CRAFT BREWERS CONFERENCE
& BrewExpo America®

Demystifying Dispense Gas

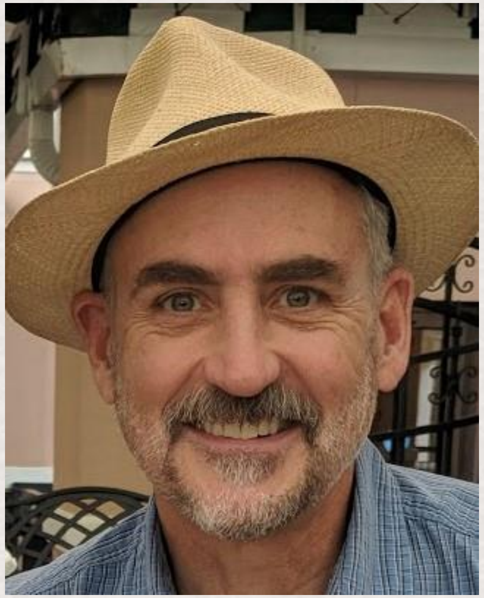
BREWERS ASSOCIATION

#CraftBrewersCon

Jaime Jurado

COO

Alamo Beer Co.



Ken Smith

Product Education

The Boston Beer Company

Purpose of Dispense Gas
What are we doing today?

Ken

1. Maintaining carbonation in beer
2. Pushing beer to the faucet, ***part I***

Jaime

3. Pushing beer to the faucet, ***part II***
4. Calculating Proper Balance and Pours, and options available

Gas is an Ingredient

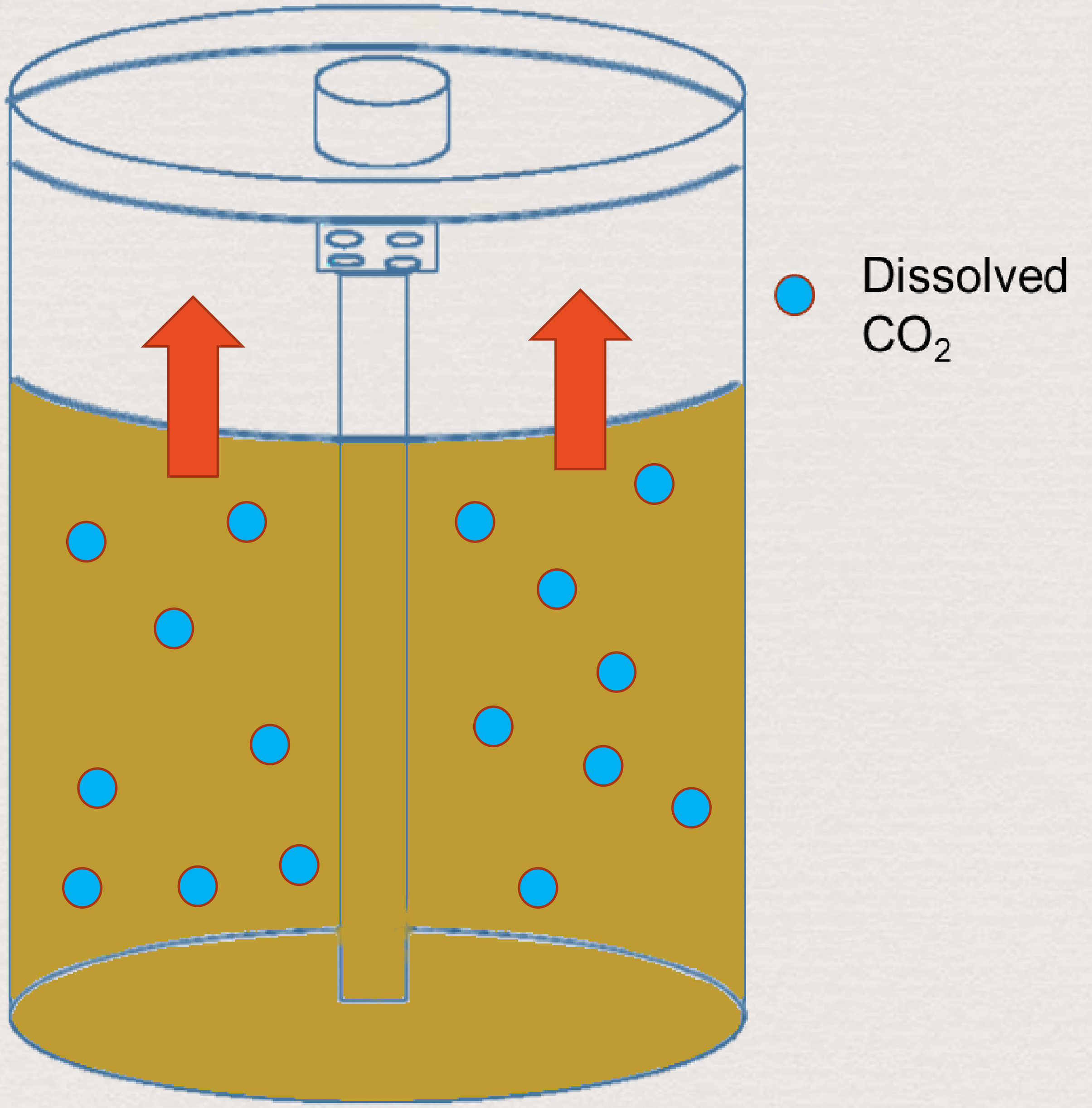
Perfect Carbonation Under Carbonation Over Carbonation

Pressure vs Beer Carbonation

Many lagers have between 2.5 – 2.7 vols of CO_2

This means (@ 2.5 v/v) that each 16 oz glass of beer has 2 ½ glasses of gas in it

The CO_2 is seeking equilibrium



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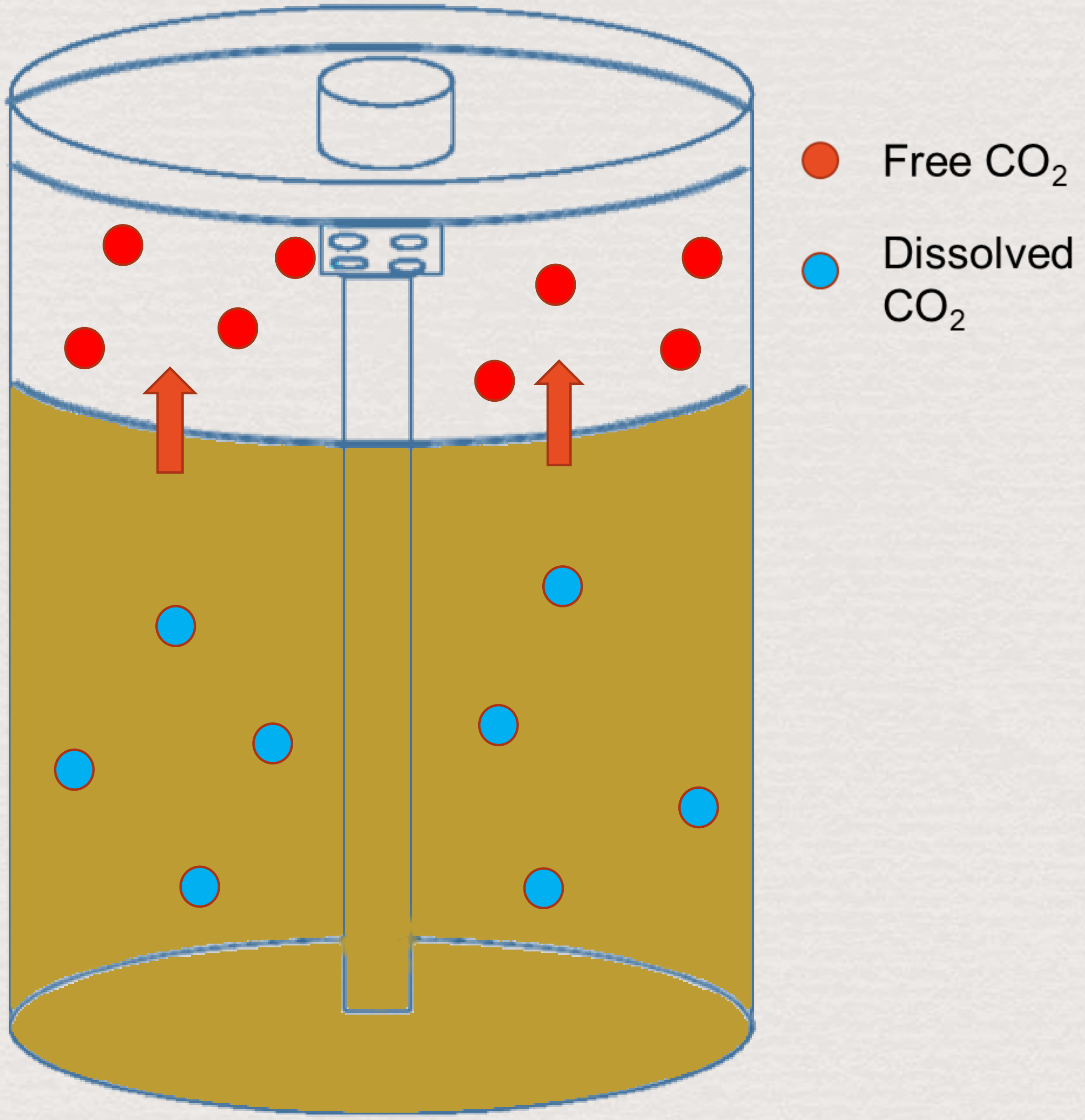

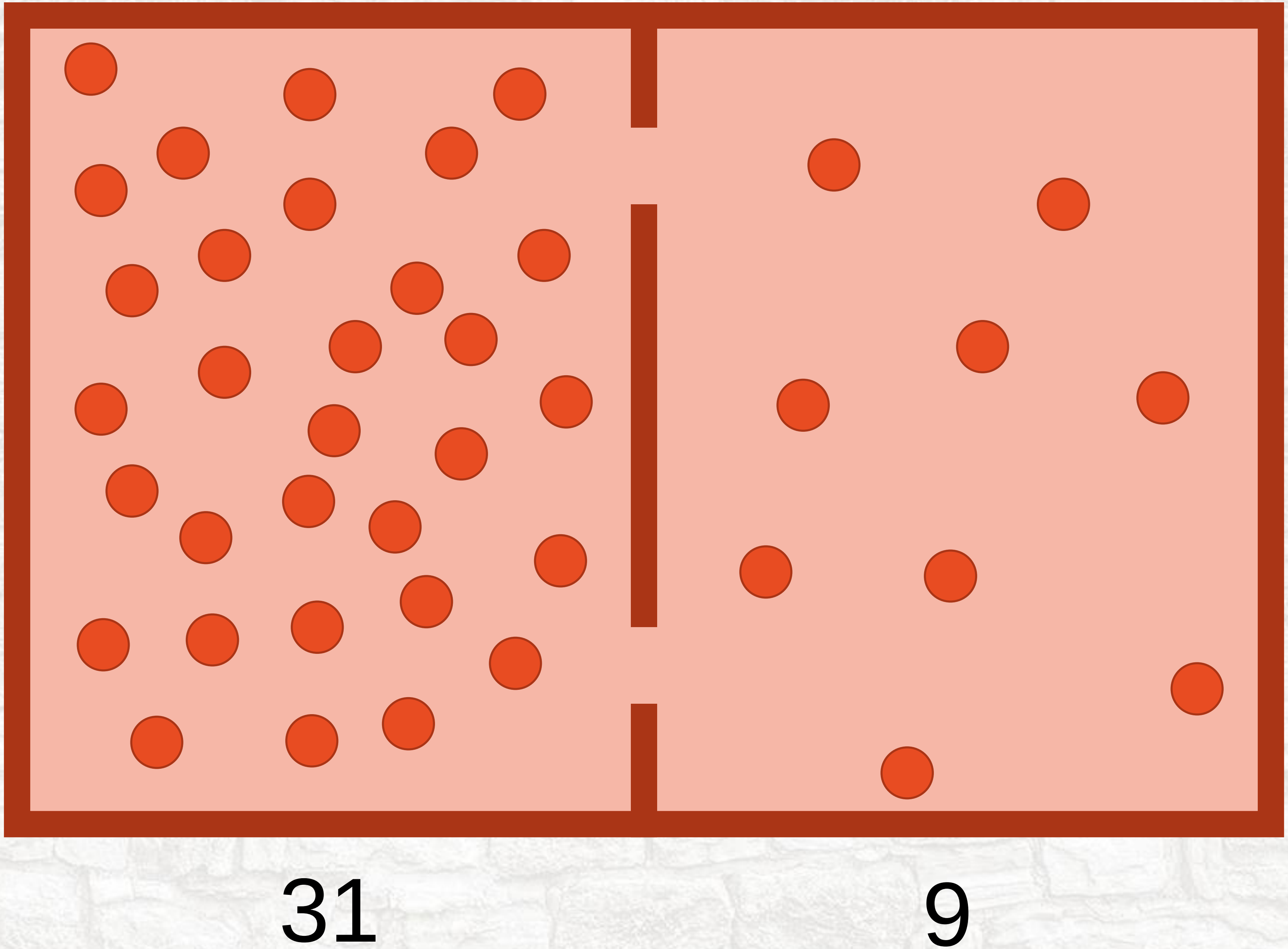
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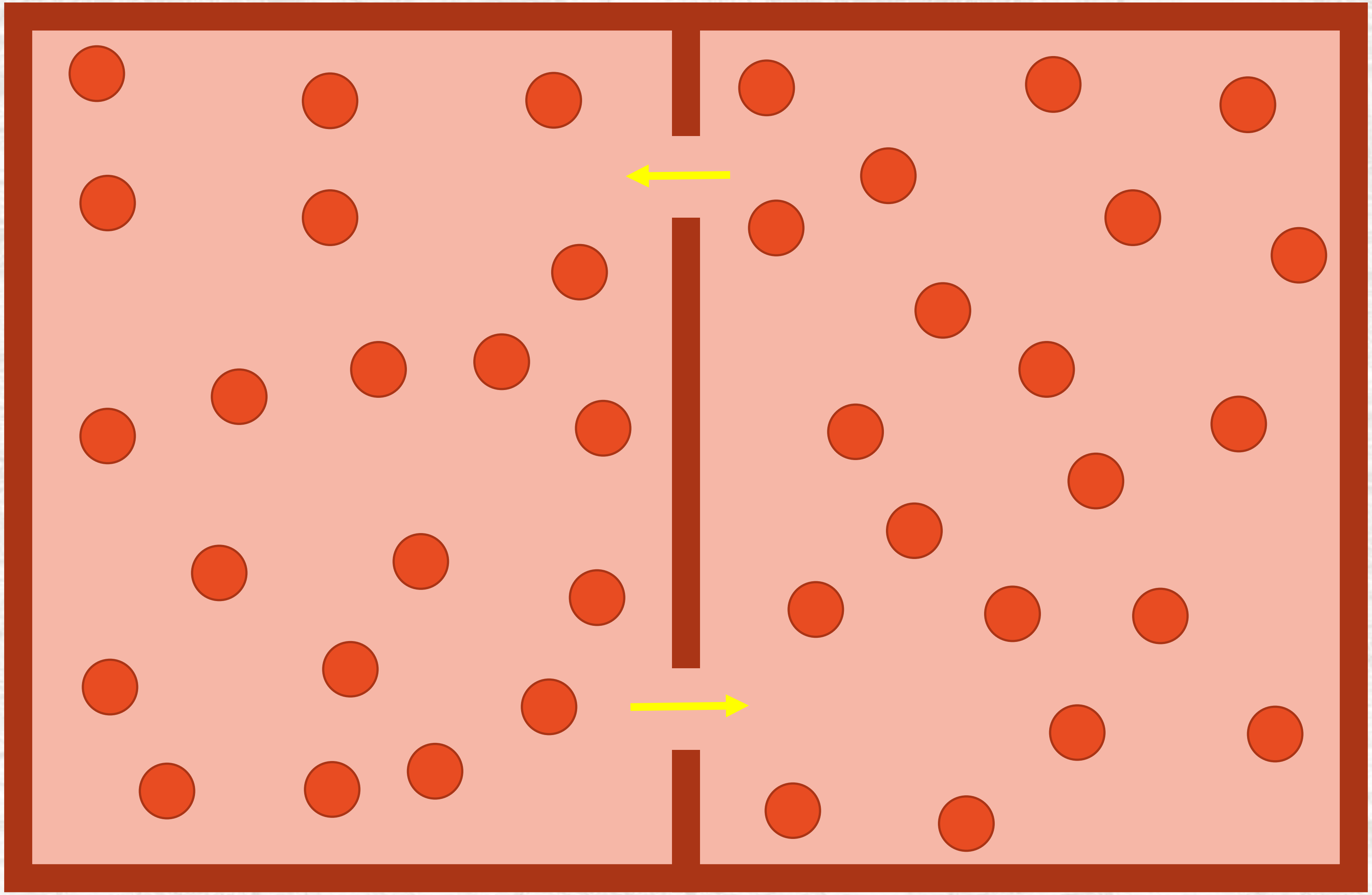

