Safety Meeting

Making high pressure connections and related safety considerations

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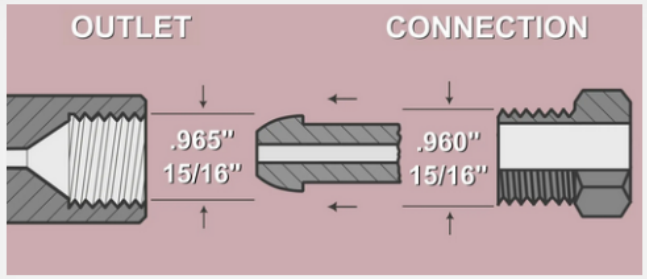
Connections to gas cylinders - CGA

Compressed Gas Association fittings

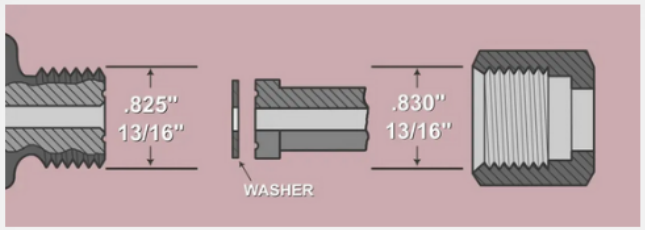
- Designed, in most cases, to create a metal-to-metal seal between the cylinder valve and the nipple
- Nuts and nipples must both be matched to the type of valve (e.g. CGA 580)
- CGA fittings are designed to prevent you from making mistakes by using different thread pitches, reverse threads, nipple sizes etc. Incompatible fittings will not work with one another.
- If a connection is leaking, there is something wrong with the connection
- **Do NOT use Teflon tape on CGA fittings, EVER!**



CGA 580 Inlet Connection

Suitable for: Argon, Helium, Krypton, Neon, Nitrogen, Tetra Fluoro Methane, Trichloroethylene, Xenon
Thread Standard: .965-14NGO-RH

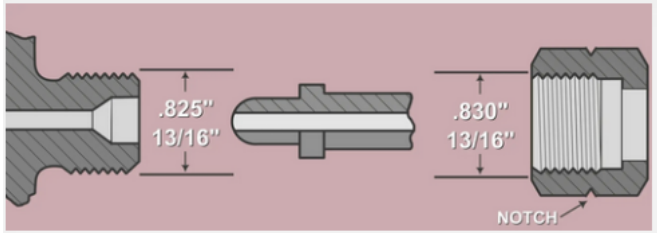
Standard cylinder valve outlet connection for pressures up to 3000 psig (20,680 kPa) FOR ABOVE GASES.



CGA 320 Inlet Connection

Suitable for: Carbon Dioxide, some gas mixtures - see CGA V-7 for further reference.
Thread Standard: .825-14NGO-RH (Flat Nipple)

Standard cylinder valve outlet connection for pressures up to 3000 psig (20,680 kPa) FOR CARBON DIOXIDE.

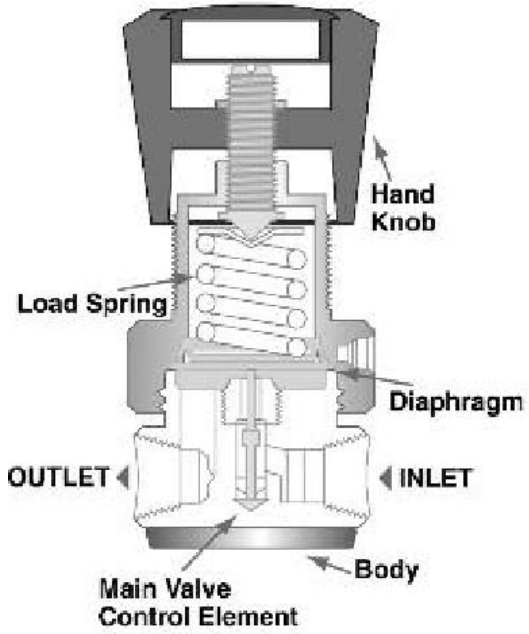


CGA 350 Inlet Connection

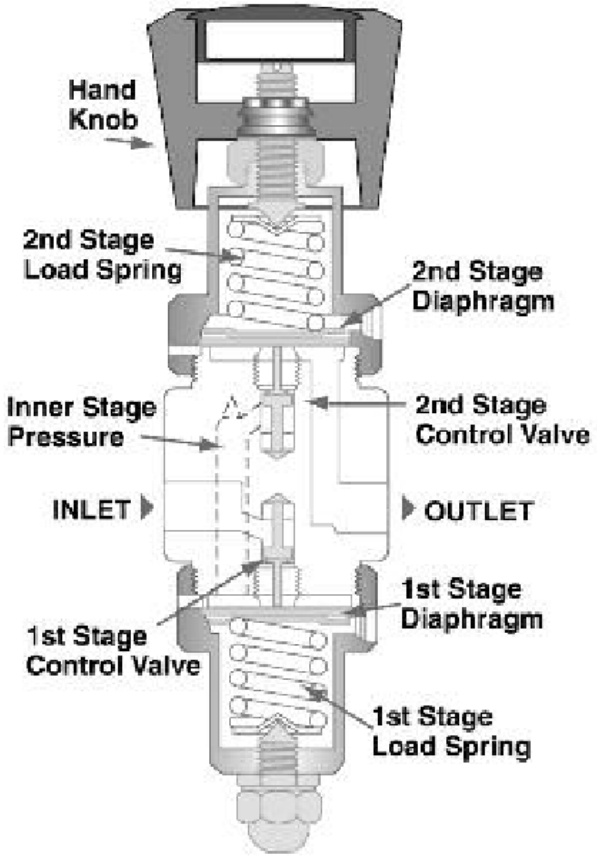
Suitable for: Arsine, Carbon Monoxide, Deuterium, Deuterium Selenide, Diborane, 1,1 Difluoroethylene, Ethane, Ethylene, Germane, Hydrogen, Hydrogen Selenide, Methane, Methyl Fluoride, Methylene Fluoride, Natural Gas, Pentaborane, Perfluorobutadiene, Phosphine, Silane, Stibine, Tetrafluoroethylene, Vinyl Fluoride.
Thread Standard: .825-14NGO-LH (Large Round Nipple)

