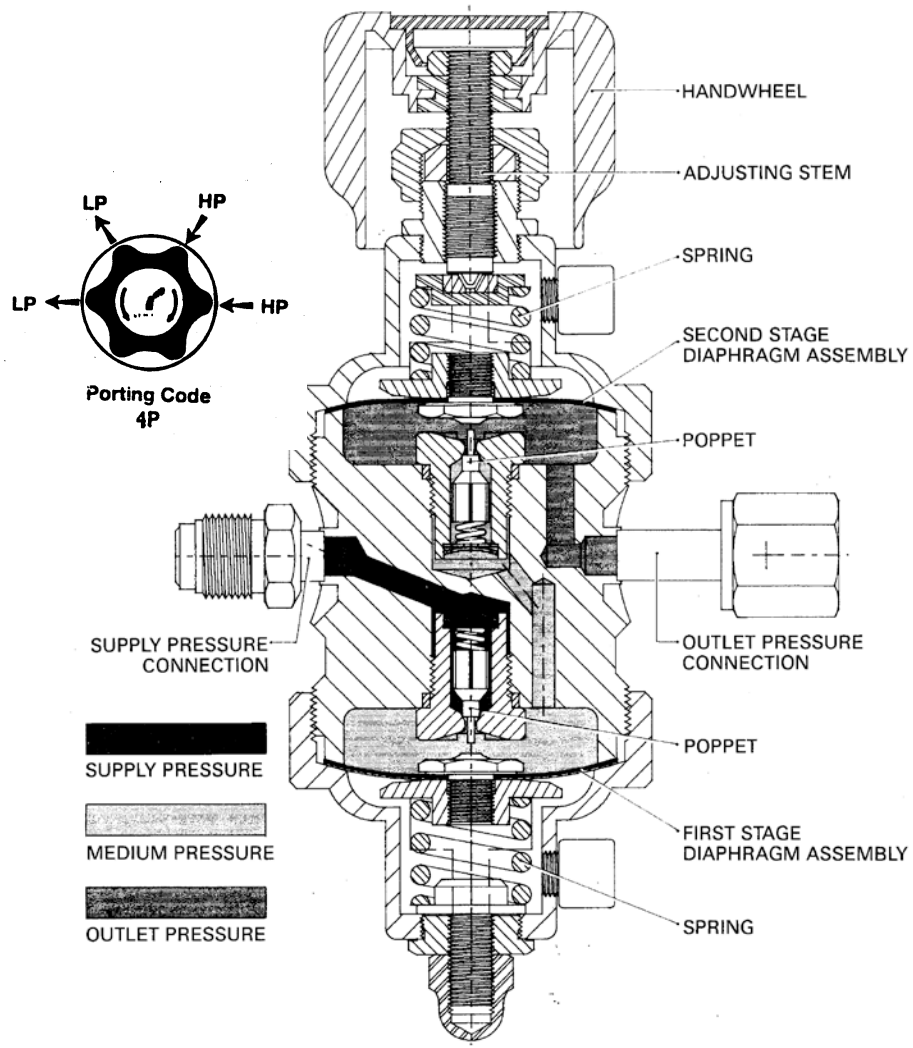


Pressure Reducing Regulators

- Two Stage Regulator

  Applications:

  - Precise Control
  - Lower Pressures
  - Lower Flows
  - Minimal Supply Pressure Effect