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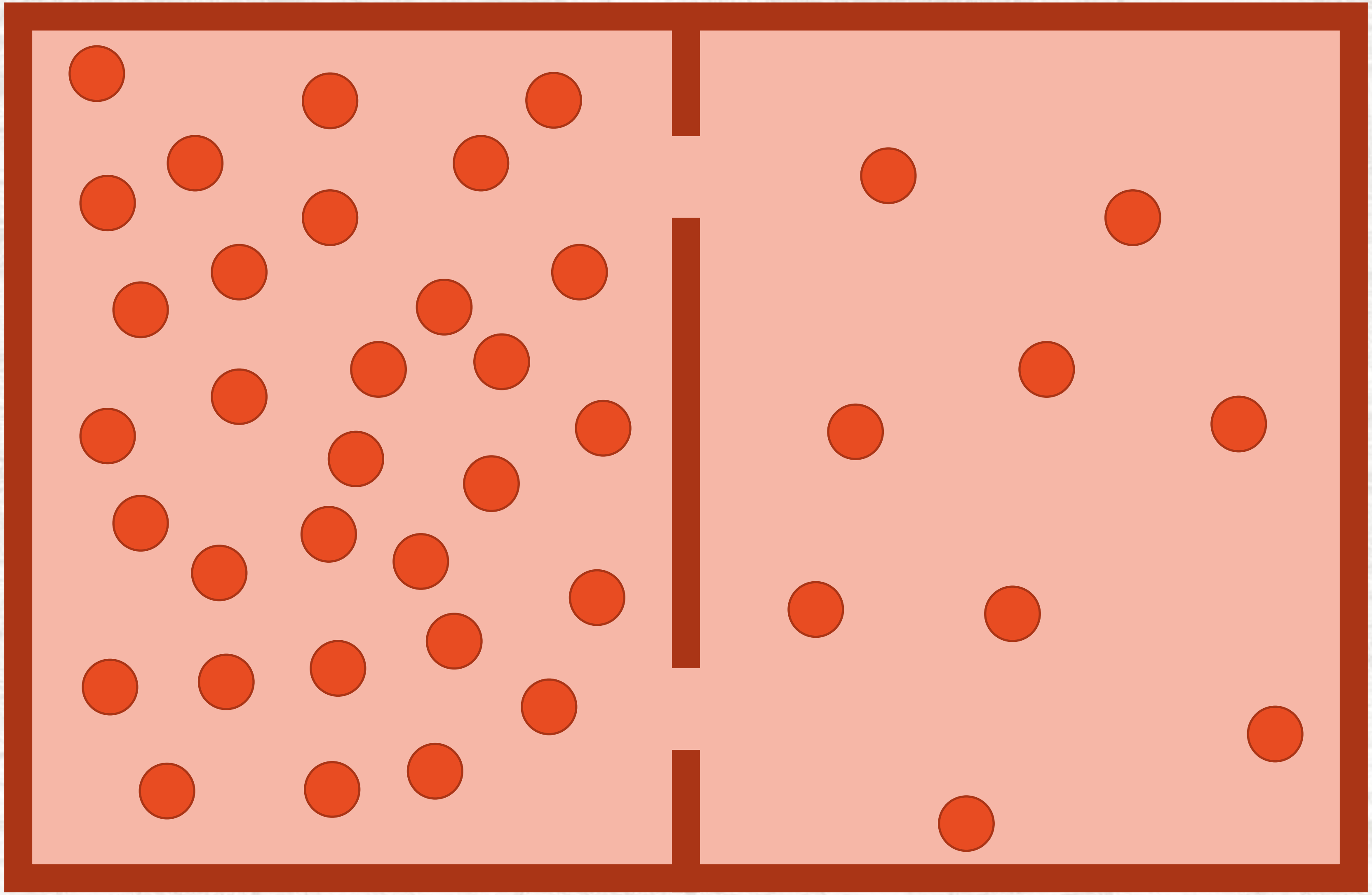

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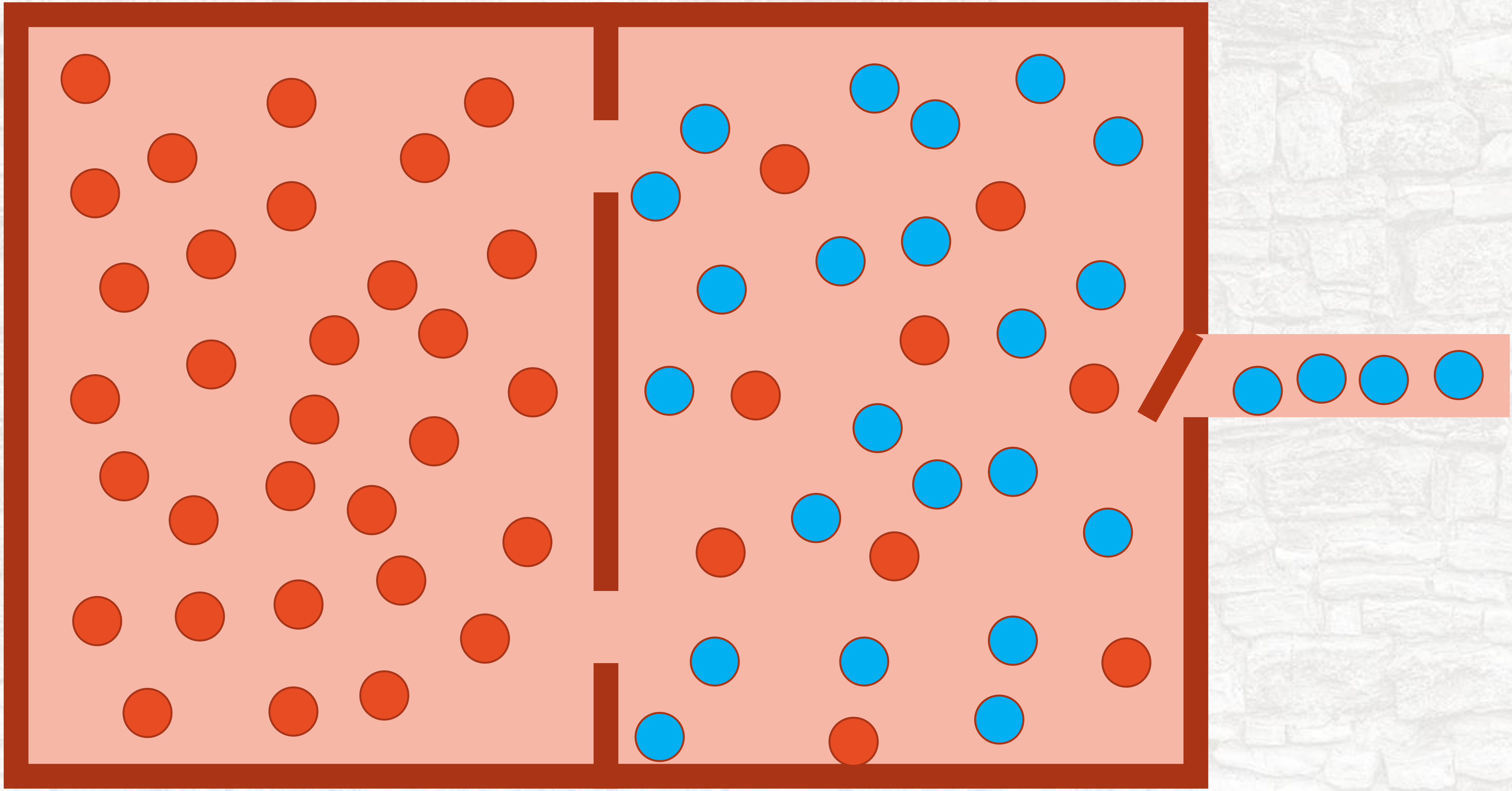

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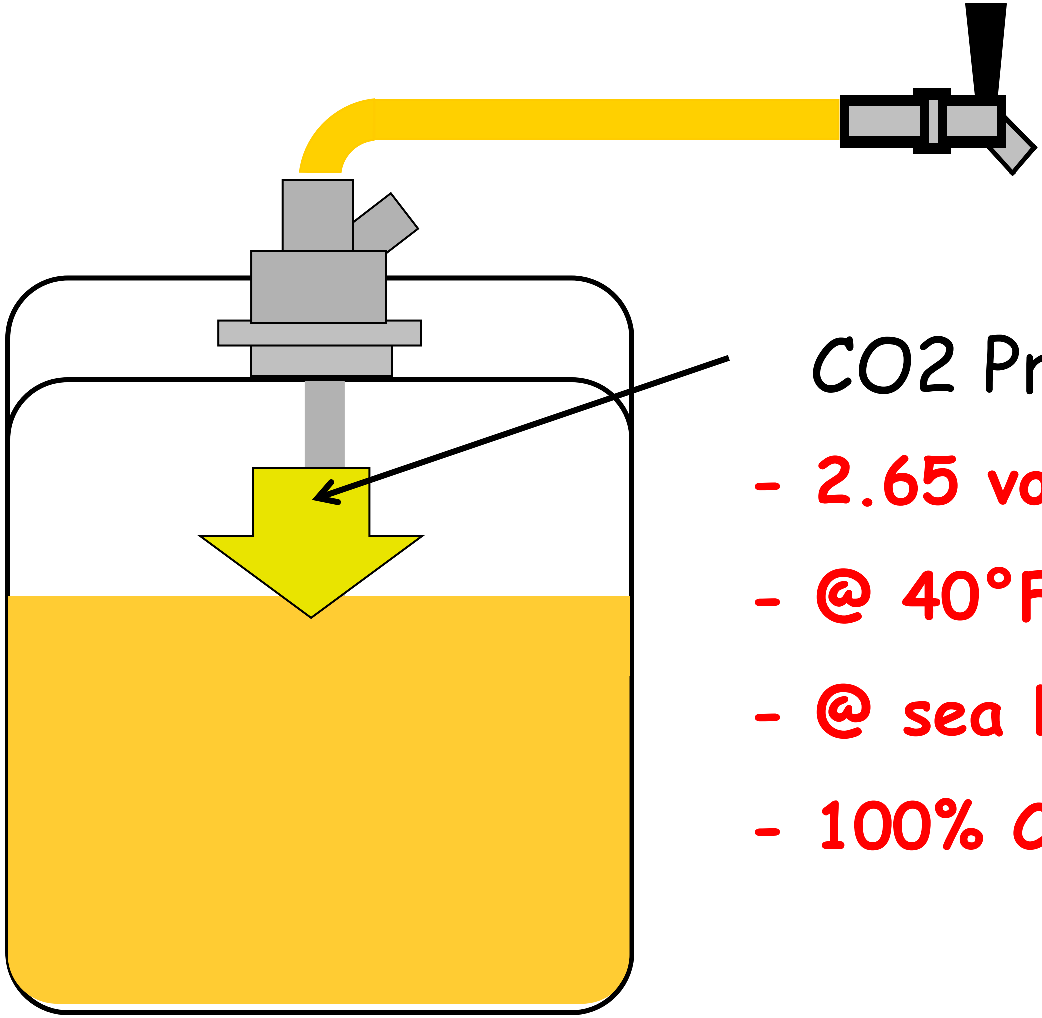
9+22=31

Pressure vs. Beer Carbonation



CO2 Pressure = ? psig

- 2.65 volumes of CO_2
- @ 40°F
- @ sea level
- 100% CO_2 Direct draw system

CO_2 Gauge Pressure Reference Chart

Determination of CO_2 Applied Gauge Pressure Given Volumes of CO_2 and Temperature*