Regulators

- Single Stage Regulators – Single step reduction of source to outlet pressure.
  - Must be monitored, as supplied pressure will vary as source pressure in a cylinder decreases
- Dual Stage regulators – Reduce source pressure in two steps, with the first stage dropping the pressure to about 3x the maximum working pressure.
  - Deliver nearly constant pressure, even with a decrease in inlet pressure
- General Purpose vs. High Purity
- SS vs. Brass – for chemical compatibility
- Regulator range (some common ranges):
  - 0-15 PSI
  - 0-30 PSI
  - 0-125 PSI
  - 0-250 PSI
  - 100-1500 PSI
  - 100-2500 PSI
- Check that the regulator range is appropriate for the task and **never replace the delivery pressure gauge on a regulator with one of a different range!**



Single stage regulator



Dual stage regulator

Pressure connections

- Low pressure – pressure up to 15,000 psi (1034 bar)
  - Swagelok gaugable tube fittings
  - Autoclave Engineers “Speedbite” fittings
  - HiP “Taper Seal” fittings (use ‘A’ designator)
  - Valco compression fittings
  - All NPT fittings
- Medium pressure – pressure up to 20,000 psi (1379 bar)
  - Autoclave Engineers Medium Pressure cone & thread
  - HiP Medium Pressure line (use ‘L’ designator)
  - Haskel/Butech “M/P” (uncommon)
  - Swagelok FK and IPT series (Very uncommon)
- High pressure – pressure up to 60,000 psi (4140 bar)
  - Autoclave Engineers High Pressure cone & thread
  - HiP High pressure line (use ‘H’ designator)
  - Haskel/Butech “H/P” (uncommon)
  - Swagelok Sno-Trik series (Very uncommon)
- Ultra High pressure – up to 150,000 psi (10350 bar)
  - Autoclave Engineers Ultra High Pressure cone & thread
  - HiP High pressure line

Assembly of Valco “internal” fittings

1. Prepare tubing
    1. Cut square with tube axis using sharp tube cutter appropriate to the task
    2. Thoroughly deburr ID and OD with deburring tool
    3. Inspect end of tubing where ferrule will seat for scratches
    4. Polish tubing to remove any scratches by rolling tubing in high grit wet/dry sandpaper (~400 grit) – polish radially, not axially!
2. Slide nut and ferrule onto tubing as shown
3. Push tubing all the way into fitting so that it seats firmly
4. Tighten until “finger tight”
5. Turn the tubing ¼ turn (90°) past the point where the ferrule starts to grab the tubing

FIGURE 1: Parts of a VICI Valco fitting

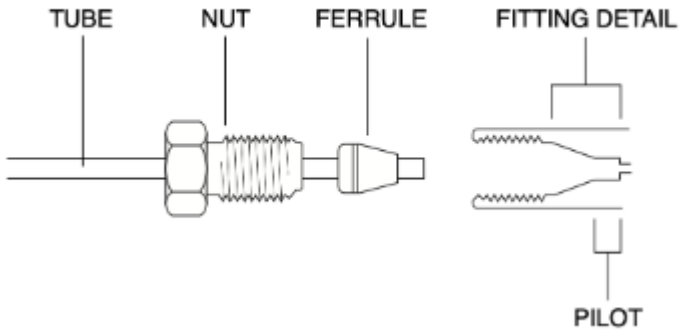
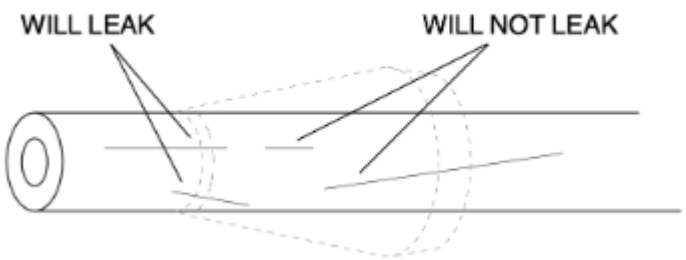
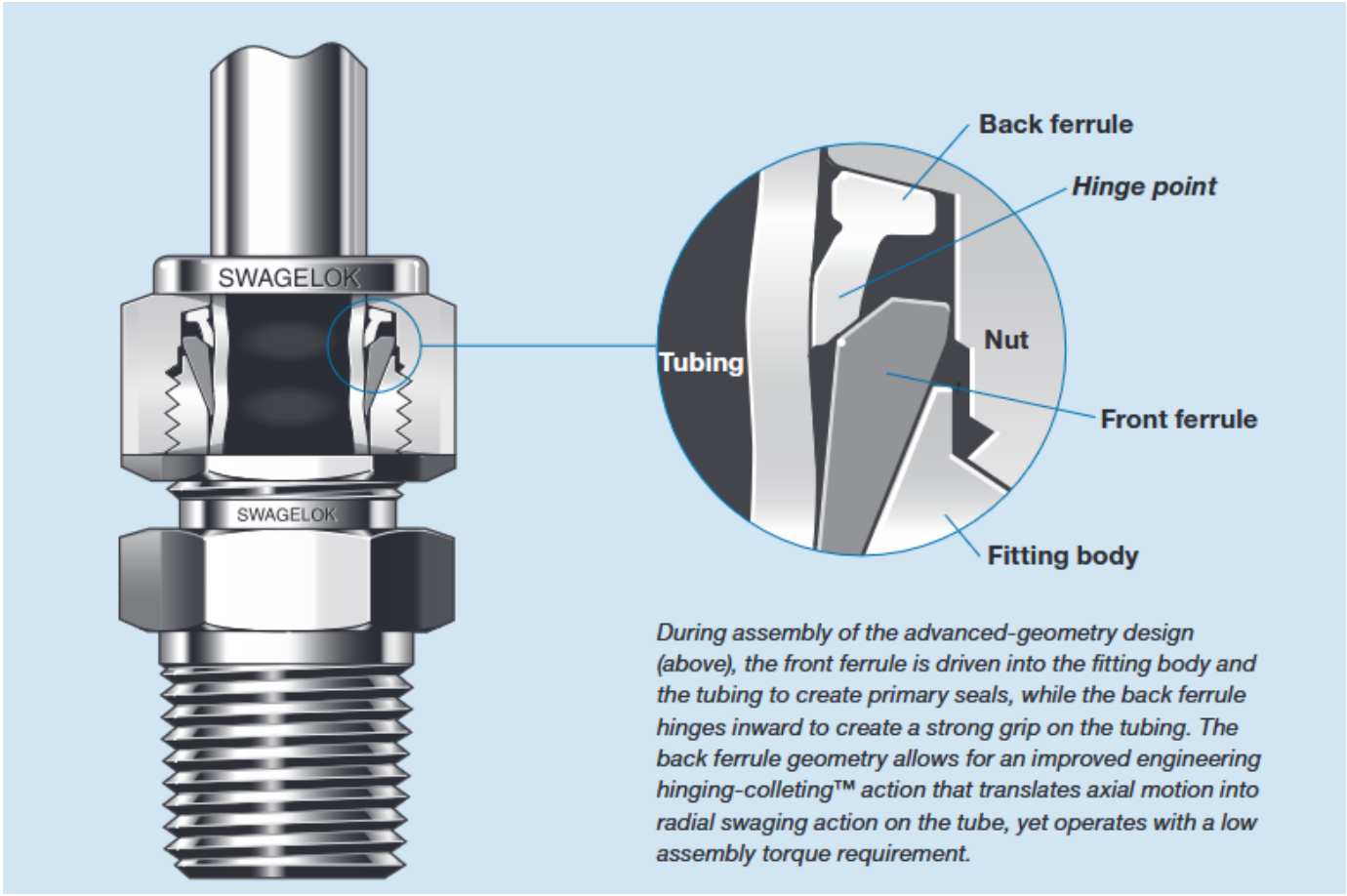