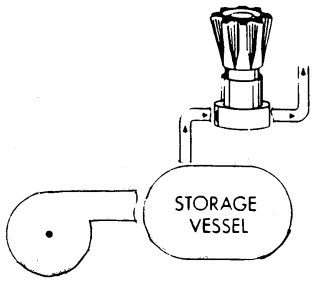


Pressure Reducing Regulators

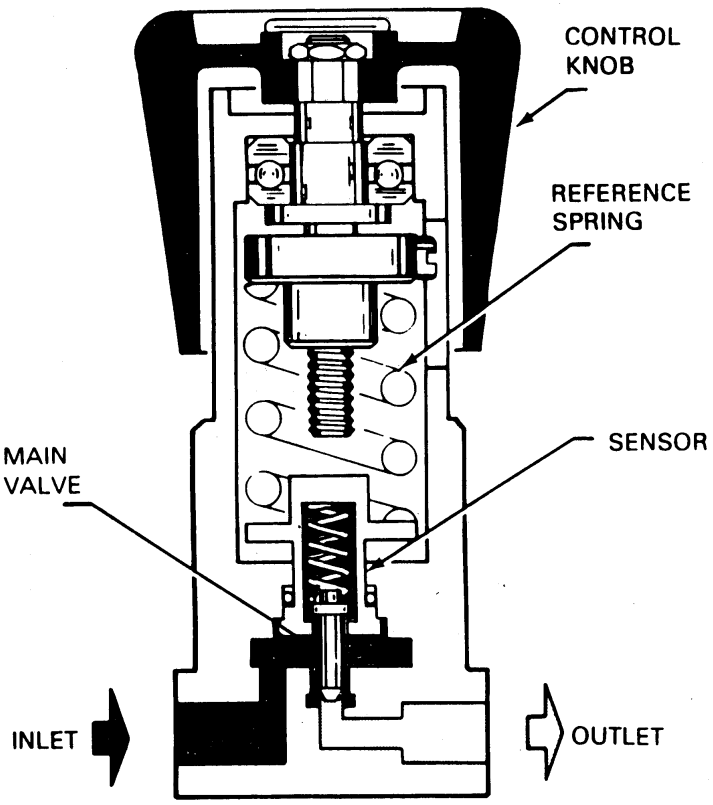
- Back Pressure Regulator

  Applications:

  - Controlling Pump Pressures
  - Fluid Sampling
  - Industrial Controls
  - Adjustable Relief for Test Consoles



VESSEL MOUNTED



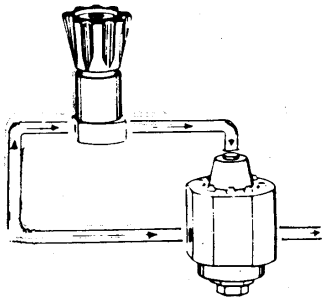
FUNCTIONAL SCHEMATIC

Pressure Reducing Regulators

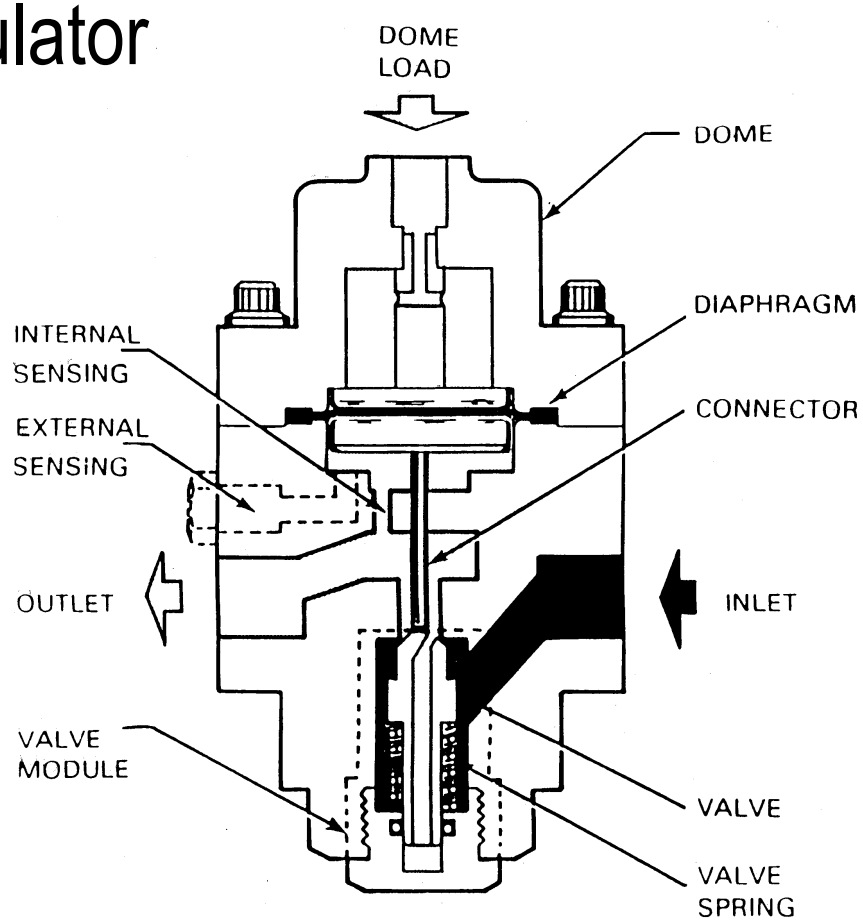
- Dome Loaded Regulator

  Applications:

  - High Pressure
  - High Flow Purge
  - Manifold Regulator
  - Test Consoles



LOADING DOME



Pressure Reducing Regulators

Cylinder Connection Listing

Gas	CGA Valve Outlet & Conn. No.
Acetylene	510
Air, Breathing	346
Air, Industrial	590*
Allene	510**
Ammonia, Anhydrous	705†
Ammonia, Electronic	660
Argon	580*
Argon–3500 psig	680***
Argon–6000 psig	677
Arsine	350/ 632
Boron Trichloride	660†
Boron Trifluoride	330†
1-3 Butadiene	510*
Butane	510*
Butenes	510*
Carbon Dioxide	320*
Carbon Monoxide	350*
Carbonyl Fluoride	660
Carbonyl Sulfide	330†
Chlorine	660**
Cyanogen	660
Cyanogen Chloride	660
Cyclopropane	510*
Deuterium	350*
Dichlorosilane	678
Dimethylamine	705†
Dimethyl Ether	510*

Gas	CGA Valve Outlet & Conn. No.
2-2 Dimethylpropane	510
Ethane	350*
Ethyl Chloride	300*
Ethylene	350*
Ethylene Oxide	510†
Fluorine	679
Germane	350
Halocarbon 12 (Dichlorodifluoromethane)	660*
Halocarbon 13 (Chlorotrifluoromethane)	660
Halocarbon 13B1 (Bromotrifluoromethane)	660
Halocarbon 14 (Tetrafluoromethane)	320*
Halocarbon 22 (Chlorodifluoromethane)	660*
Halocarbon 23 (Fluoroform)	660
Halocarbon 114 (2,2 Dichlorotetrafluoroethane)	660*
Halocarbon 115 (Chloropentafluoroethane)	660*
Halocarbon 116 (Hexafluoroethane)	660
Halocarbon 142B (Chloro-1,1-Difluoroethane)	510

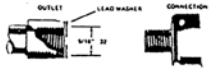
Gas	CGA Valve Outlet & Conn. No.
Halocarbon 1113 (Chlorotrifluoroethylene	510
Helium–3500 psig	680***
Helium	580*
Hexafluoropropylene	660*
Hydrogen	350*
Hydrogen–3500 psig	695***
Hydrogen Bromide	330†
Hydrogen Chloride	330**
Hydrogen Fluoride	660†
Hydrogen Iodide	330†
Hydrogen Selenide	350
Hydrogen Sulfide	330**
Isobutane	510*
Isobutylene	510*
Krypton	580
"Manufactured Gas B"	350
Methane	350*
Methyl Bromide	330
3-Methyl Butene-1	510
Methyl Chloride	660*
Methyl Fluoride	350
Methyl Mercaptan	330**
Monomethylamine	705†
Neon	580*
Nitric Oxide	660
Nitrogen	580*
Nitrogen–3500 psig	680***

Gas	CGA Valve Outlet & Conn. No.
Nitrogen–6000 psig	677
Nitrogen Dioxide	660
Nitrogen Trioxide	660
Nitrous Oxide	326*
Octofluorocyclobutane	660*
Oxygen	540*
Oxygen Mixtures Over 23%	296
Perfluoropropane	660*
Phosgene	660
Phosphine	350/ 632
Phosphorus Pentafluoride	660†
Propane	510*
Propylene	510*
Silane (High Pressure)	350/ 632
Silicon Tetrafluoride	330†
Sulfur Dioxide	660**
Sulfur Hexafluoride	590*
Sulfur Tetrafluoride	330†
Trimethylamine	705†
Vinyl Bromide	510
Vinyl Methyl Ether	510
Xenon	580**

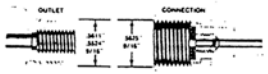
*Lecture bottles use CGA No. 170 †Lecture bottles use CGA No. 180 **Lecture bottles use CGA No. 11(

All drawings are arranged in numerical order according to the valve connection number. The accurate diameter of the valve outlet is given below each drawing along with the thread designation. For ease of measurement and identification, approximate fractional dimensions may be found on each drawing.

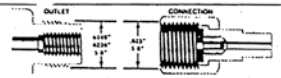
The left hand portion of each drawing marked "OUTLET" represents the cylinder valve, while the right hand portion marked "CONNECTION" represents the mating connection normally found in regulators, control valves, and manifolds.