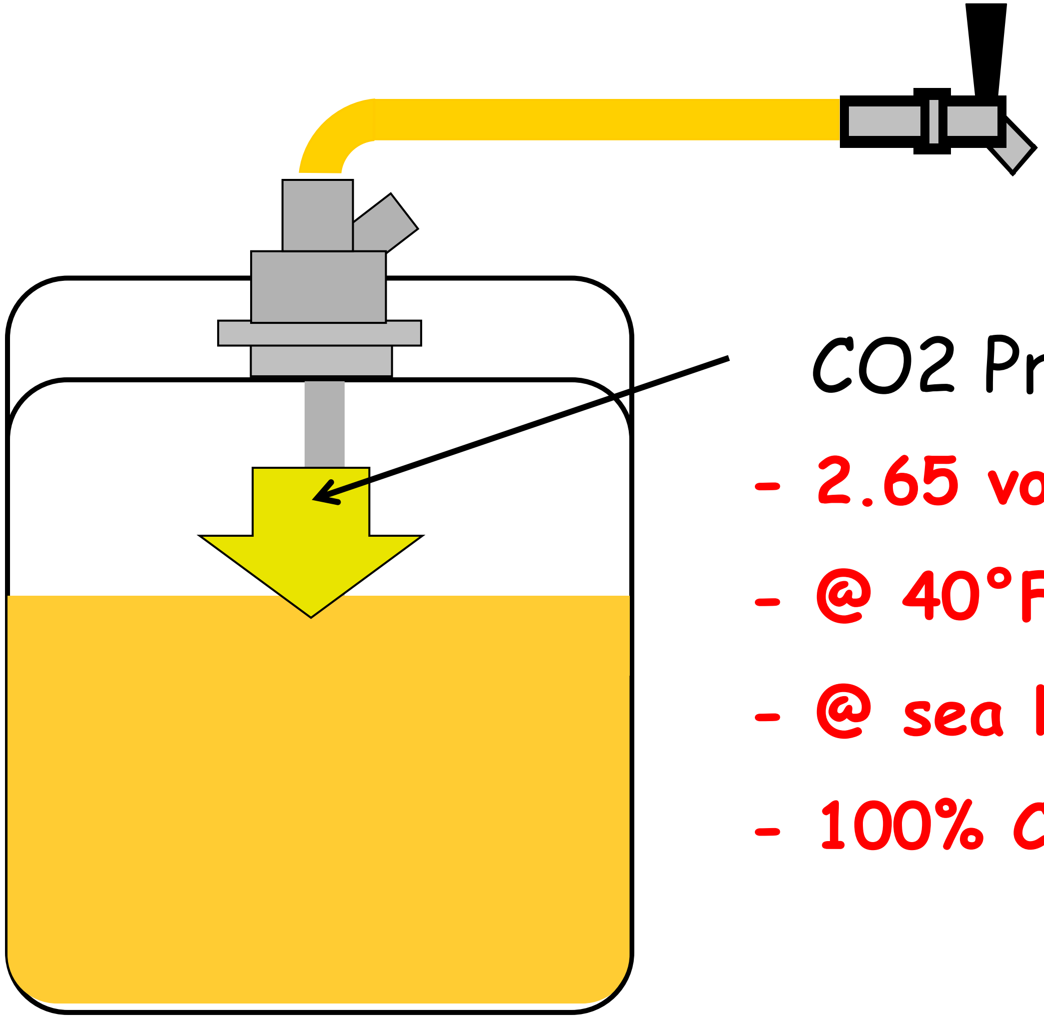
Vol. CO_2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1
Temp. °F	psig	psig	psig	psig	psig	psig	psig	psig	psig	psig	psig
33	5.0	6.0	6.9	7.9	8.8	9.8	10.7	11.7	12.6	13.6	14.5
34	5.2	6.2	7.2	8.1	9.1	10.1	11.1	[illegible]	[illegible]	[illegible]	15.0
35	5.6	6.6	7.6	8.6	9.7	10.7	11.7	[illegible]	[illegible]	[illegible]	15.8
36	6.1	7.1	8.2	9.2	10.2	11.3	12.3	[illegible]	[illegible]	[illegible]	16.5
37	6.6	7.6	8.7	9.8	10.8	11.9	12.9	[illegible]	[illegible]	[illegible]	17.2
38	7.0	8.1	9.2	10.3	11.3	12.4	13.5	[illegible]	[illegible]	[illegible]	17.8
39	7.6	8.7	9.8	10.8	11.9	13.0	14.1	[illegible]	[illegible]	[illegible]	18.5
40	8.0	9.1	10.2	11.3	12.4	13.5	14.6	[illegible]	[illegible]	[illegible]	19.0
41	8.3	9.4	10.6	11.7	12.8	13.9	15.1	[illegible]	[illegible]	[illegible]	19.5
42	8.8	9.9	11.0	12.2	13.3	14.4	15.6	[illegible]	[illegible]	[illegible]	20.1

What do you need to know?

1. Volumes of CO_2
2. Serving Temp

* Chart assumes sea level as altitude. Add 1 psi for every 2,000 ft. above sea level.

Pressure vs. Beer Carbonation

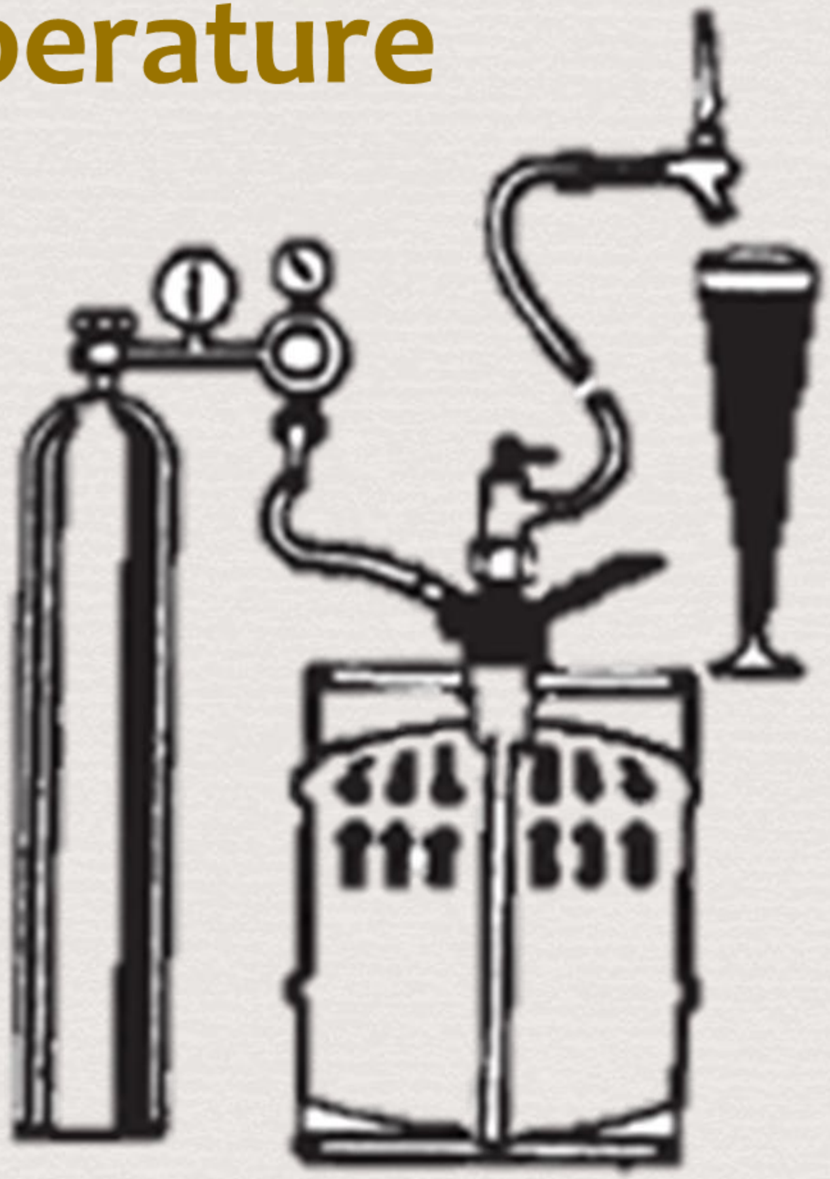


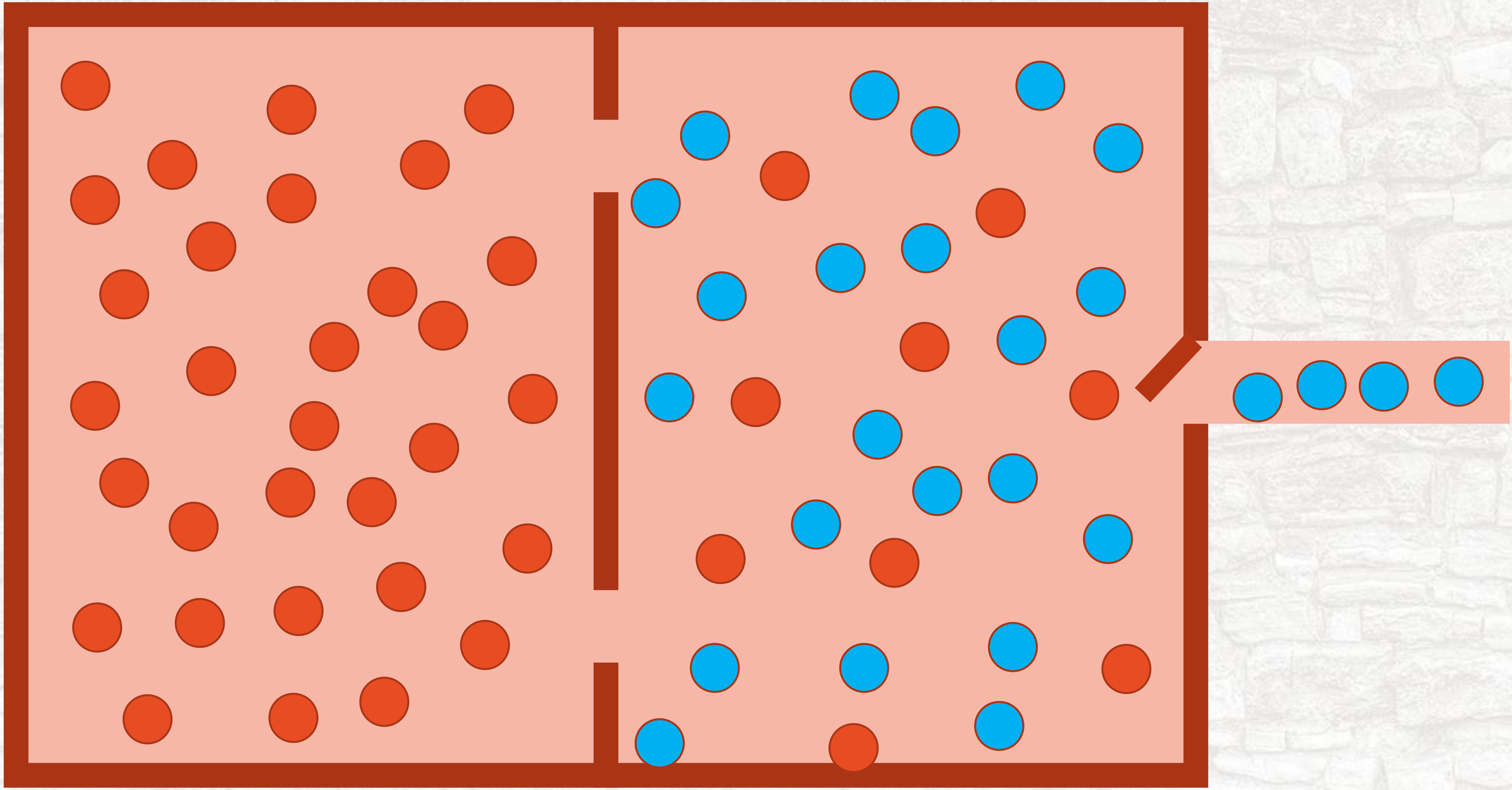
CO2 Pressure = **14 psig**

- 2.65 volumes of CO_2
- @ 40°F
- @ sea level
- 100% CO_2 Direct draw system

Pressure vs. Temperature

As temperature **increases** so must **pressure** to maintain the same volumes of CO2 and vice a versa





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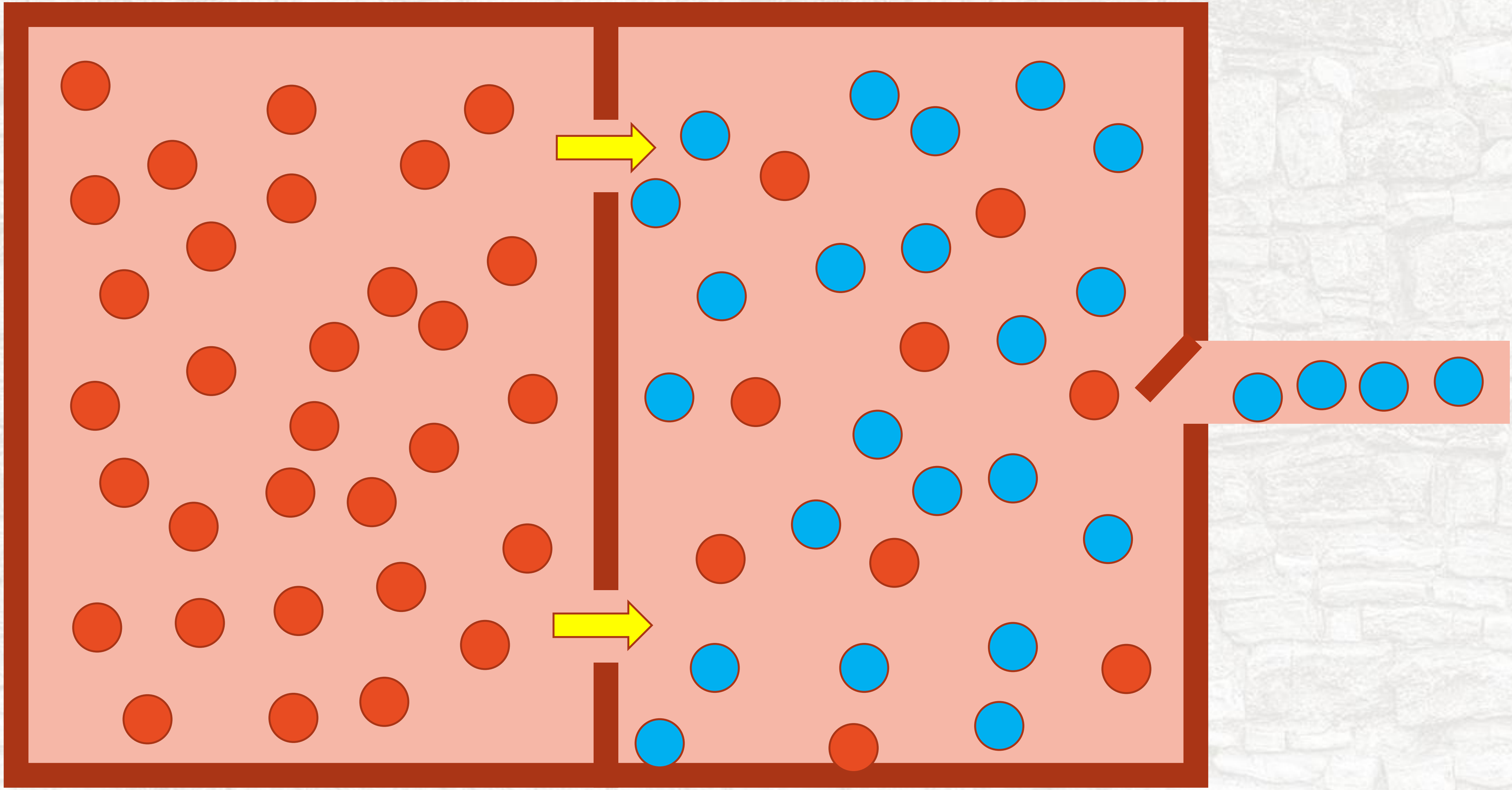