FIGURE 2: Scratches on tubing



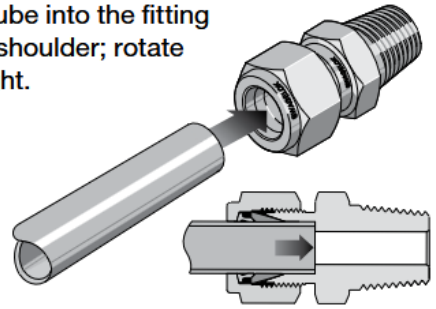
Assembly of Swagelok tube fittings



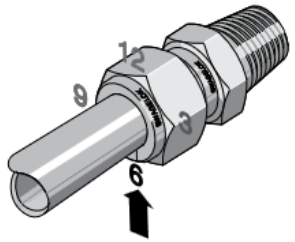
During assembly of the advanced-geometry design (above), the front ferrule is driven into the fitting body and the tubing to create primary seals, while the back ferrule hinges inward to create a strong grip on the tubing. The back ferrule geometry allows for an improved engineering hinging-colleting™ action that translates axial motion into radial swaging action on the tube, yet operates with a low assembly torque requirement.

Fully insert the tube into the fitting and against the shoulder; rotate the nut finger-tight.

High-pressure applications and high safety-factor systems: *Further tighten the nut until the tube will not turn by hand or move axially in the fitting.*

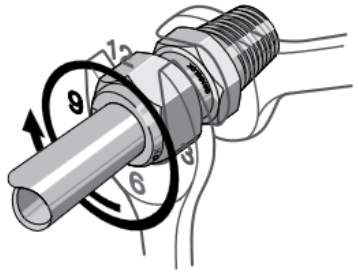


Mark the nut at the 6 o'clock position.



While holding the fitting body steady, tighten the nut one and one-quarter turns to the 9 o'clock position.

For 1/16, 1/8, and 3/16 in.; 2, 3, and 4 mm tube fittings, tighten the nut three-quarters turn to the 3 o'clock position.



Note: Ferrules and fitting should be a harder material than tubing

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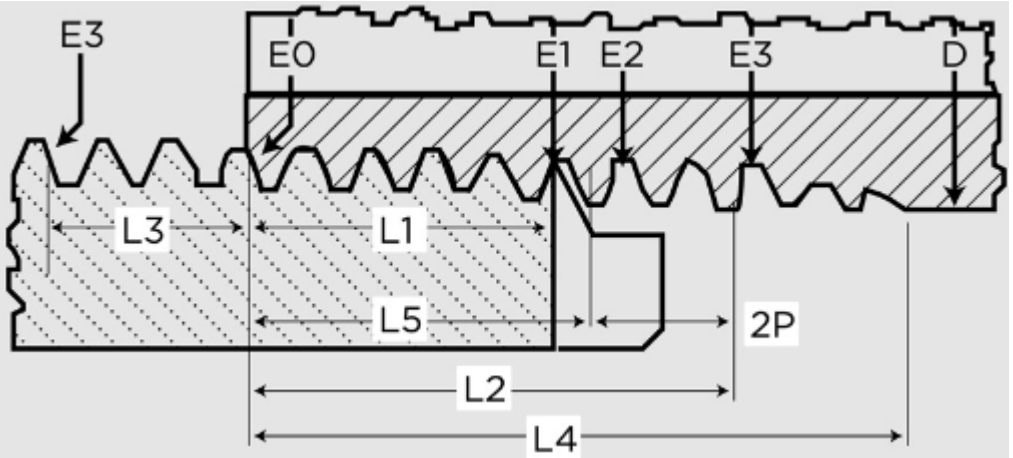
Assembly of pipe thread fittings

ASME Standard B1.20.1 Pipe Threads

1. Establish dry fit position (hand tight, no thread tape)
   - *Investigate if threads don't properly engage for dry-fit.*
2. Apply thread tape (at least two turns) or appropriate pipe thread compound
3. Reassemble fitting to dry fit position
4. Tighten a further 3 turns – "Wrench makeup length" (see chart for NPT threads larger than 2")
5. Fittings will experience damage and deformation on repeated connection and cannot be reused indefinitely



NPS	Pipe OD	TPI	Length of Effective Thread External **L2**	Hand Engagement plus Wrench Makeup Lengths – not necessarily equal to length of effective Thread			
				Hand Tightened Engagement Length **L1**	Wrench Makeup Length **L3**	Hand Tight Threads	**Wrench Makeup Threads**
1/8"	0.405	27	0.2639	0.1615	0.1111	4.36	**3**
1/4"	0.540	18	0.4018	0.2278	0.1667	4.10	**3**
3/8"	0.675	18	0.4078	0.2400	0.1667	4.32	**3**
1/2"	0.840	14	0.5337	0.320	0.2143	4.48	**3**
3/4"	1.050	14	0.5457	0.339	0.2143	4.75	**3**
1"	1.315	11.5	0.6828	0.400	0.2609	4.60	**3**
1-1/4"	1.660	11.5	0.7068	0.420	0.2609	4.83	**3**
1-1/2"	1.900	11.5	0.7235	0.420	0.2609	4.83	**3**
2"	2.375	11.5	0.7565	0.436	0.2609	5.01	**3**
3"	3-1/2"	8	1.2000	0.766	0.2500	6.13	2
4"	4-1/2"	8	1.3000	0.844	0.2500	6.75	2
6"	6-5/8"	8	1.5125	0.958	0.2500	7.66	2

Teflon tape and “Tight”

- Only use Teflon tape on NPT or BSPT (i.e. tapered thread) fittings!
- **NEVER** use Teflon tape on compression, CGA, or cone and thread fittings!!!
- Do **NOT** overtighten!
- If your connection is leaking, there is something wrong – most good connections will hold a good amount of pressure with torque as low as “finger-tight”
  - 99% of leaks are due to poorly prepared tubing or an axially scratched sealing surface
- Overtightening can damage expensive parts. Leave the gorilla in the zoo.