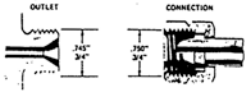
CONNECTION 110
LECTURE BOTTLE OUTLET—CORROSIVE GASES
5/16"-32 RH INT. using Flat Seat with Washer



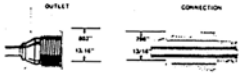
CONNECTION 170
LECTURE BOTTLE OUTLET—NON-CORROSIVE GASES
9/16"-18 RH EXT. and 5/16"-32 RH INT. using Flat Seat with Washer



CONNECTION 180
LECTURE BOTTLE OUTLET—CORROSIVE GASES
5/8"-18 RH EXT. and 5/16"-32 RH INT. using Flat Seat with Washer

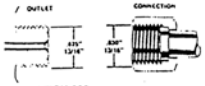


CONNECTION 290
.745"-14 LH EXT. accepting a Bullet Shaped Nipple

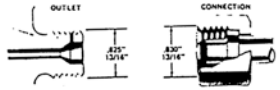


CONNECTION 296
.803"-14 RH INT. accepting a Bullet Shaped Nipple

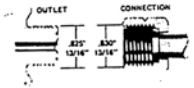
Cylinder Connection Listing



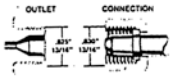
CONNECTION 320
.825"-14 RH EXT. used with Flat Seat and Washer



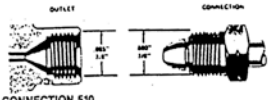
CONNECTION 326
.825"-14 RH EXT. accepting a Round Shaped Nipple



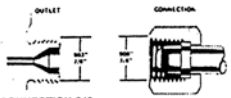
CONNECTION 330
.825"-14 LH EXT. used with Flat Seat and Washer



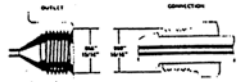
CONNECTION 350
.825"-14 LH EXT. accepting a Round Shaped Nipple



CONNECTION 510
.885"-14 LH INT. accepting a Bullet Shaped Nipple



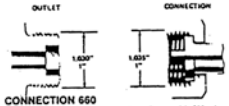
CONNECTION 540
.903"-14 RH EXT. accepting a Round Shaped Nipple



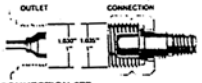
CONNECTION 580
.965"-14 RH INT. accepting a Bullet Shaped Nipple

CONNECTION 590
.965"-14 LH INT. accepting a Bullet Shaped Nipple

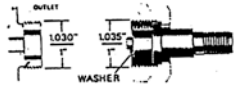
CONNECTION 632
1.030"-14 NGO RH EXT. With Washer and Wire Clip.



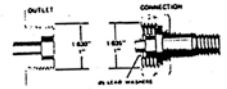
CONNECTION 660
1.030"-14 RH EXT. using Flat Seat with Washer



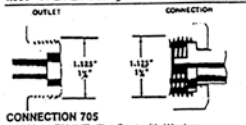
CONNECTION 677
1.030"-14 LH EXT. accepting a Round Shaped Nipple



CONNECTION 678
1.030"-14 LH EXT. (Short Nipple) using Flat Seat with Washer



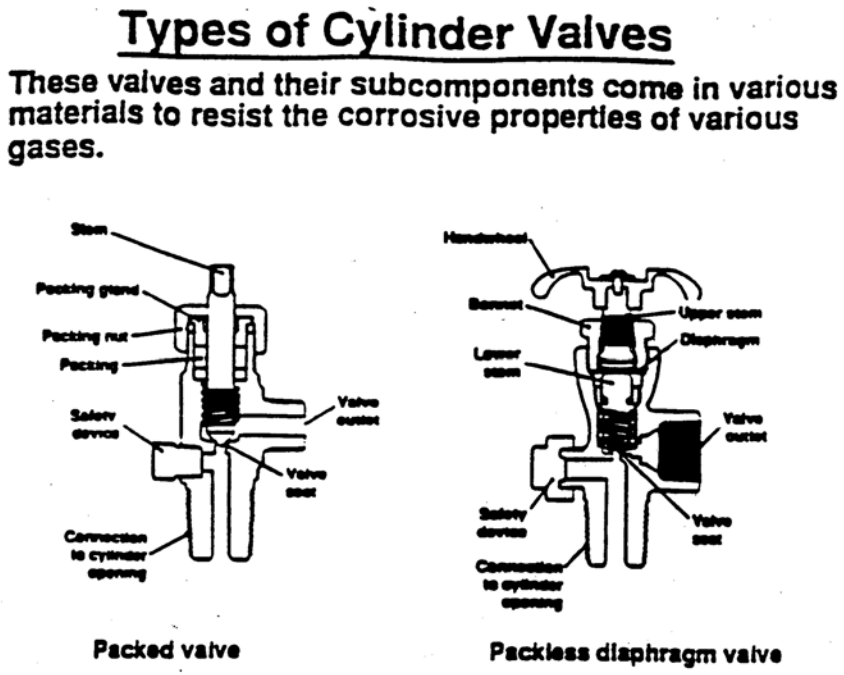
CONNECTION 679
1.030"-14 LH EXT. using Small Flat Seat with Washer