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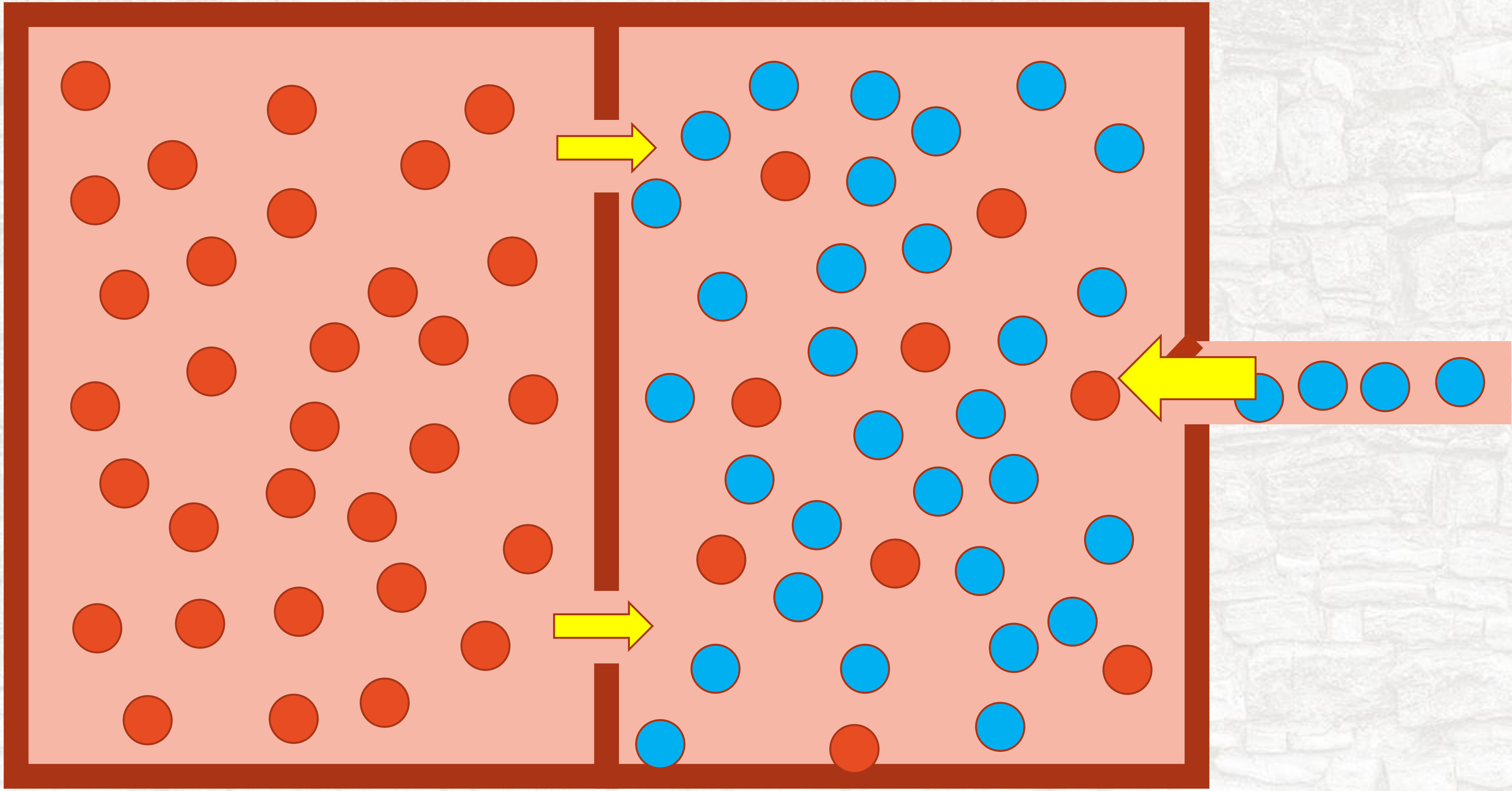

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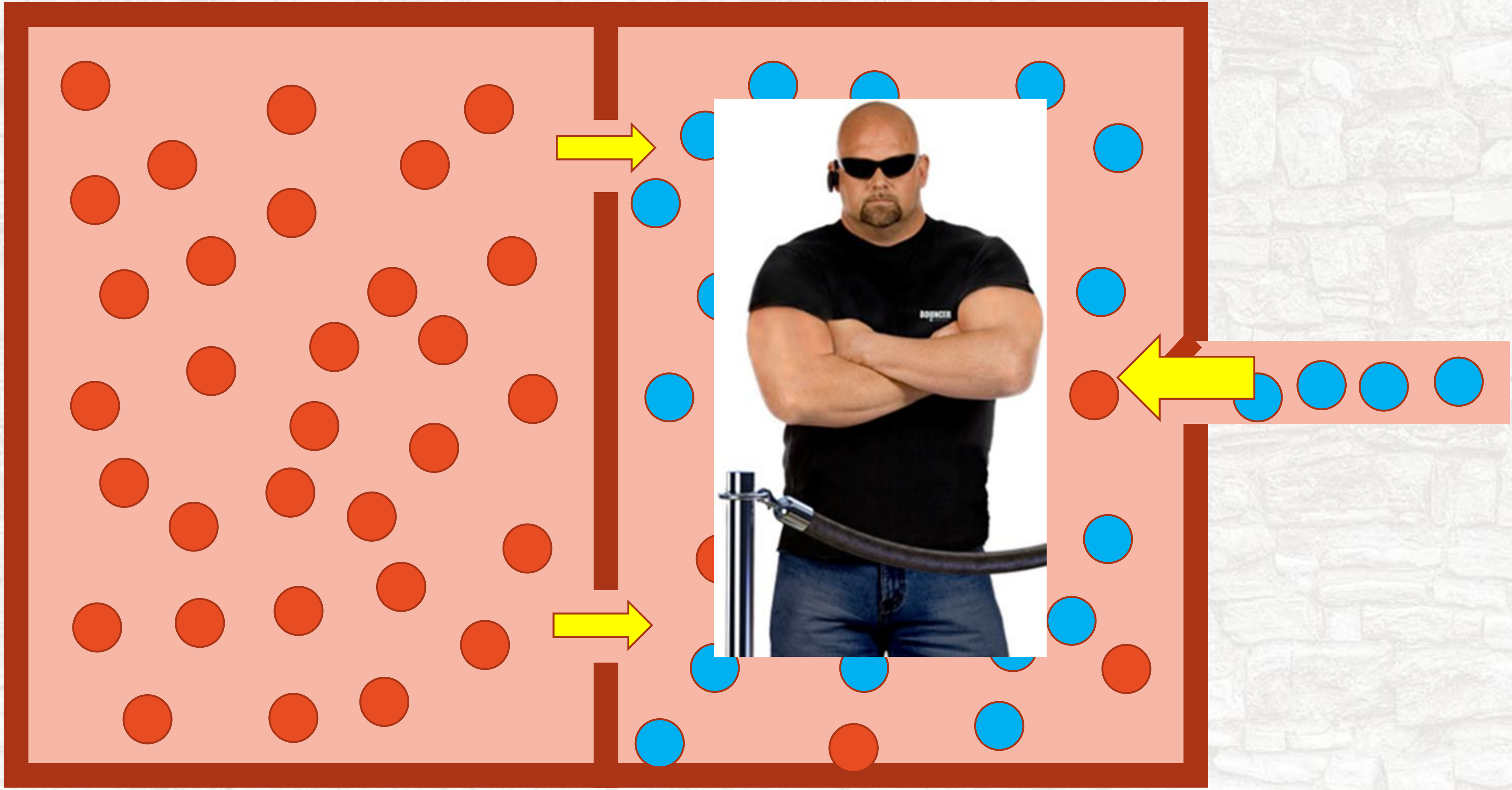

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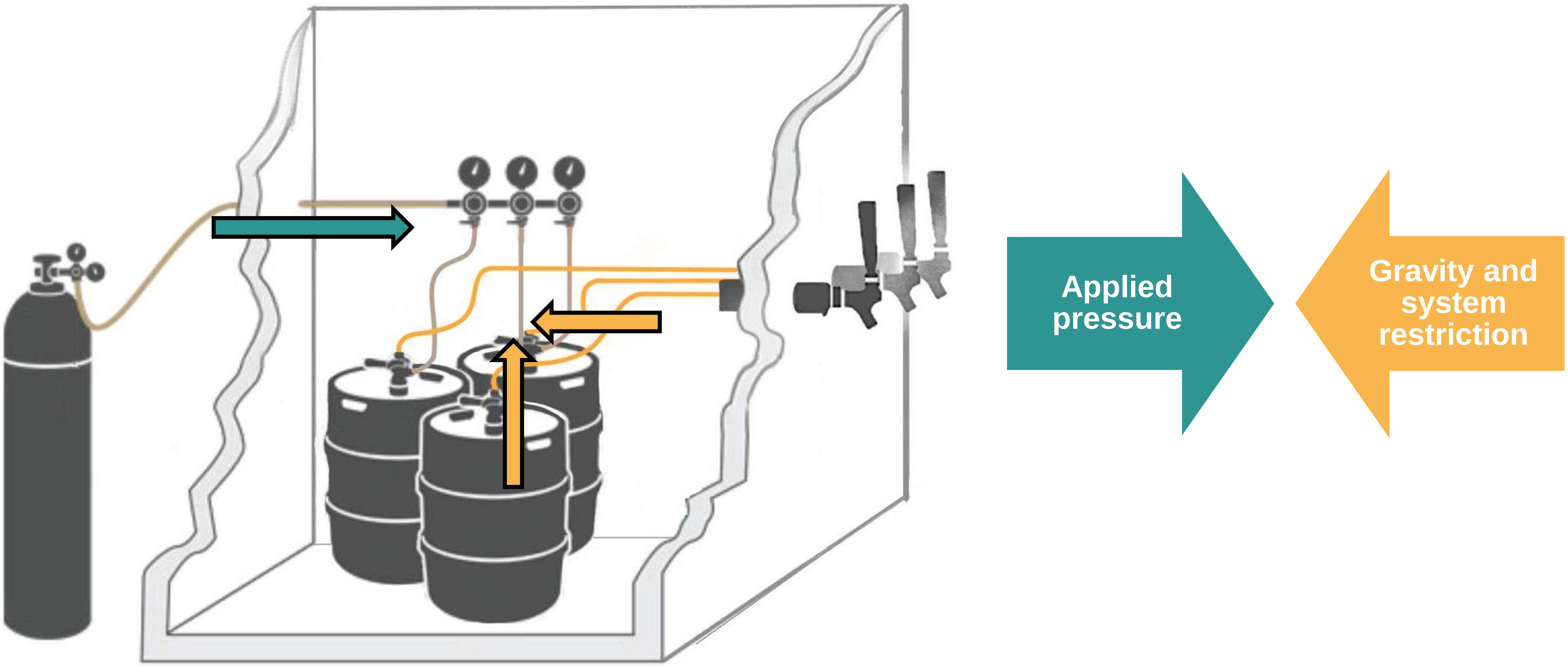
Pressure vs. Temperature

Volumes of CO2 in the beer	9 psi	**11 psi**	13 psi
34° F	2.5	2.7	2.9
38° F	2.3	**2.5**	2.7
42° F	2.1	2.3	2.5

Push beer from keg to faucet

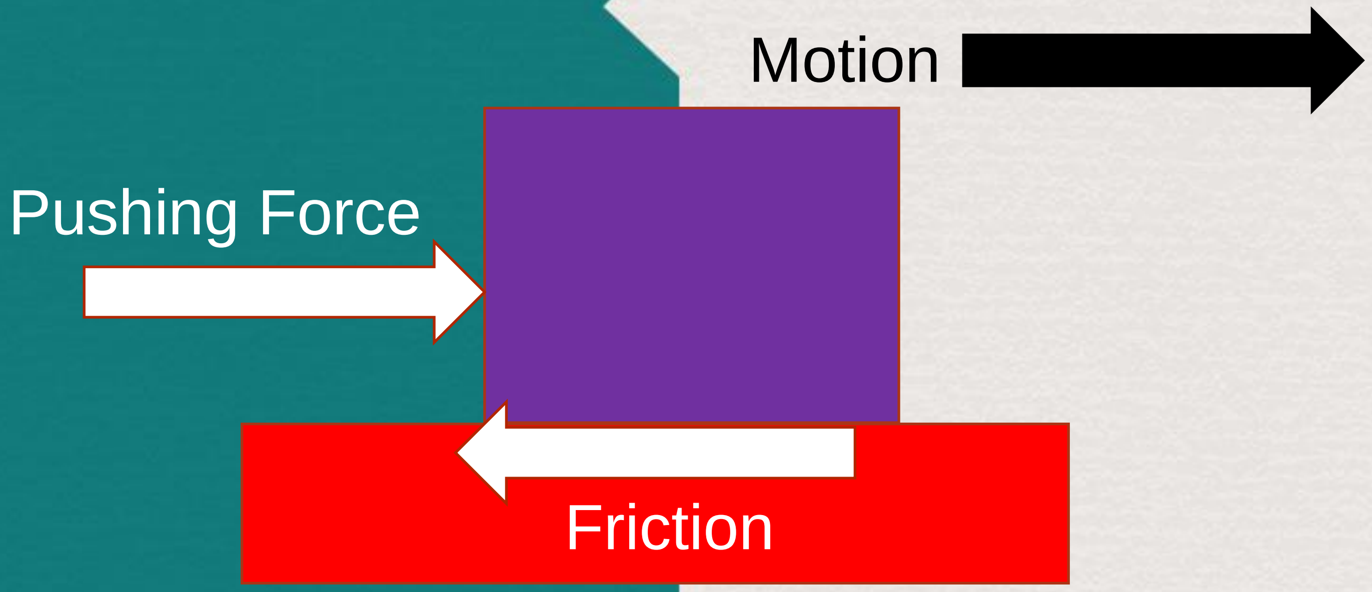


Pressure vs. Resistance

RESISTANCE is the **FRICTION** beer encounters as it moves from the keg to the faucet

APPLIED PRESSURE

The amount of PSI force to overcome resistance



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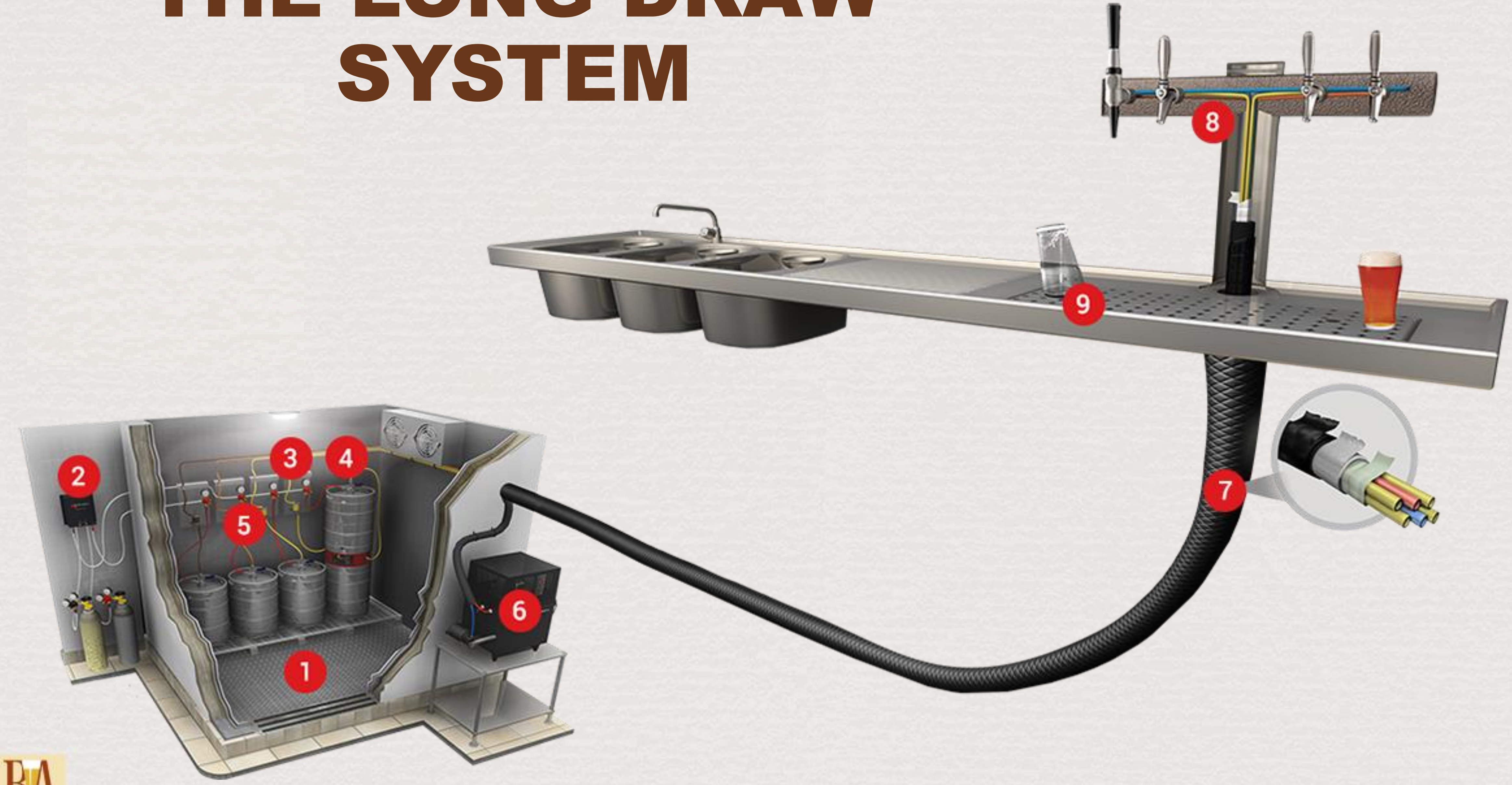
SHORT - Direct Draw