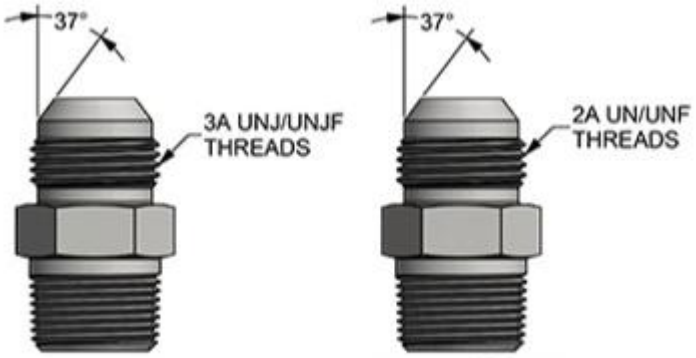
AN / JIC-37° Fittings

Do not overtighten: overtightening will over-flare and damage fitting

Ideally, torque to specification:

Torque Specification Guidelines

Nut Size	Minimum Torque[1]	Maximum Torque[1]
-02	50	80
-03	70	105
-04	100	140
-05	130	180
-06	150	195
-08	270	350
-10	360	430
-12	460	550



AN Fittng

SAE/ISO 37° Flare
(Parker Triple-Lok)

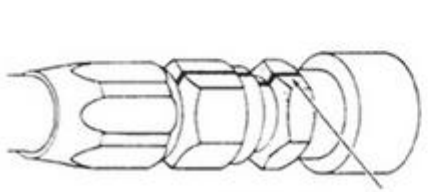
Alternatively, use 'Flats' method:

Flats Method

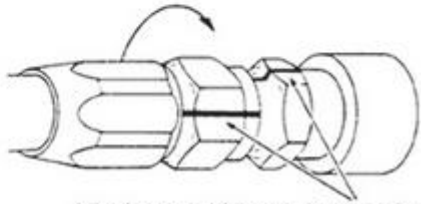
Here are the steps for an excellent method of tightening. Anyone can tell if the joint was tightened and how much.

1. Tighten the nut by hand until it bottoms the seats.
2. Using a marker, draw a line lengthwise on the nut and extend it onto the adapter.
3. Using a wrench, rotate the nut to tighten. Turn the nut the amount shown on the chart.

Size	Number of Hex Flats Rotations
-04	1½ to 1¾
-06	1 to 1½
-08	1¼ to 1¾
-10	1¼ to 1¾
-12	1to 1½
-16	¾ to 1
-20	½ to ¾
-24	½ to ¾



Mark a line on the nut and adapter before torquing.



Misalignment of the mark shows the amount which the nut was tightened.

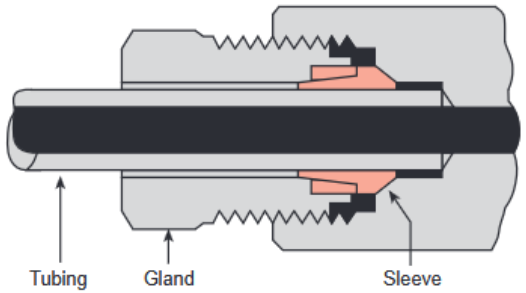
Assembly of HiP Taper-Seal fittings

To make a NEW connection:

1. Lubricate the male threads of the Taper-seal gland, and the back of the outer collar on the sleeve with a process compatible lubricant.
2. Assemble the Taper-seal gland, sleeve and tubing into the component or assembly mandrel and tighten finger-tight.
3. Rotate the gland nut clockwise one half turn and stop. Back off the gland nut and repeat this step approximately 3 – 4 times until the gland stops rotating or “bottoms out”. Do not rotate the gland nut continuously clockwise or galling between the outer collar and inner sleeve may occur.
4. Remove the tube with the gland and sleeve attached, and inspect the sleeve assembly to be sure the outer collar has slid completely down over the inner sleeve. No gaps should be present.

Correctly Assembled Taper Seal Connection

Incorrect Assembly



Connection	Recommended Torque
AF1	55 inch pounds
AF2	10 foot pounds initial to compress sleeve onto tube 25 foot pounds to tighten connection
AF4	30 foot pounds initial to compress sleeve onto tube 50 foot pounds to tighten connection
AF6	40 foot pounds initial to compress sleeve onto tube 60 foot pounds to tighten connection

Assembly of AE SpeedBite fittings

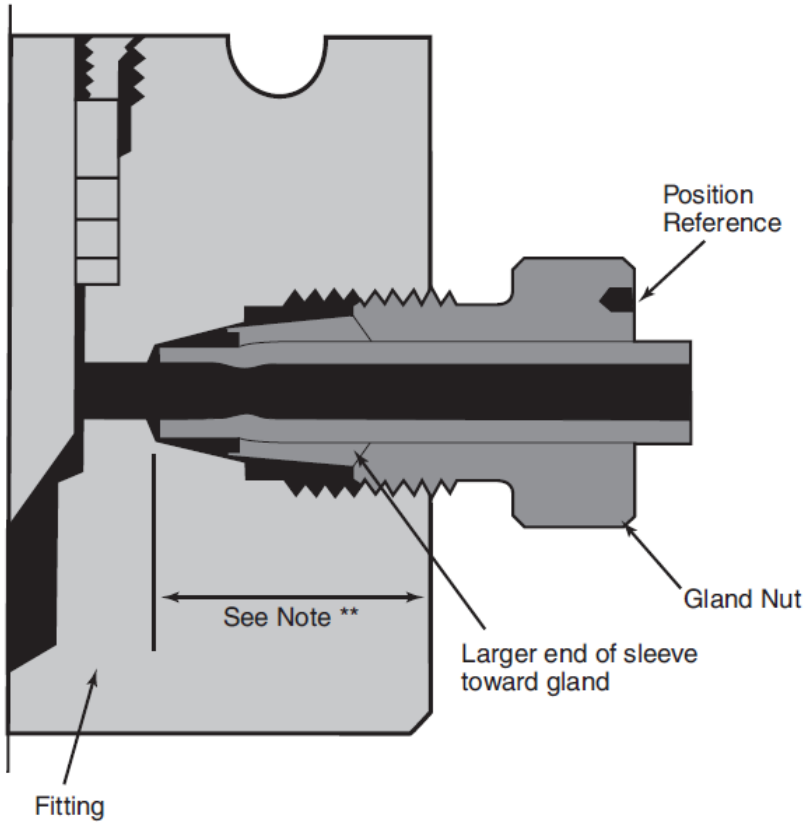
To make a NEW connection:

1. Cut tubing to length, deburr, and remove axial scratches
2. Lubricate male threads and slip gland and sleeve onto tubing. Larger end of sleeve should be toward gland.
3. Push tubing into fitting until it bottoms out.
4. Turn gland until “finger-tight”.
5. Tighten gland until sleeve begins to grip tubing “Wrench-tight”
6. From “Wrench-tight” note starting position and tighten 1-1/4 turns.

To reassemble previously made connections, only 1/8 to 3/8 of a turn from “finger-tight” is required

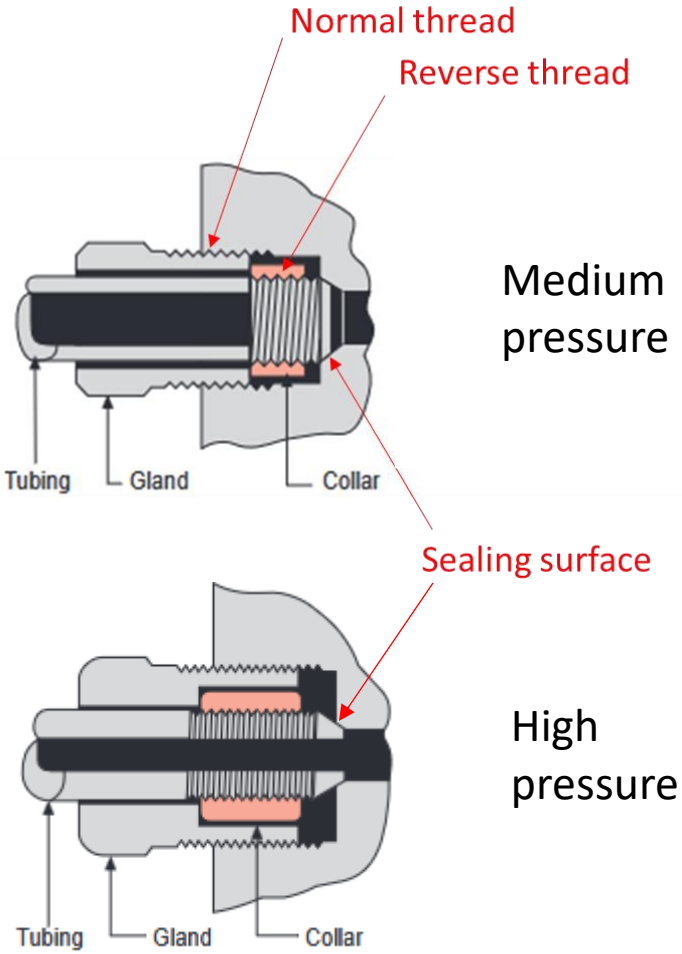
SpeedBite Adapter Sealing Torque	
Connection Type	**Torque (Nm)**
W125	19 in-lbs (2.1)
SW250	71 in-lbs (8.0)
SW375	170 in-lbs (19.21)
SW500	155 in-lbs (17.5)

Figure 1



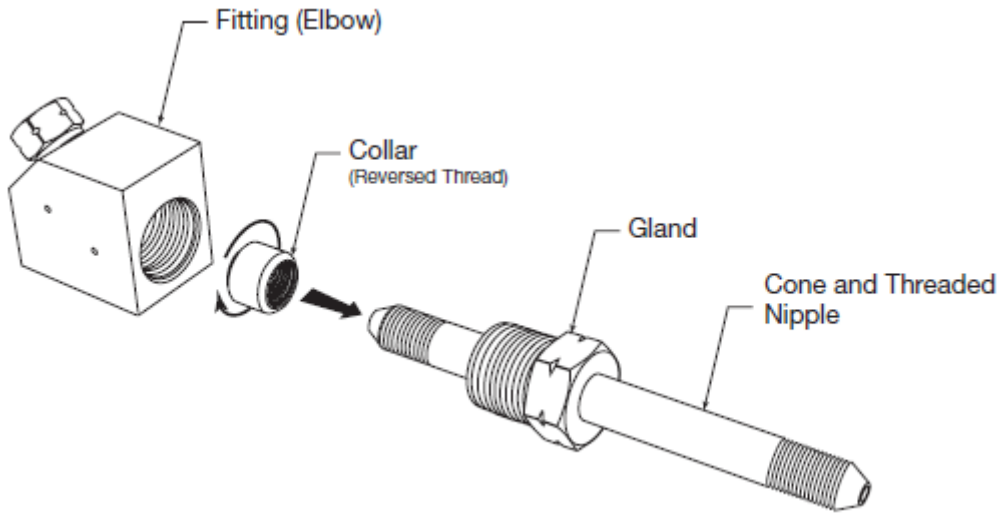
Assembly of HiP & AE medium- and high-pressure fittings

- Design changes from a compressed ferrule to “cone and thread”
  - Seal is formed directly between end of tubing and fitting
  - End of tubing must be prepared using special tooling in advance or purchased in standard lengths
  - Tubing is left-hand threaded and then shaped to a ‘cone’.
  - Collar self-tightens against gland as gland is tightens, driving tubing into fitting



Assembly of HiP & AE medium- and high-pressure fittings (cont'd)

1. Inspect seat cone and tube cone to verify free of all surface imperfections
2. Lubricate male threads of gland nut and collar gland surface with appropriate lubricant
3. Slip gland nut on tubing as shown
4. Thread collar on tubing until 1-1/2 to 2 full threads are exposed between collar and cone
5. Insert tubing connection, engage gland nut and tighten "finger-tight" (at least 4 complete turns for Medium Pressure, 5-6 turns for High Pressure)
6. Tighten gland nut with torque wrench (REQUIRED) to values specified in manual. (cone and thread connections typically require ***MUCH LESS*** torque than compression fittings)