CONNECTION 705
1.125"-14 RH INT. Flat Seat with Washer

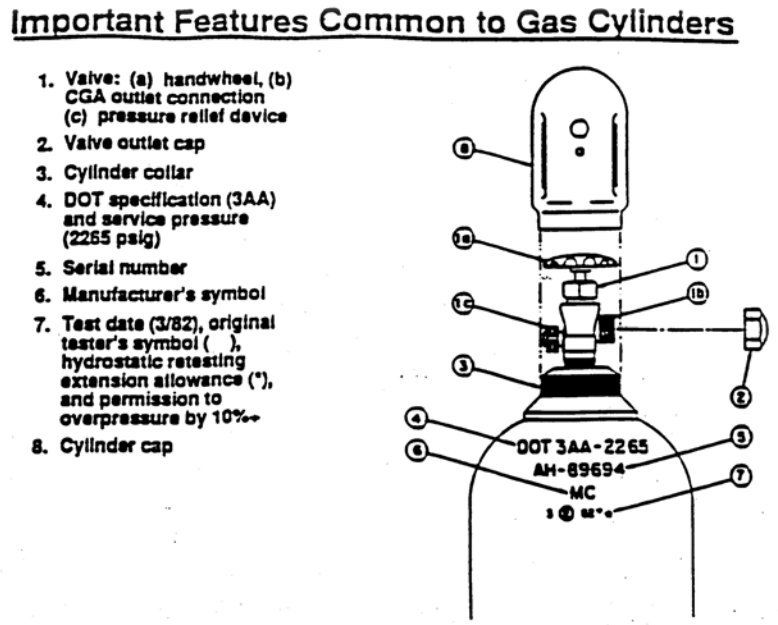
Pressure Reducing Regulators

- Cylinder Relief Devices
  - Type:
    - Spring loaded
    - Frangible disc
    - Fusible plug
    - Frangible disk backed by fusible metal
    - No relief device
  - Use:
    - propane, mapp gas
    - CO_2, N_2, O_2, argon, He
    - acetylene, chlorine
    - hydrogen, methane
    - arsine, fluorine, phosgene



Pressure Reducing Regulators

- Compressed Gas Cylinder Handling
  - DOT cylinder identification
  - *,+, Hydro test date
  - Cylinder status tag
  - Use proper discharge controls
  - Keep cylinders away from heat



Pressure Reducing Regulators

- Always
  - Read the shoulder label on the cylinder, verify gas
  - Select the proper regulator for the gas being used
  - Secure the cylinder before installing the regulator
  - Inspect the cylinder valve and regulator for damage

Pressure Reducing Regulators

- Always (continued)
  - Make sure the cylinder valve and regulator connections are free of dirt, oil, grease, and foreign material
  - Close the regulator by turning the pressure control knob counterclockwise until the knob turns freely without tension before opening the cylinder valve
  - Open the cylinder valve slowly

Pressure Reducing Regulators

- Never
  - Use a damaged regulator
  - Adjust, remove, or plug relief devices
  - Change CGA or inlet connection
  - Lubricate any part of the regulator or cylinder valve

Pressure Reducing Regulators

- Never (continued)
  - Force threaded connections
  - Stand in front of the regulator while opening the cylinder valve
  - Attempt to perform any type of repair to the regulators, consult an authorized repair shop

Pressure Reducing Regulators

- Glossary
  - Droop
    - This is the amount of outlet pressure decrease with respect to increasing flow demand on a pressure reducing regulator. It can be expressed in percentage change of the set point or can be shown as pounds per square inch change with respect to flow increases
  - Lockup
    - This is the amount of outlet pressure increase beyond the set pressure with respect to decreasing flow demand on a pressure reducing regulator.
  - Critical Flow
    - This is also sometimes referred to as sonic flow and is the maximum flow which can pass through a regulator or an orifice