Beer is dispensed directly from storage area

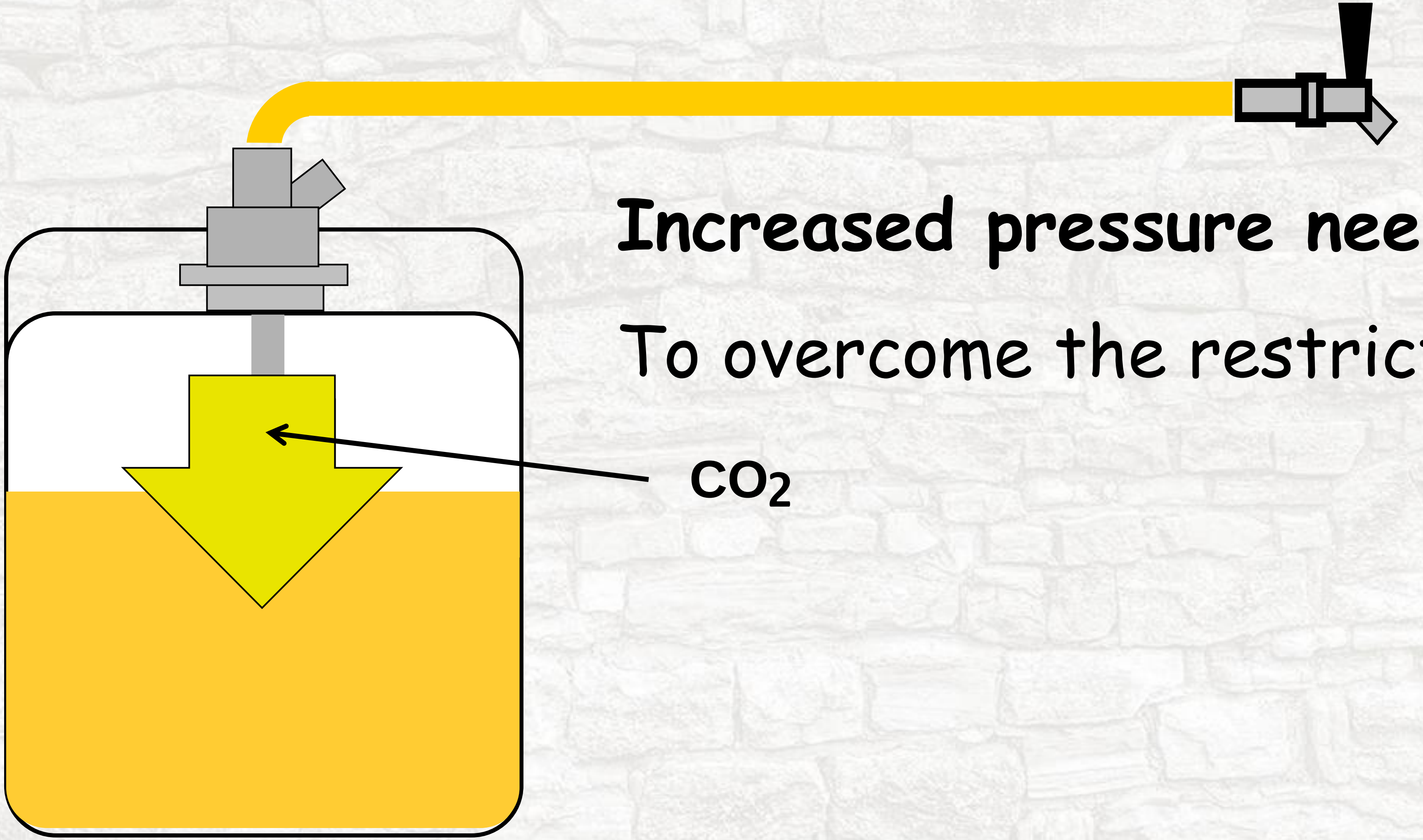
- Direct draw box
- Walk in cooler
- Event trailer

WHY ALL THAT TUBING INSIDE THE BOX?

THE LONG DRAW SYSTEM



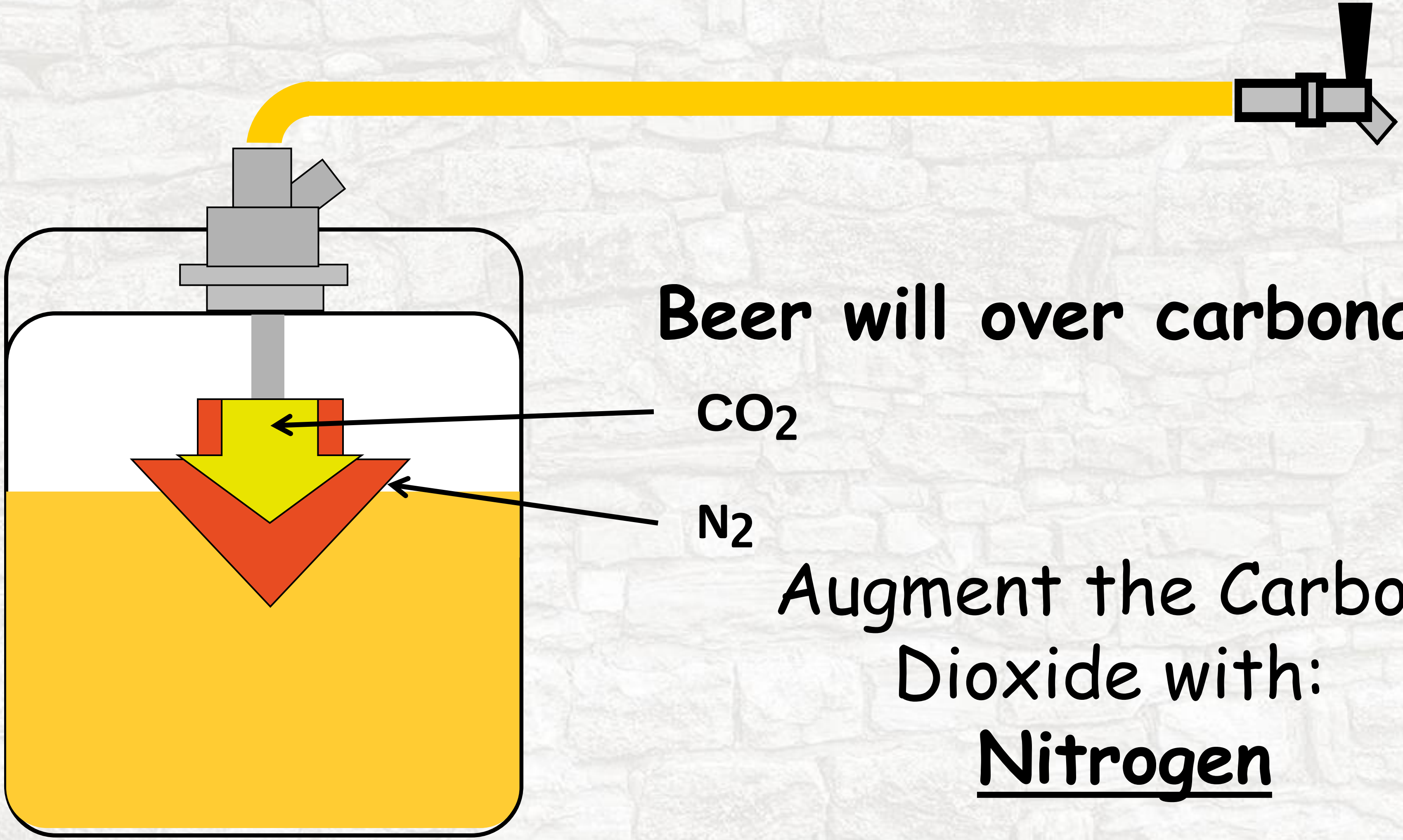
Pressure and Beer Carbonation



Increased pressure needed

To overcome the restriction

Pressure and Beer Carbonation



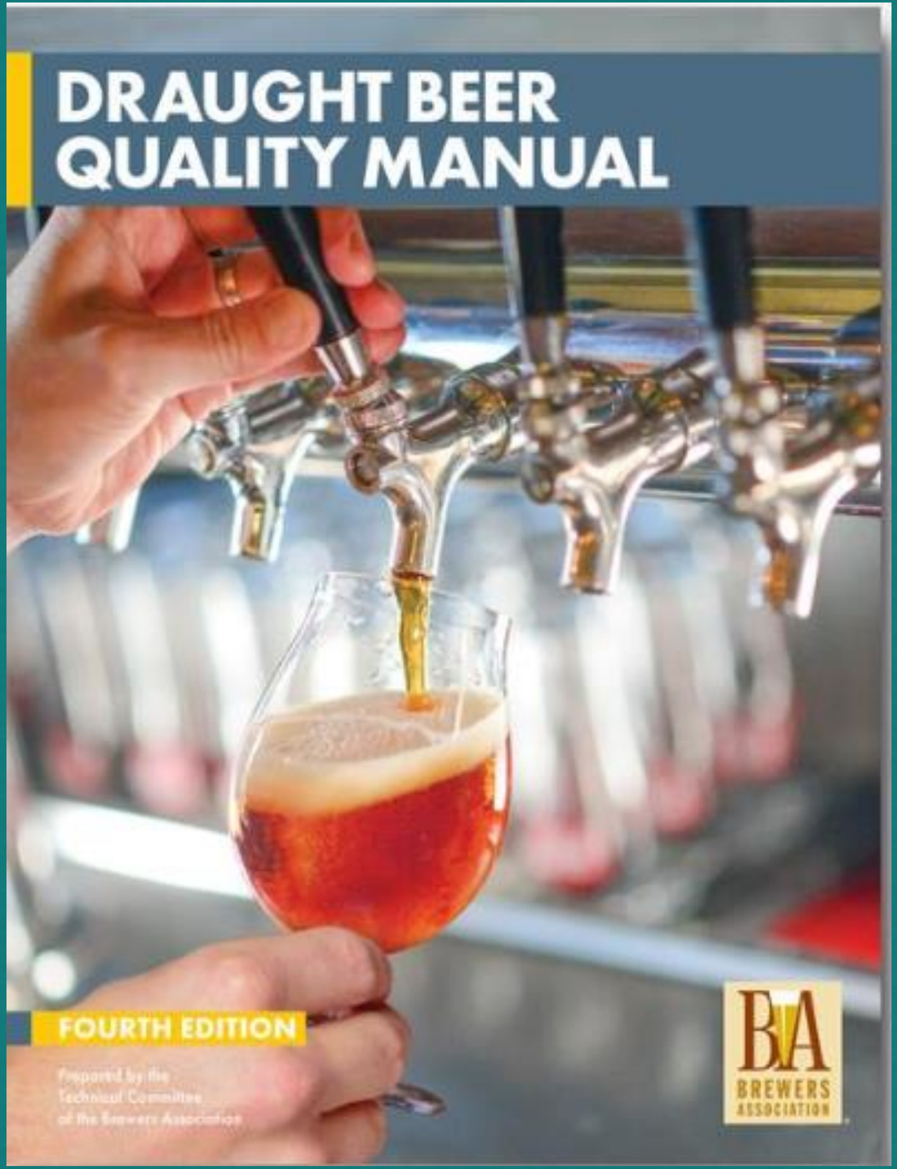
Beer will over carbonate!

CO_2

N_2

Augment the Carbon Dioxide with:

Nitrogen



BA (free) State of Art Resource

- We'll use our unique and practical 'textbook'
- Our framework is focused on attaining ***BALANCE to dispense perfect beer…***
  - Temperature
  - Pressure
  - Resistance & Components
  - ***Our options!***

Jaime's focus is on longer systems and how we realize optimal dispense…

Hagen–Poiseuille equation: …a small increase in the internal diameter of the beer line yields a significant increase in flow rate of beer

TABLE 4.1. COMMON MATERIALS AND DIAMETERS USED FOR BEER LINE AND THEIR DYNAMIC RESISTANCE VALUES

Type	Size	Resistance (lb./ft.)*	Volume (fl. oz./ft.)
Vinyl/flexible	3/16" ID	3.00	1/6
Vinyl/flexible	1/4" ID	0.85	1/3
Vinyl/flexible	5/16" ID	0.40	1/2
Vinyl/flexible	3/8" ID	0.20	3/4
Vinyl/flexible	1/2" ID	0.025	1 1/3
Barrier	1/4" ID	0.30	1/3
Barrier	5/16" ID	0.10	1/2
Barrier	3/8" ID	0.06	3/4
Stainless	1/4" OD	1.20	1/6
Stainless	5/16" OD	0.30	1/3
Stainless	3/8" OD	0.12	1/2

3. RESISTANCE

DRAUGHT SYSTEM BALANCE

When applied pressure equals system resistance, a draught system will pour clear-flowing beer at the rate of 1 gal./min., or approximately 2 fl. oz./sec.

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EXAMPLE 1: LONG-DRAW, CLOSED-REMOTE SYSTEM

This example for a long-draw, closed-remote system assumes that the dispensing gas blend mixture is already fixed; there is a vertical lift of 12 feet; and the beer trunk line total run is 120 feet. Find the operating pressure of the system, and then determine the appropriate tubing size for the trunks and choker-line tubing length.