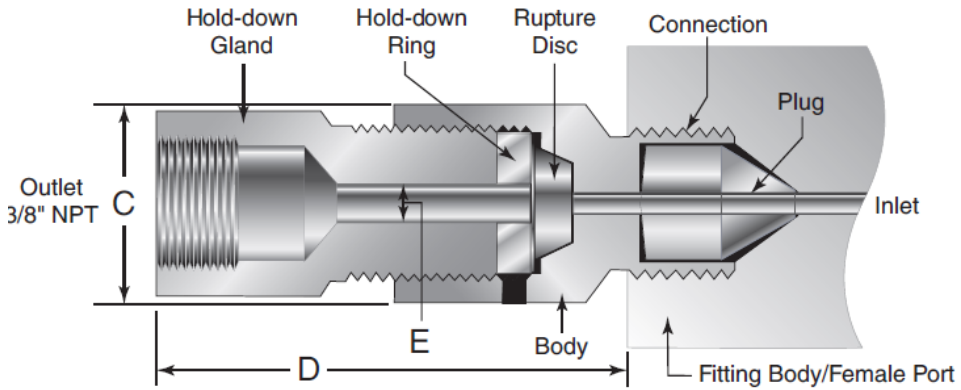


Pressure Relief

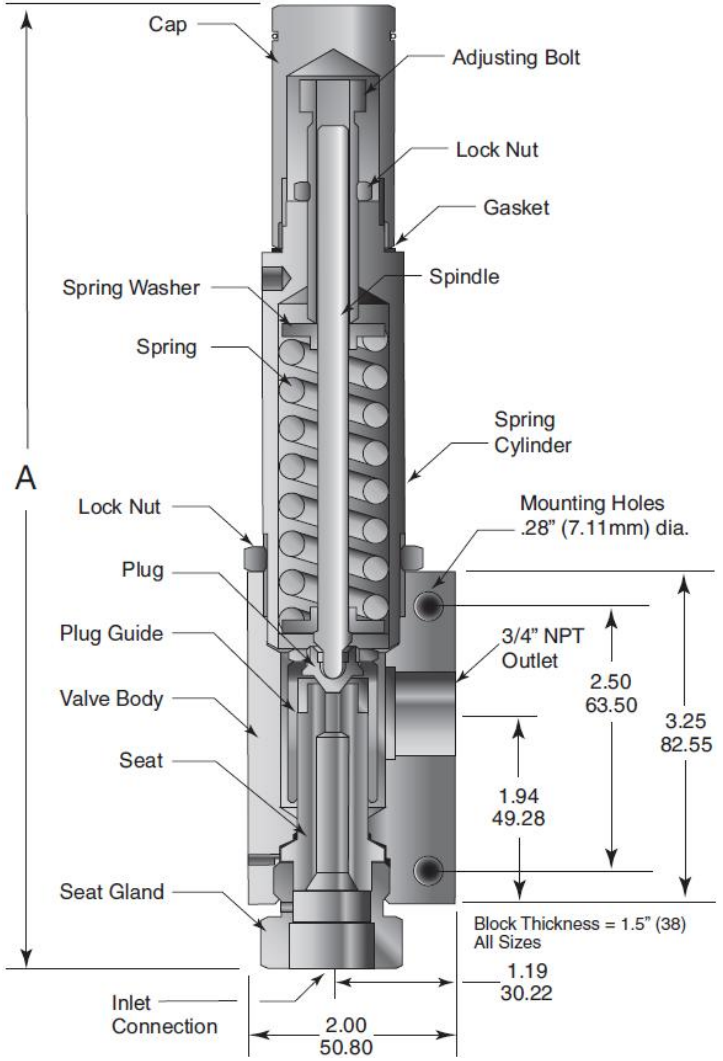
Any pressurized system **MUST HAVE** a relief valve for safety

Two main types of pressure relief:

1. Safety head (burst disc)
   - Single pressure – once it blows, contents of system will vent completely
   - May fail if relief port clogs (e.g. with catalyst)
2. Proportional pressure relief
   - Usually set pressure can be adjusted
   - Opens in proportion to scale of overpressure
   - Should re-seat once pressure drops to normal level
   - May fail if relief port clogs (e.g. with catalyst)
   - If elastomeric seat material is used, it must be compatible with process fluid