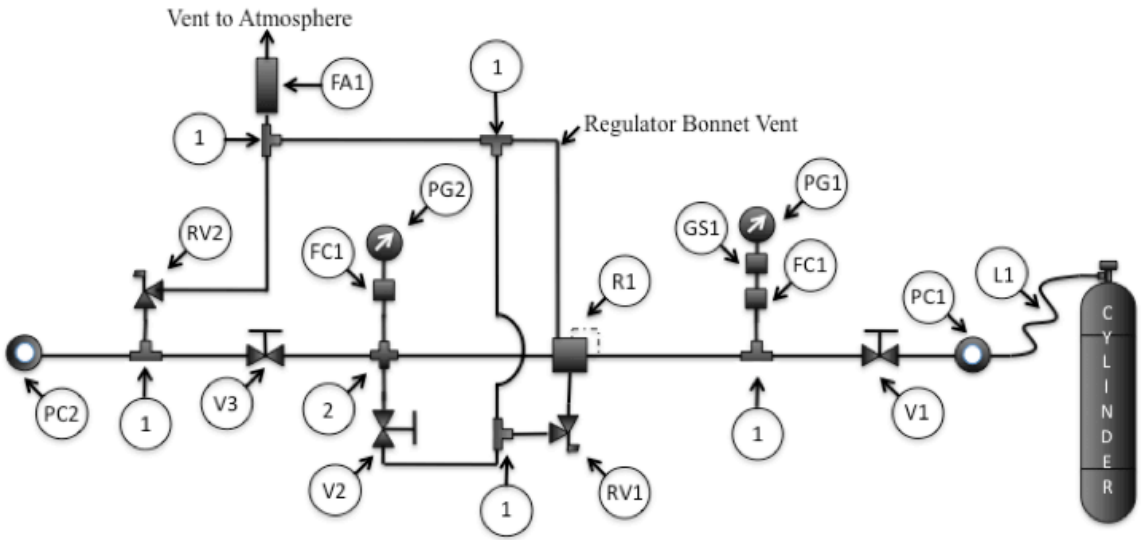
Pressure Reducing Regulators

- Glossary (continued)
  - Creep
    - This is an increase in outlet pressure occurring after lockup. Creep normally appears as a gradual rise in outlet pressure over a period of time. The usual cause of creep is contamination in the regulator seat causing the regulator to remain slightly open henceforth additional outlet pressure.
  - Bubble Tight Shutoff
    - Determined by connecting the outlet of a regulator with a piece of tubing and submerging the end under an inch or two of water. With inlet pressure applied and the regulator in an off condition, there should not be any bubbles within a time period of one minute. This constitutes “Bubble Tight Shutoff”.
  - Set Point
    - This is the control point desired for operation of a regulator.