Beer Conditions

Beer temperature: 35°F
Beer carbonation: 2.6 volumes CO_2
Dispensing gas: 70% CO_2/30% N_2 blend

First, you must determine the gauge pressure of the blended gas required to maintain the correct level of carbonation. From Appendix C, this calculation is:

$$a = \left(\frac{b + 14.7}{c}\right) - 14.7$$

where *a* is the gauge pressure of the blended gas, *b* is the ideal gauge pressure of pure CO_2 for this situation (in this case, 10.7 psi; see table B.1 in appendix B), c is the proportion of CO_2 in the blended gas, and atmospheric pressure is assumed to be 14.7 psi (i.e., sea level).

$$a = \left(\frac{10.7 + 14.7}{0.70}\right) - 14.7$$
$$= (25.4/0.70) - 14.7$$
$$= 36.3 - 14.7$$
$$= 21.6 \text{ psi (round to 22 psi)}$$

Static Resistance

Vertical lift (faucet height above center of keg): 12 ft.

Static resistance = 12 ft. × 0.5 lb./ft.
= 6.0 lb.

EXAMPLE 2: FORCED-AIR 10-FOOT RUN

In this example of a forced-air system, the beer cooler is directly over the bar. There is a 10 ft. fall from the center of the kegs to the faucet height, and the total run length is also exactly 10 ft.

Beer Conditions

Beer temperature: 33°F
Beer carbonation: 2.8 volumes CO_2
Dispensing gas: 100% CO_2

We know the gauge pressure needed to maintain carbonation is 11.7 psig (see table B.1 in Appendix B).

Static Resistance

Vertical fall: 10 ft. (faucet is 10 ft. below the center of the keg)

Static resistance = 10 ft. × –0.5 lb./ft.
= –5.0 lb.

Note that the resistance here is negative. Because there is a drop between the keg and the faucet, the static resistance is contributing to the pressure applied by the gas to the beer.

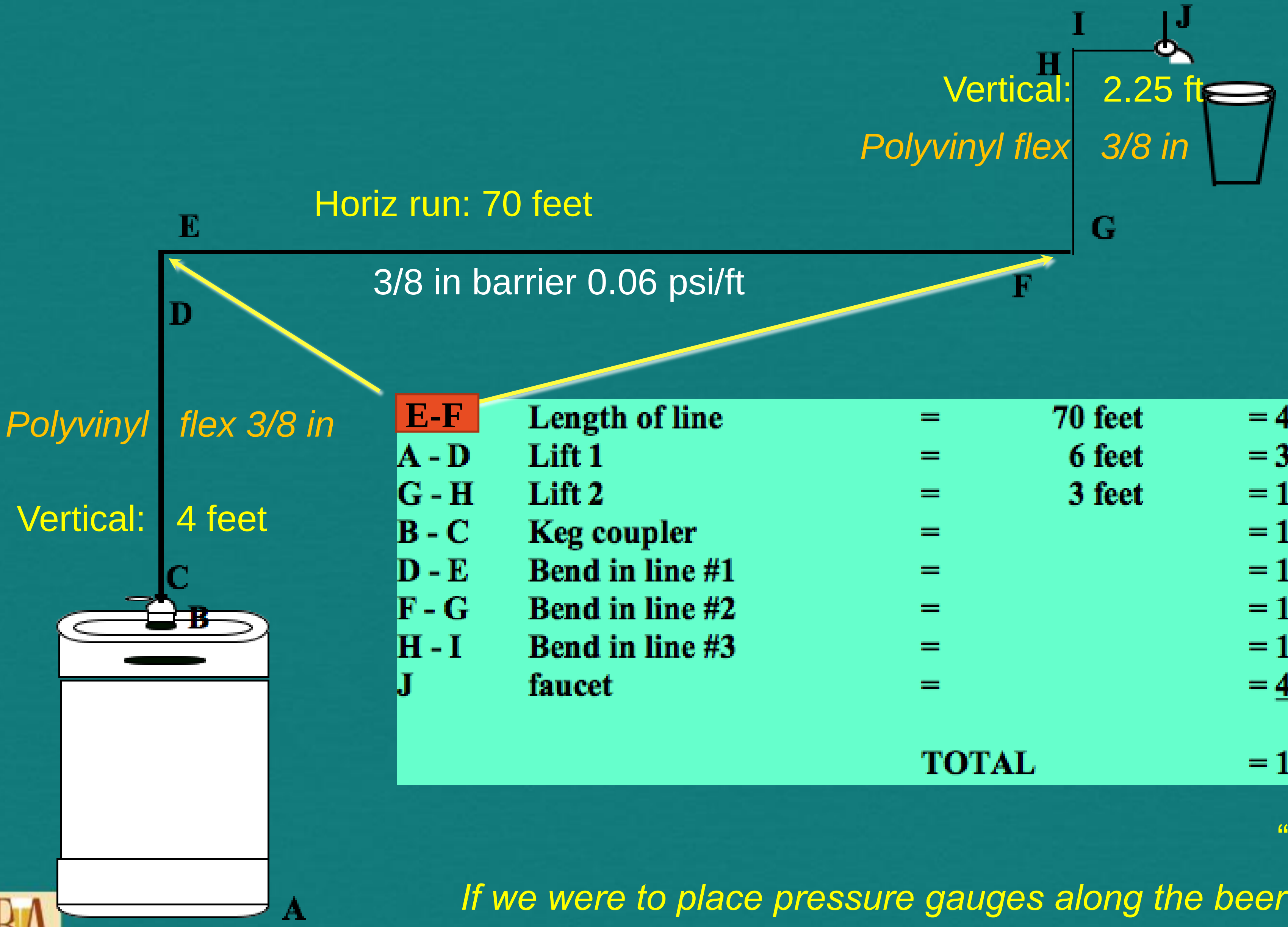
Balance

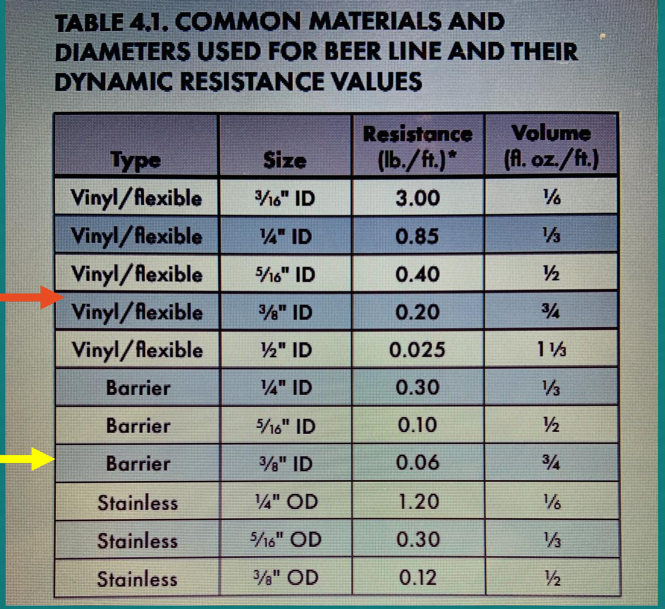
The applied dispensing pressure of 11.7 psi combined with the 5 psi of static pressure (i.e., negative 5 lb. static resistance) must be balanced by the total system resistance. This balancing has to come from dynamic resistance imparted by the beer line restriction of 16.7 lbs.

Dynamic resistance required = 11.7 + 5
= 16.7 lb.

Beer Line Restriction

Examples on Pages 41 and 42





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Vinyl/flexible	3/8" ID	0.20	3/4
Vinyl/flexible	1/2" ID	0.025	1 1/3
Barrier	1/4" ID	0.30	1/3
Barrier	5/16" ID	0.10	1/2
Barrier	3/8" ID	0.06	3/4
Stainless	1/4" OD	1.20	1/6
Stainless	5/16" OD	0.30	1/3
Stainless	3/8" OD	0.12	1/2

E-F	Length of line	=	70 feet	= 4.5 psi
A - D	Lift 1	=	6 feet	= 3.0 psi
G - H	Lift 2	=	3 feet	= 1.5psi
B - C	Keg coupler	=		= 1.0 psi
D - E	Bend in line #1	=		= 1.0 psi
F - G	Bend in line #2	=		= 1.0 psi
H - I	Bend in line #3	=		= 1.0 psi
J	faucet	=		= 4.0 psi
		TOTAL		= 17.0 psi

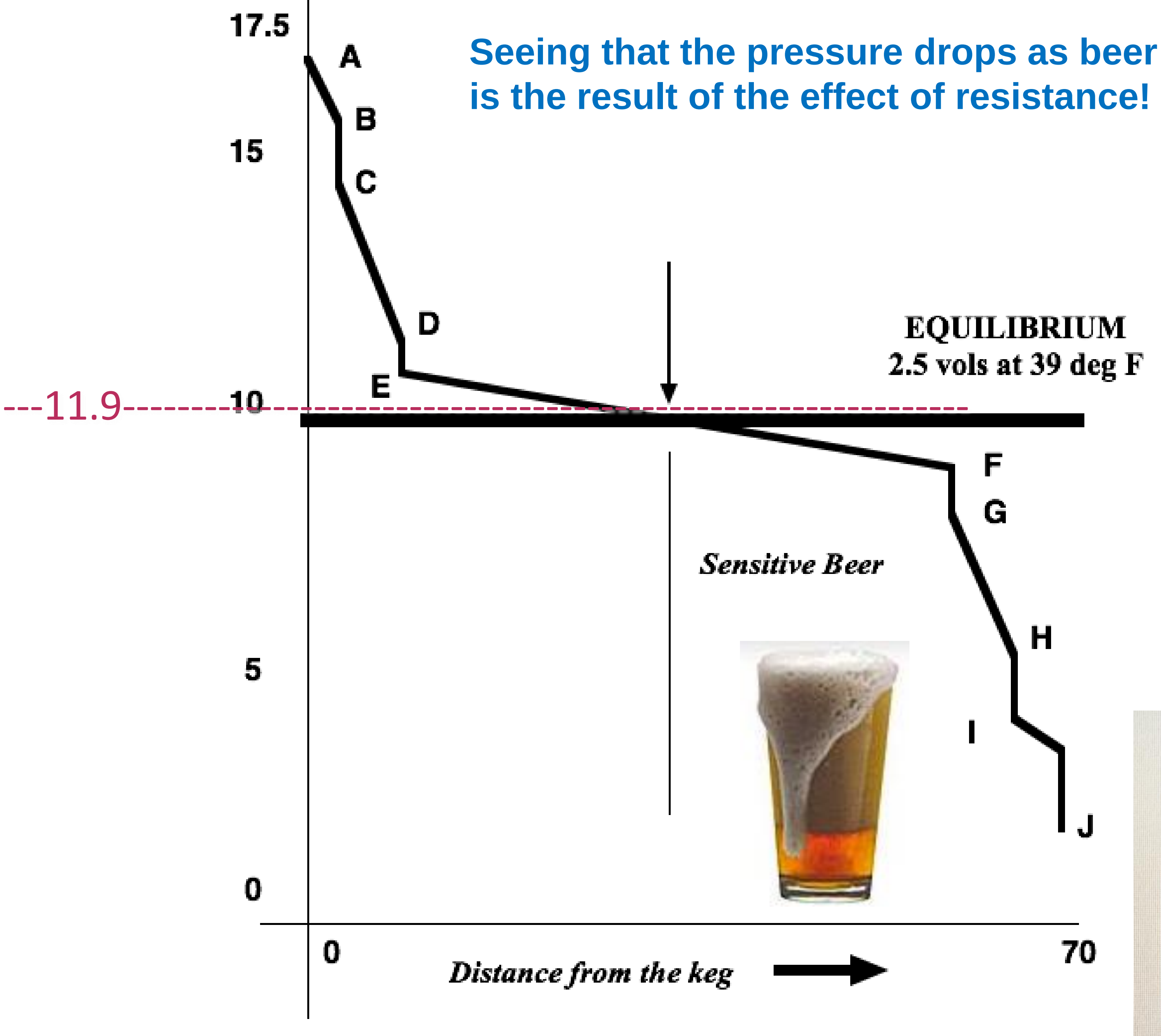
4 feet lift:
4 * 0.2 = 0.8 psig
4 * 0.5 = 2 psig
Total : 2.8 …*3 psig*

2.25 feet lift:
2.25 * 0.2 = 0.45 psig
2.25 * 0.5 = 1.12 psig
Total : 1.52 …*1.5 psig*

"System resistance"

If we were to place pressure gauges along the beer line…

Seeing that the pressure drops as beer progresses down the beerline is the result of the effect of resistance!



It's ok to interpolate!

TABLE 3.1. BEER CARBONATION AT SEA LEVEL IN VOLUMES CO_2 AS A FUNCTION OF SYSTEM TEMPERATURE AND CO_2 PRESSURE*

	CO_2 pressure (psi)		
Temp (°F)	9	11	13
34	2.5	2.7	2.9
38	2.3	2.5	2.7
42	2.1	2.3	2.5

*Pressures rounded for purposes of illustration. Do not use this table for system adjustment.

TABLE 3.2. DETERMINATION OF PURE CO_2 EQUILIBRIUM GAUGE PRESSURE (PSIG) FOR GIVEN VOLUMES OF CO_2 AND TEMPERATURE

	Volumes of CO_2										
Temp. (°F)	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1
33	5.0	6.0	6.9	7.9	8.8	9.8	10.7	11.7	12.6	13.6	14.5
34	5.2	6.2	7.2	8.1	9.1	10.1	11.1	12.0	13.0	14.0	15.0
35	5.6	6.6	7.6	8.6	9.7	10.7	11.7	12.7	13.7	14.8	15.8
36	6.1	7.1	8.2	9.2	10.2	11.3	12.3	13.4	14.4	15.5	16.5
37	6.6	7.6	8.7	9.8	10.8	11.9	12.9	14.0	15.1	16.1	17.2
38	7.0	8.1	9.2	10.3	11.3	12.4	13.5	14.5	15.6	16.7	17.8
39	7.6	8.7	9.8	10.8	11.9	13.0	14.1	15.2	16.3	17.4	18.5
40	8.0	9.1	10.2	11.3	12.4	13.5	14.6	15.7	16.8	17.9	19.0
41	8.3	9.4	10.6	11.7	12.8	13.9	15.1	16.2	17.3	18.4	19.5
42	8.8	9.9	11.0	12.2	13.3	14.4	15.6	16.7	17.8	19.0	20.1

Source: Data from *Methods of Analysis*, 5th ed. (Milwaukee, WI: American Society of Brewing Chemists, 1949).
Note: Values assume sea-level altitude. Add 1 psi for every 2000 ft. above sea level.