Example Safety Head



Example Proportional Relief

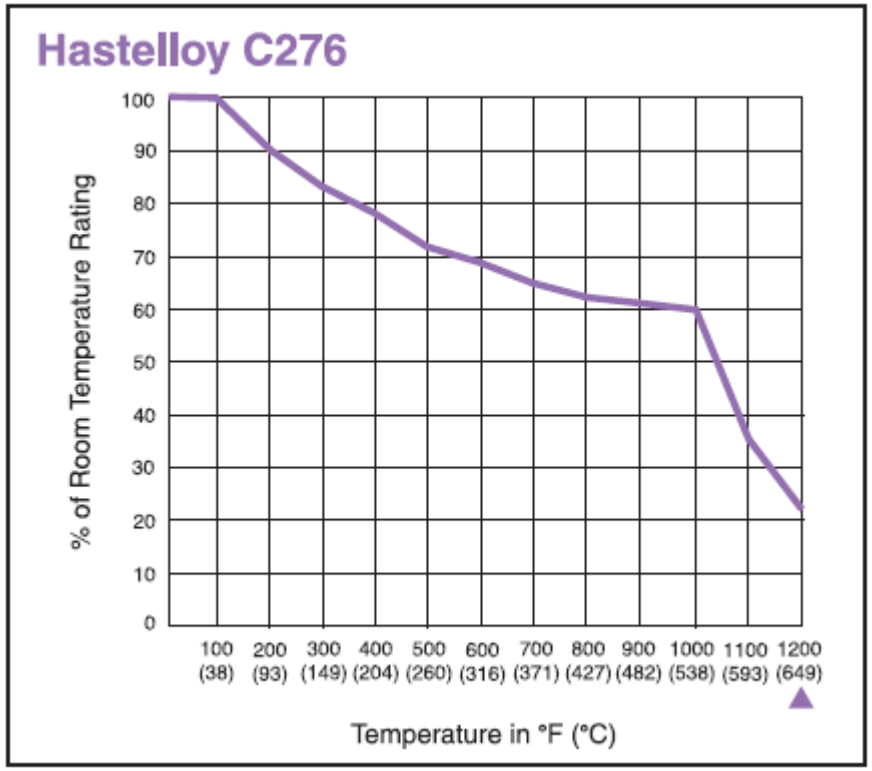
Material selection considerations

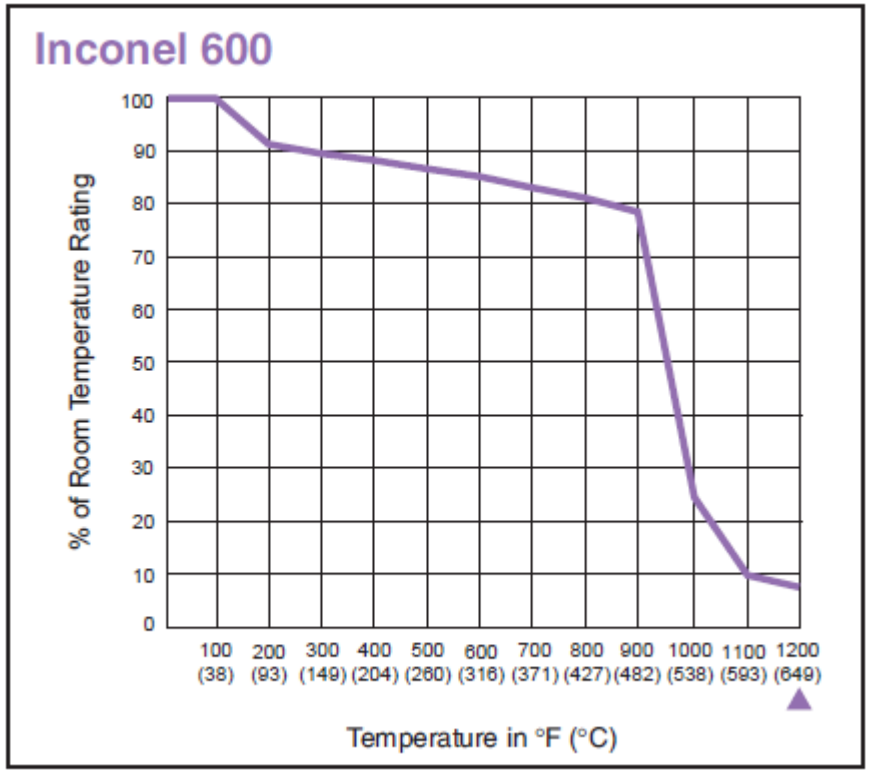
Tubing (Seamless) - Low Pressure**

Valve Series	Tubing Size Outside x Inside Diameter Inches (mm)	Material vs. Pressure Rating psi (bar) @ Room Temperature ††*						
		316ANLD	Hastelloy C276	Inconel 600	Inconel 625	Monel 400	Nickel 200	Titanium Gr2
Low Pressure	1/16 x 0.026 (1.59 x 0.66)	15,000 (1034.20)	15,000 (1034.20)	15,000 (1034.20)	15,000 (1034.20)	11,500 (792.88)	7,100 (489.52	11,500 (792.88
	1/8 x 0.052 (3.19 x 1.32)	15,000 (1034.20)	15,000 (1034.20)	15,000 (1034.20)	15,000 (1034.20)	12,000 (827.36)	7,200 (496.41)	12,000 (827.36)
	1/8 x 0.062 (3.19 x 1.57)	11,650 (803.23)	14,000 (965)	11,000 (758.41)	11,650 (803.23)	9,900 (682.57)	6,000 (413.68)	7,500 (517.10)
	1/8 x 0.069 (3.19 x 1.75)	9,950 (686.02)	11,000 (758.41)	10,600 (730.83)	11,500 (792.88)	9,300 (641.26)	5,300 (365.42)	6,650 (458.49)
	1/8 x 0.085 (3.19 x 2.16)	6,850 (472.28)	7,750 (534.34)	7,300 (503.31)	10,000 (689.46)	6,400 (441.26)	3,650 (251.65)	4,450 (306.81)
	1/4 x 0.125 (6.35 x 3.18)	11,650 (803.23)	11,500 (792.88)	11,500 (792.88)	12,500 (861.83)	9,900 (682.57)	6,000 (413.68)	7,500 (517.10)
	1/4 x 0.180 (6.35 x 4.57)	5,450 (375.76)	6,650 (458.49)	6,300 (434.36)	9,000 (620.52)	5,500 (379.21)	3,150 (217.18)	3,900 (268.89)
	1/4 x 0.194 (6.35 x 4.93)	4,600 (317.15)	5,200 (358.52)	4,900 (337.84)	7,200 (496.41)	4,300 (296.47)	2,450 (168.92)	3,050 (210.29)

“Low Pressure” fittings are typically limited to the pressure rating of the tubing that is being used, which will vary based on OD, wall thickness, and material