Pressure Reducing Regulators

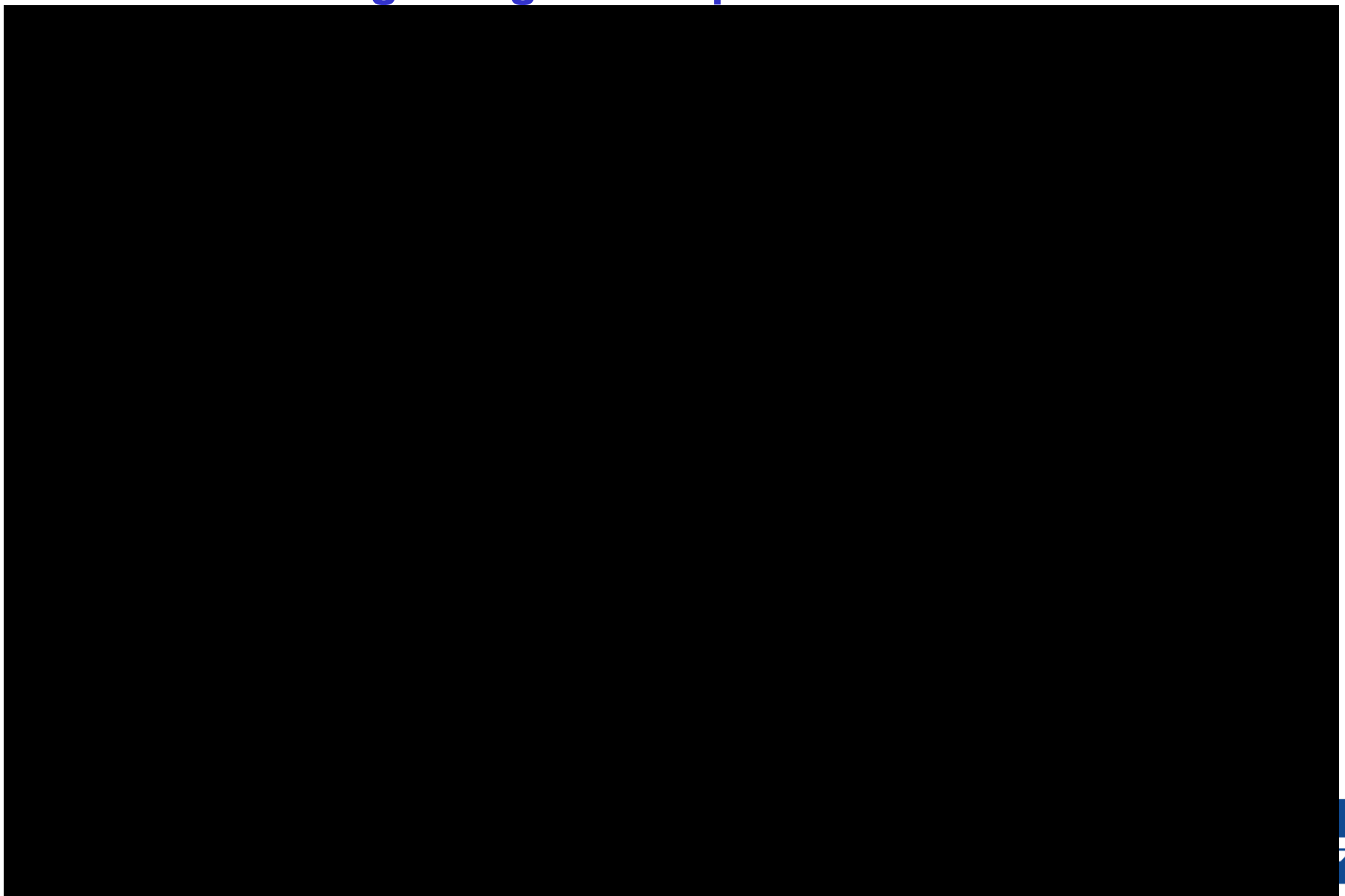
- Glossary (continued)
  - CGA Fittings
    - Compressed Gas Association (CGA) is the group that has established standards in the gas industry for fittings which are used to attach to gas cylinders.
  - DIN Fittings
    - Deutsches Institut für Normung (DIN), English translation would be German Industrial Standard. The DIN system was developed by Germans and is used in Europe.
  - Coefficient of flow (C_v)
    - For a valve is the volume of water in U.S. gallons per minute at room temperature…which will flow through the valve with the stem fully open…with a pressure drop of 1 psi across the valve. C_v is the valve sizing factor that permits selection of the appropriate valve to meet the flow requirements of a given fluid system.