Table 3.2, page 38

SAME DATA…
DIFFERENT PRESENTATIONS

PSI / °F	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
32	2.15	2.27	2.38	2.48	2.59	2.70	2.80	2.90	3.00	3.11	3.21					
33	2.10	2.23	2.33	2.43	2.53	2.63	2.74	2.84	2.96	3.06	3.15	3.25				
34	2.06	2.18	2.28	2.38	2.48	2.58	2.69	2.79	2.90	3.00	3.09	3.19				
35	2.02	2.14	2.24	2.34	2.43	2.52	2.63	2.73	2.83	2.93	3.02	3.12	3.22			
36	1.98	2.09	2.19	2.29	2.38	2.47	2.57	2.67	2.77	2.86	2.96	3.05	3.15	3.24		
37	1.94	2.04	2.14	2.24	2.33	2.42	2.52	2.62	2.71	2.80	2.90	3.00	3.09	3.18	3.27	
38	1.90	2.00	2.10	2.20	2.29	2.38	2.48	2.57	2.66	2.75	2.85	2.94	3.03	3.12	3.21	
39	1.86	1.96	2.06	2.15	2.25	2.34	2.43	2.52	2.61	2.70	2.80	2.89	2.98	3.07	3.16	3.25
40	1.83	1.92	2.01	2.10	2.20	2.30	2.39	2.47	2.56	2.65	2.75	2.84	2.93	3.01	3.10	3.19
41	1.79	1.88	1.97	2.06	2.16	2.25	2.34	2.43	2.52	2.60	2.70	2.79	2.88	2.96	3.05	3.14
42	1.75	1.85	1.94	2.02	2.12	2.21	2.30	2.39	2.48	2.56	2.65	2.74	2.83	2.91	3.00	3.09
43	1.72	1.81	1.90	1.99	2.08	2.17	2.26	2.34	2.43	2.52	2.61	2.69	2.78	2.86	2.95	3.04
44	1.69	1.78	1.87	1.95	2.04	2.13	2.22	2.30	2.39	2.47	2.56	2.64	2.73	2.81	2.90	2.99
45	1.66	1.75	1.84	1.91	2.00	2.08	2.17	2.26	2.34	2.42	2.51	2.60	2.69	2.77	2.86	2.94

sea level" CO_2 chart

"Atmospheric pressure decreases by about 1 psi per 2000 feet gained in elevation. To account for this loss of pressure, add 1 psi to the regulator setting for every 2000 feet gained in elevation"--*page 18*

MIXED GAS….

Nitrogen is sparingly soluble

Provides motive force without increasing carbonation

Appendix C:
CARBONATION, BLENDED GAS, GAS LAWS, AND PARTIAL PRESSURES

- CO_2 = 100% CO_2
- …so 10 psig applied = 10 psig CO2
- 40% N_2 + 60% CO_2 = 60% CO_2
- …so 10 psig applied = 6 psig CO2

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Determination of needed Mixed Gas Composition: calculation

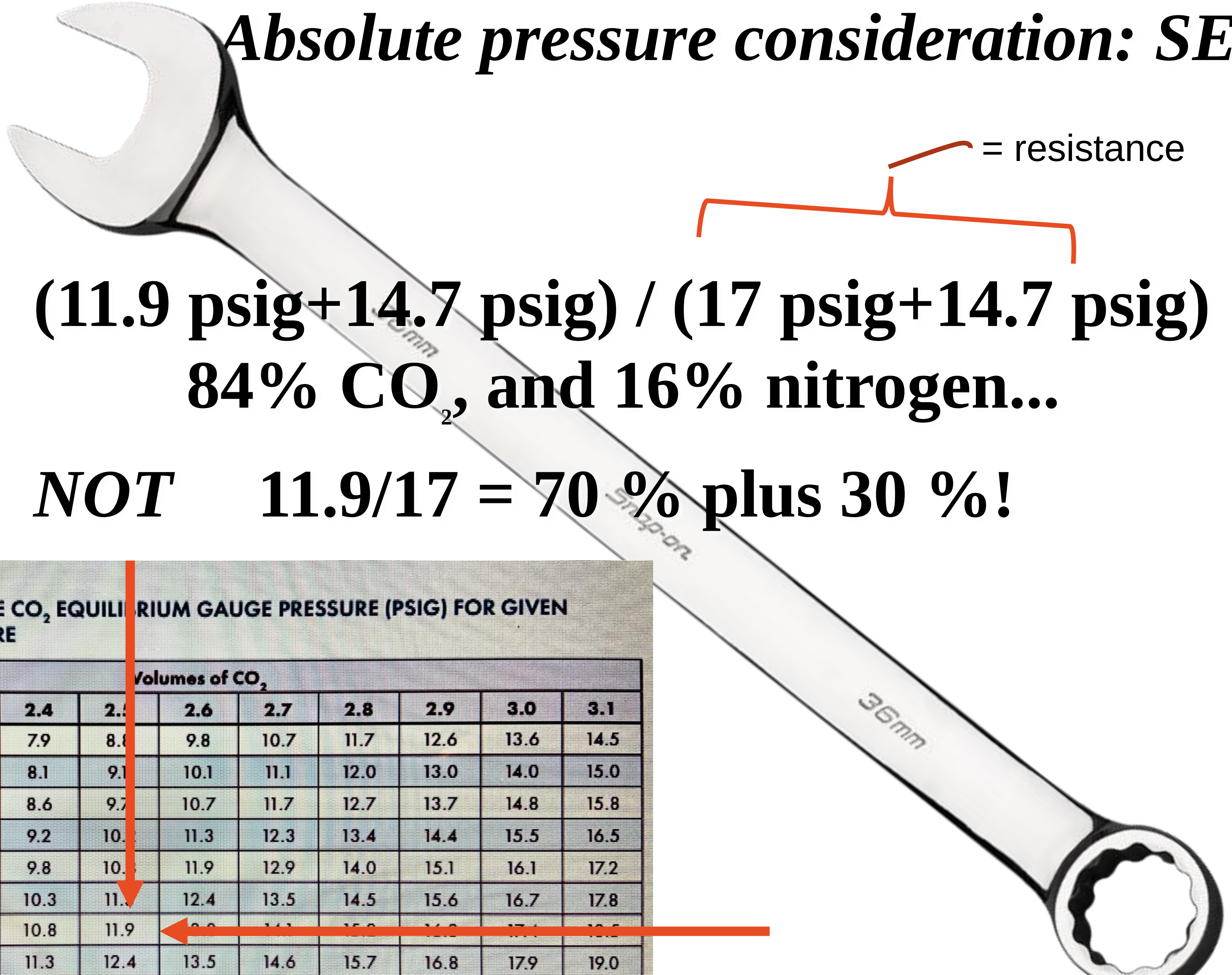
1. Determine equilibrium *absolute* pressure[a] to maintain proper level of CO_2.

2. Determine the total *absolute* gas pressure to move the beer to the tap.

3. Divide the equilibrium absolute CO_2 pressure ("1") by the total absolute gas pressure ("2") to obtain the CO_2 portion of the gas.

[a]absolute pressure = gauge pressure + atmospheric pressure (i.e. 14.7 psi @ sea level; 12.1 psi in Denver; 9.7 psi @ 10,000 ft)

Example 1… our 2.5 vol ale at 39 deg F



Absolute pressure consideration: SEA LEVEL

= resistance

(11.9 psig+14.7 psig) / (17 psig+14.7 psig) =

84% CO_2, and 16% nitrogen...

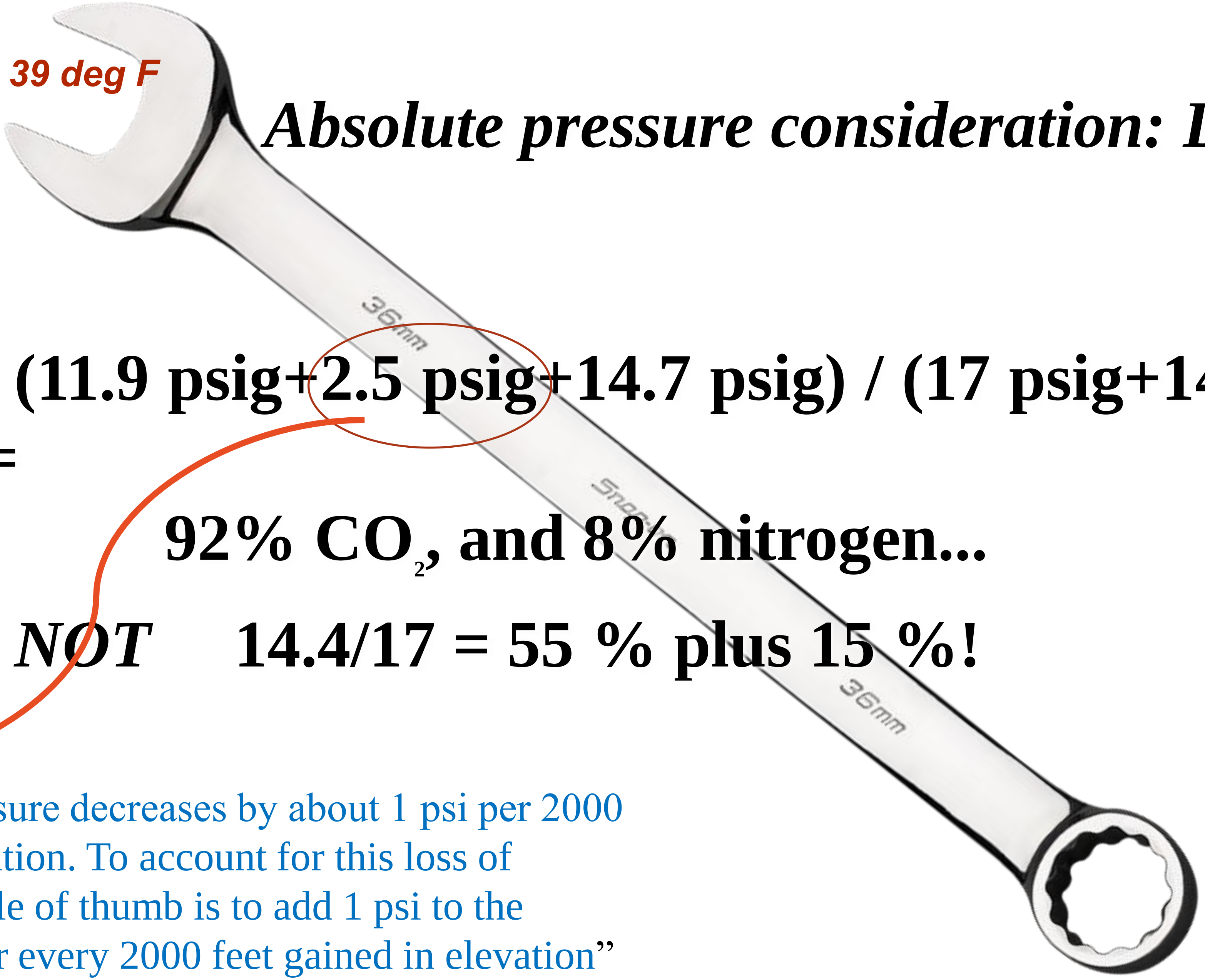
NOT **11.9/17 = 70 % plus 30 %!**

TABLE 3.2. DETERMINATION OF PURE CO_2 EQUILI[illegible]RIUM GAUGE PRESSURE (PSIG) FOR GIVEN VOLUMES OF CO_2 AND TEMPERATURE

	Volumes of CO_2										
Temp. (°F)	2.1	2.2	2.3	2.4	2.[illegible]	2.6	2.7	2.8	2.9	3.0	3.1
33	5.0	6.0	6.9	7.9	8.[illegible]	9.8	10.7	11.7	12.6	13.6	14.5
34	5.2	6.2	7.2	8.1	9.[illegible]	10.1	11.1	12.0	13.0	14.0	15.0
35	5.6	6.6	7.6	8.6	9.[illegible]	10.7	11.7	12.7	13.7	14.8	15.8
36	6.1	7.1	8.2	9.2	10.[illegible]	11.3	12.3	13.4	14.4	15.5	16.5
37	6.6	7.6	8.7	9.8	10.[illegible]	11.9	12.9	14.0	15.1	16.1	17.2
38	7.0	8.1	9.2	10.3	11.[illegible]	12.4	13.5	14.5	15.6	16.7	17.8
39	7.6	8.7	9.8	10.8	11.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	8.0	9.1	10.2	11.3	12.4	13.5	14.6	15.7	16.8	17.9	19.0

Example 1
…our 2.5 vol ale at 39 deg F

Absolute pressure consideration: DENVER



(11.9 psig+2.5 psig+14.7 psig) / (17 psig+14.7 psig)

=

92% CO_2, and 8% nitrogen...

NOT **14.4/17 = 55 % plus 15 %!**

"Atmospheric pressure decreases by about 1 psi per 2000 feet gained in elevation. To account for this loss of pressure, a good rule of thumb is to add 1 psi to the regulator setting for every 2000 feet gained in elevation"

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GAS BLENDERS

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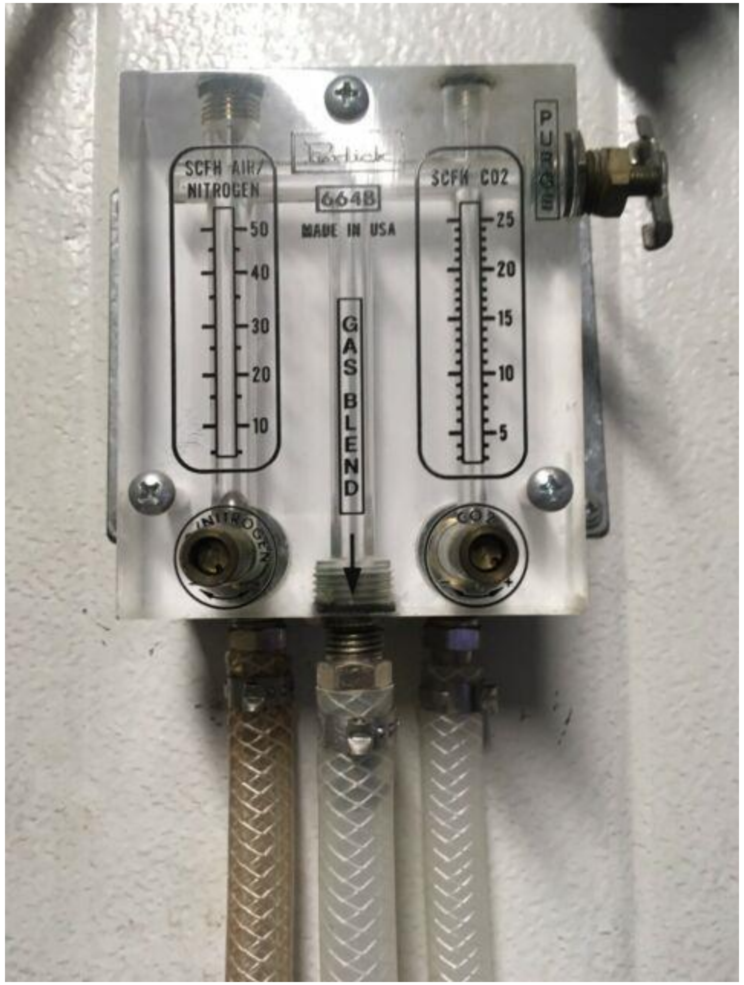