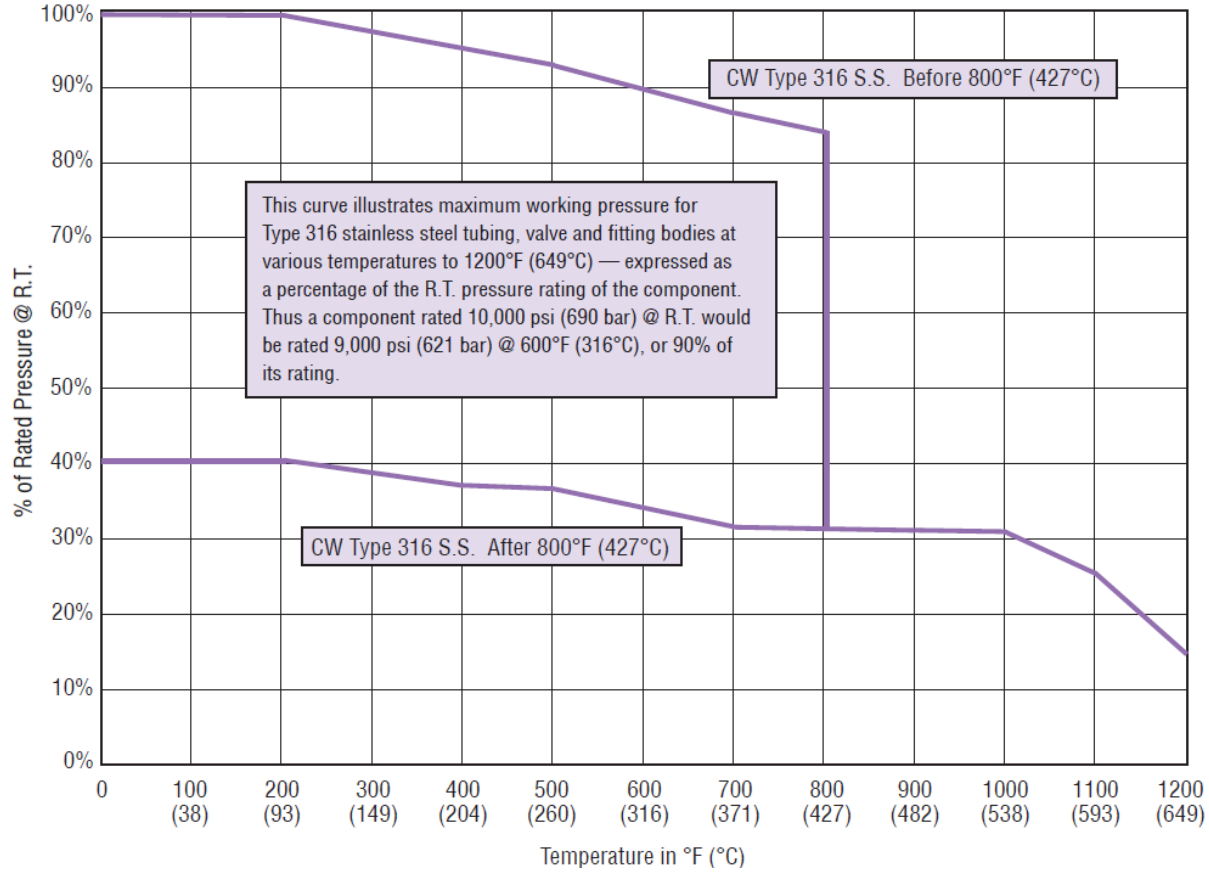
Effect of temperature on materials





- Materials weaken and their pressure rating decreases as temperature increases
- Different materials weaken and de-rate differently

Effect of temperature on materials: 316 SS



- Cold-worked 316 SS is permanently weakened and de-rated once it is exposed to temperatures above 427 °C, where the precipitation of chromium carbides in grain boundaries begins to occur.

A final thought:

You are ultimately responsible for your own safety!!!

References

- https://www.parker.com/content/dam/Parker-com/Literature/Instrumentation-Products-Division/Autoclave/FluidComponentsFullCatalog.pdf
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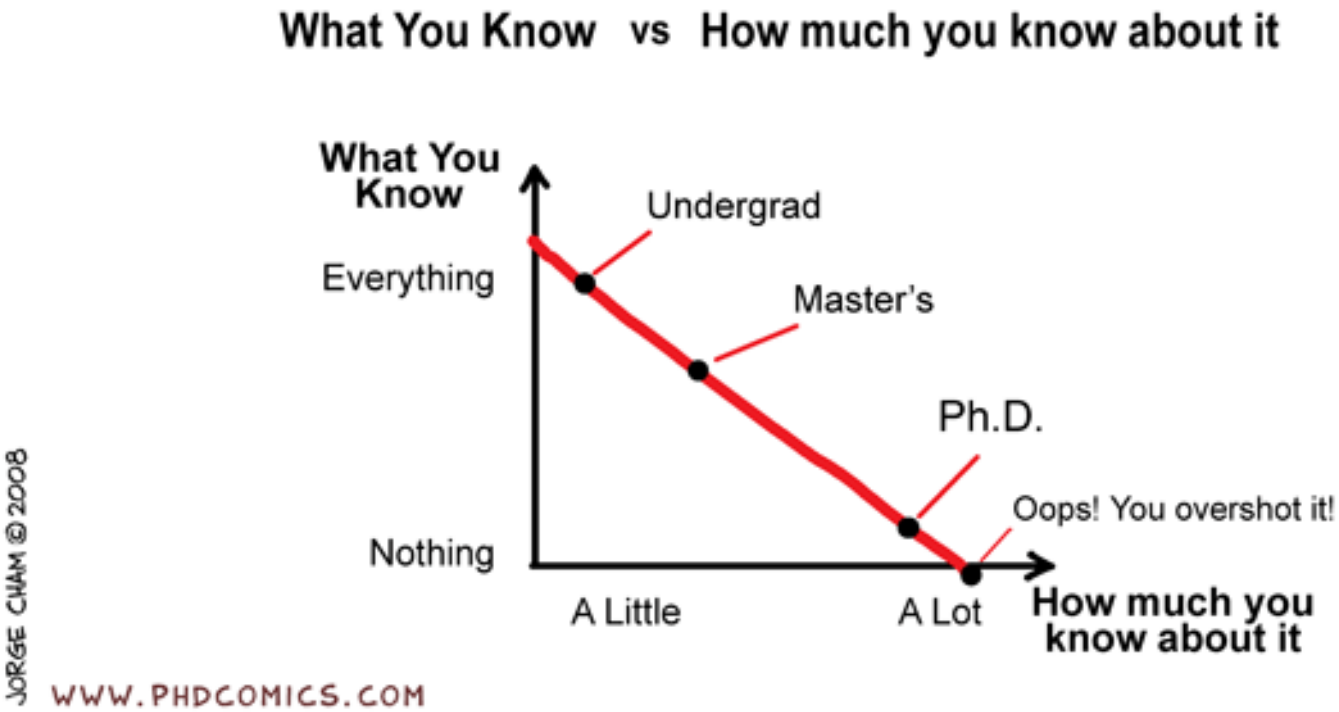
What You Know vs How much you know about it
What You Know
Everything
Nothing
Undergrad
Master's
Ph.D.
Oops! You overshot it!
A Little
A Lot
How much you know about it
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THANK YOU!

Cylinder Comparison Chart

Matheson Tri-Gas Specialty	Matheson Tri-Gas Electronics	Nominal Dimensions	Material of Construction	AGT	Airgas	Air Liquide	Linde	Air Products	Praxair
B1		30x53	S	1/2Ton				A-5	HT
1F		15x50	S	LP30	350	110	110	A-1	PX/FX
		12x43	S	LP15	65	55		A-3	FC
HF		12x18	S	LP05	25	22LP			
		9x36	S	LP05					
		8x9	S	LP01					
1L	QK	9x55	S	49	300	49	049	A	T
1A	QA	9x51	S	44	200	44	044	B	K
1R	QX	8x48	A	29AL	150A	30AL		B(AL)	AS
2	GA	9x26	S	16	80	16	016	C	Q
2R	GX	7x33	A	16AL	80A	22AL		C(AL)	AQ
3	UA	6x19	S	7	35	7	007	D-1	G
3R	UX	7x16	A	6AL	33A	7AL		D-1(AL)	AG
4	JA	4x13	S	3	10	3	003	D	F
LB		2x12	S	LB		LB		LB	LB

A= Aluminum; S= Steel