Second day: assemble pressure system described in engineering safety note

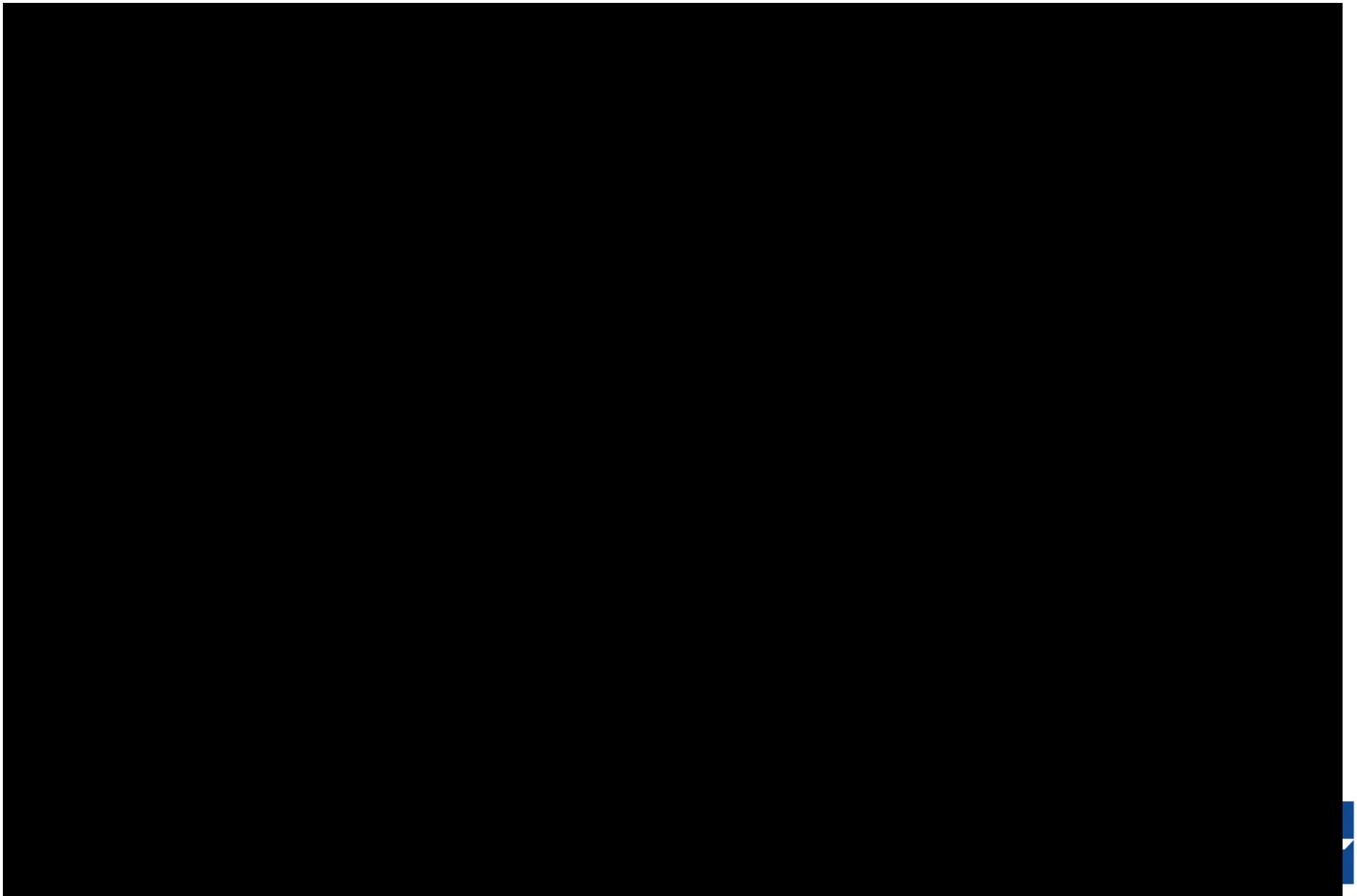


Line Item	Manufacturer	Description	Part #	M A W P
1	Swagelok	Tee Fitting Quarter Inch	SS-400-3	7000 PSIG
2	Swagelok	Union Cross	SS-400-4	7000 PSIG
PC1-PC2	Swagelok	Bulkhead Union	SS-400-61	7000 PSIG
PG1	Swagelok	Gauge 5000 PSIG	PGI-83C-PG5000-CAOX	5000 PSIG
PG2	Swagelok	Gauge 400 PSIG	PGI-83C-PG400-CAOX	400 PSIG
R1	Swagelok	Single Stage Regulator	KPR1GRH412E6000 0 Flow Coefficient .06	3600 IN 250 OUT PSIG
RV1	Swagelok	Relief Valve	KVV11DL1 Flow Coefficient .1	Set at 300 PSIG
RV2	Swagelok	Relief Valve	SS-4R3A Flow Coefficient .16	Set at 250 PSIG
V1	Swagelok	Needle Valve	SS-1VS4	5000 PSIG
V2-V3	Hoke	Needle Valve	D371264Y	5000 PSIG
GS1	Swagelok	Gauge Snubber	SS-4-SA-EG	6600 PSIG
FC1	Swagelok	Female Connector	SS-400-7-4	6600 PSIG
Misc	Swagelok	SS Tubing ¼ " X .049 Wall	Seamless	7000 PSIG
L1	Western Enterprises	350 CGA Pigtail 580 CGA Pigtail	PH83CV PH92CV	3000 PSIG
FA1	Matheson Tri-Gas	Flash Arrestor	6103A	50 PSIG

Second day: video illustrates planning, component installation, tube cutting and bending, compression fittings, and leak testing using mass spectrometer leak detector



Third day: video illustrates data acquisition setup, pressure test, leak test at MAWP, and system operation



Future work: maintain web-based class and complete hands-on class

- ***Maintain and continuously improve web-based class*** **by collecting comments and suggestions and incorporating them into the class**
- ***Complete preparation of hands-on class*** **by developing student's workbooks, class notes, reference materials, and work tables.**
- ***Peer review hands-on class*** **by inviting members of the safety panel and other H_2 safety experts to review class materials, class activities, facilities, and teaching approach**
- ***Teach hands-on class.*** **We envision 3-day sessions with up to 6 students. Instruction at other institutions possible if appropriate facilities exist**

Collaborations

- **Extensive peer review (two rounds of reviews and 40 pages of comments) conducted by the Hydrogen Safety Panel and the Laboratory Safety Managers.**

- **We look forward to collaborating with the hydrogen community for continuously improving class materials**

Summary

- *We are contributing to safe hydrogen operations* by developing instructional materials for researchers and operators
- *Web-based class* (now complete) addresses the need of laboratory researchers handling small amounts of hydrogen www.h2labsafety.org
- *Hands-on class* (in process) will present in-depth information for technical personnel tasked with installing and testing hydrogen systems
- *Participation from the hydrogen community* will improve the class through suggestions, bug reports, etc.