On-site nitrogen generators

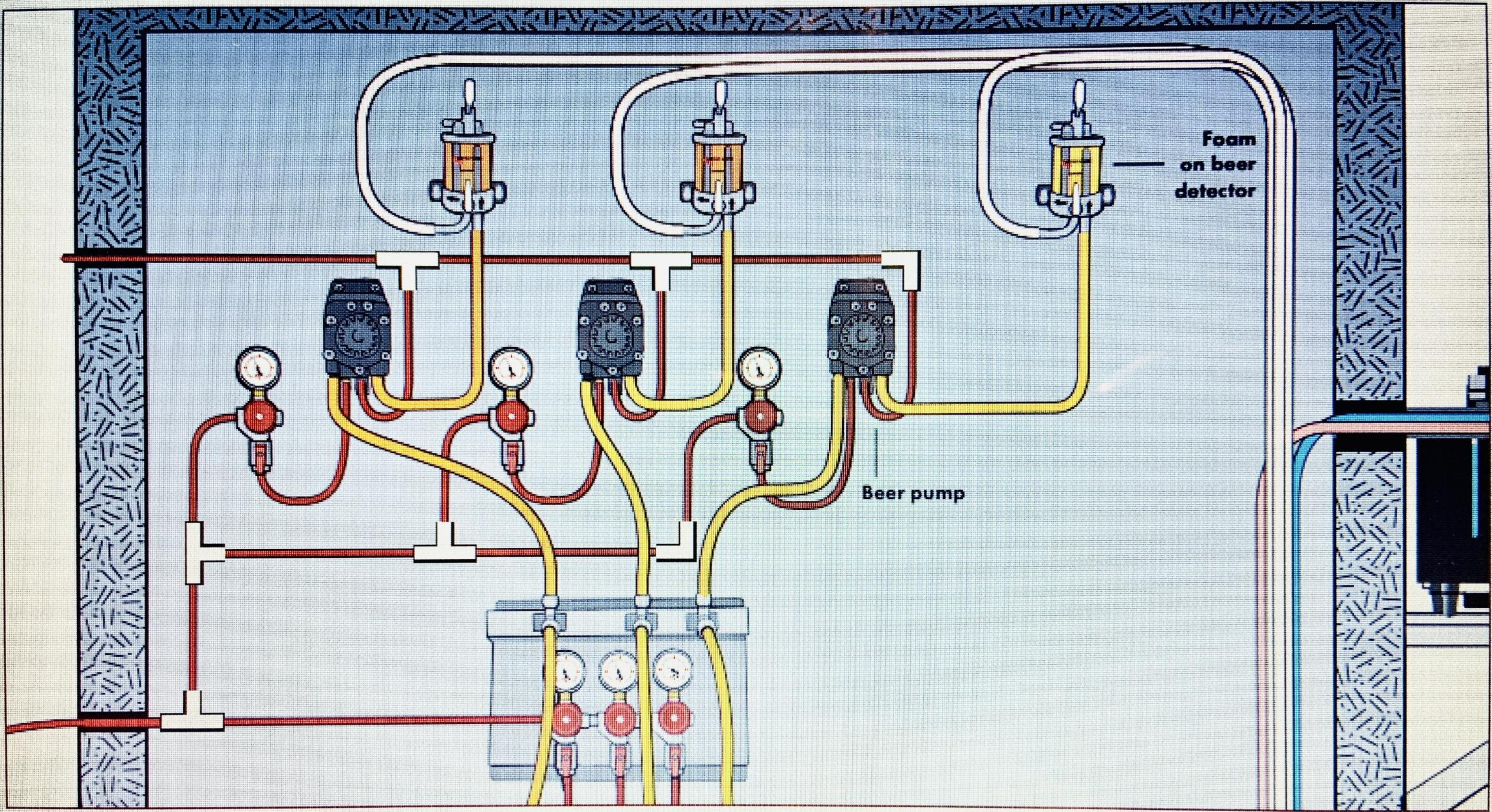
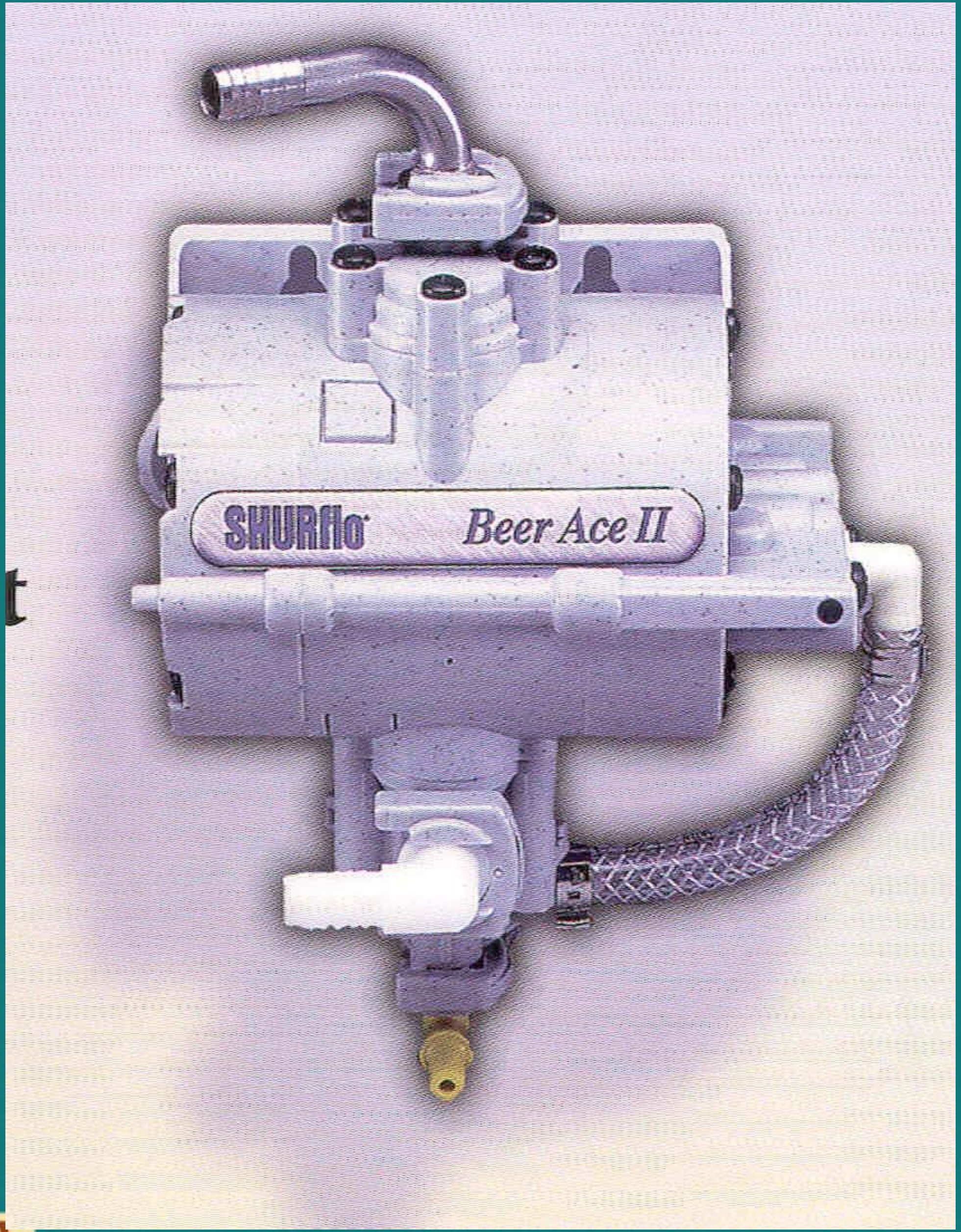
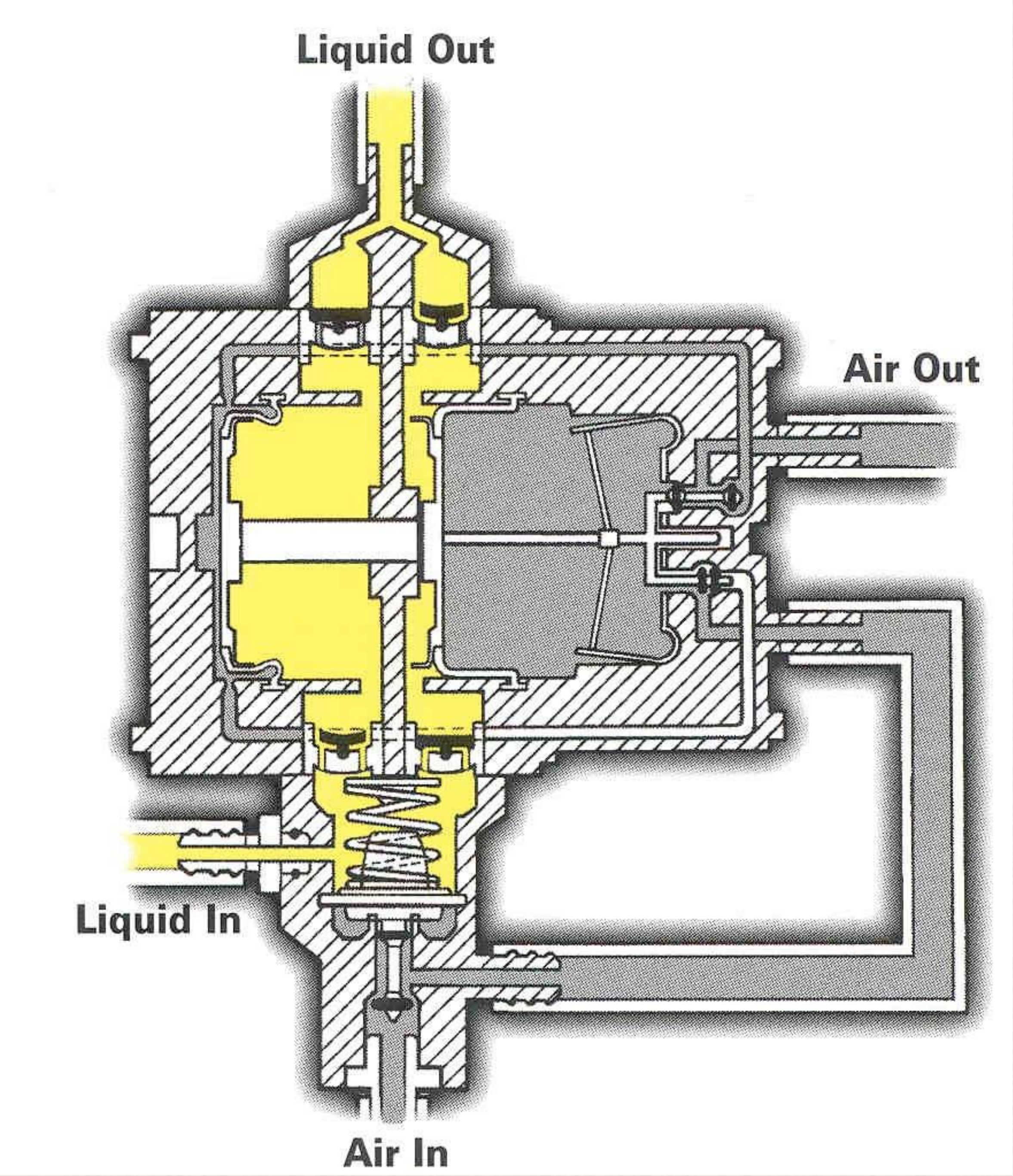
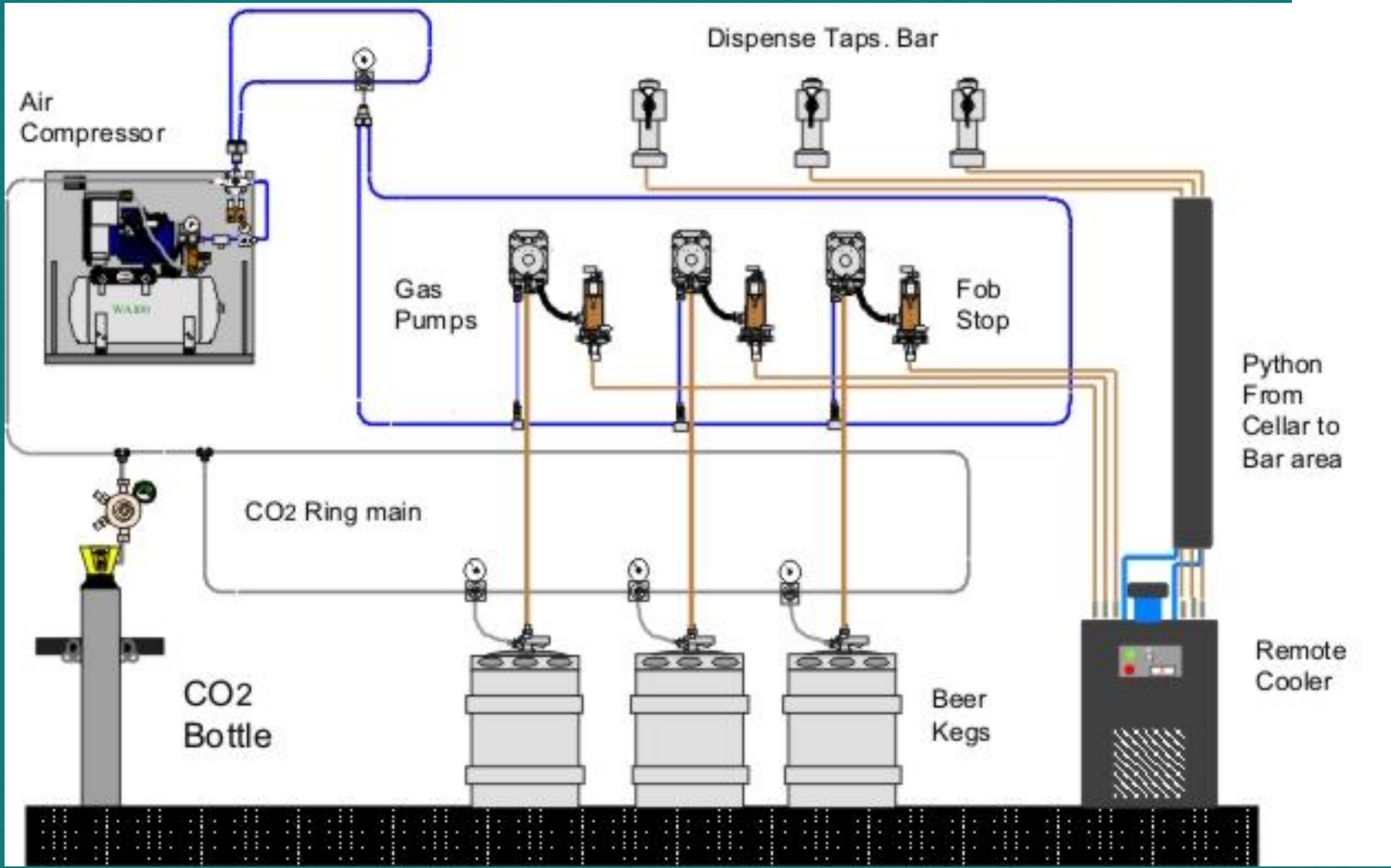


Figure 4.8. Beer pumps and FOBs in walk-in cooler.

8.50 x 11.00 in


SHURflo
Beer Ace II


Liquid Out
Air Out
Liquid In
Air In



Dispense Taps. Bar
Air Compressor
Gas Pumps
Fob Stop
Python From Cellar to Bar area
CO2 Ring main
CO2 Bottle
Beer Kegs
Remote Cooler

FLOJET
FLOJET

THANK YOU!

ALAMO BEER COMPANY
SAN ANTONIO, TEXAS

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· ESTD. 1984 ·

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