



chapter 5

a matter of balance

all beer contains dissolved carbon dioxide. Brewers control the amount of it in each beer to influence the overall character of the beer. For beer servers, its presence can be both a blessing and a curse.

Ideally, we deliver beer to the consumer's glass while maintaining its CO₂ content. When this happens, the beer pours "clear" without foaming and we create a pleasing head on the beer without waste. But too many draught systems fail at this goal. Foamy beer comes out the faucet and servers overflow the glass trying to get a decent pour. Beer quality and retailer economics both suffer.

To put beautiful, high-quality beer in the glass and maximize retailer profits, we must consider the concepts of balance and how they apply to draught systems. This chapter introduces the concepts then looks at some practical examples.

Components of Balance

To understand and manage draught system balance, we'll look at four measurements: beer temperature, applied pressure, resistance and beer carbonation level.

We measure **beer temperature** in degrees Fahr-

enheit. Just remember that we want to know the temperature of the actual beer. Since it takes a keg of beer many hours to stabilize at the temperature of the cooler, the beer temperature can vary quite a bit from the setting of the thermostat in your cooler. (See the section entitled "Cold Storage and Proper Chilling of Kegs before Serving" for further details.)

We measure **applied pressure** in pounds per-square-inch-gauge abbreviated as "psig," or often just "psi." The pressure applied to any keg is shown by the gas regulator attached to it.

Resistance comes from components like the beer line and changes in elevation as the beer flows from keg to glass. We measure resistance in pounds and account for two types: static and dynamic.

Static resistance comes from the effect of gravity, which slows beer being pushed to a level above the keg. Each foot of increased elevation adds approximately 0.5 pound of resistance to a system. If the beer travels to a faucet below the keg level, each foot of decreased elevation subtracts 0.5 pound of resistance from the system. The gravity factor remains the same regardless of tube length, bends, junctions or other

configuration issues. When the keg and faucet heads are at the same height, there is no static resistance and this factor has a value of zero.

Dynamic resistance comes from all the beer components in a system. Items like couplers and faucets have specified resistance values. Beer lines provide a certain resistance for each foot the beer travels. We have mentioned beer lines made from vinyl, barrier tubing and even stainless steel. Each type and diameter has a different resistance (stated as “restriction”) to beer flow as shown in the nearby chart. (Note: This chart is provided as an example only. Please consult your equipment manufacturer for values suited to your beer lines and system components.)

BEER TUBING			
Type	Size	Restriction	Volume
Vinyl	3/16" ID	3.00 lbs/ft	1/6 oz/ft
Vinyl	1/4" ID	0.85 lbs/ft	1/3 oz/ft
Vinyl	5/16" Id	0.40 LBS/ft	1/2 oz/ft
Vinyl	3/8: ID	0.20 lbs/ft	3/4 oz/ft
Vinyl	1/2" ID	0.025 lbs/ft	1-1/3 oz/ft
Barrier	1/4" ID	0.30 lbs/ft	1/3 oz/ft
Stainless	5/16" ID	0.10 lbs/ft	1/2 oz/ft
Stainless	3/8" ID	0.06 lbs/ft	3/4 oz/ft
Stainless	1/4" OD	1.20 lbs/ft	1/6 oz/ft
Stainless	5/16" OD	0.30 lbs/ft	1/3 oz/ft
Stainless	3/8" OD	0.12 lbs/ft	1/2 oz/ft

Brewers measure beer **carbonation** in volumes of CO₂. A typical value might be 2.5 volumes of CO₂ meaning literally that 2.5 keg-volumes of uncompressed CO₂ have been dissolved into one keg of beer. Carbonation levels in typical beers run from 2.2 to 2.8 volumes of CO₂, but values can range from as little as 1.2 to as high as 4.0 in specialty beers.

Now that we understand the concepts of beer temperature, applied pressure, resistance and carbonation, let's look at how they all interact in a draught system.

Carbonation Dynamics

Beer carbonation responds to changes in storage and serving conditions. Let's consider an average keg with a carbonation of 2.5 volumes of CO₂ and see what happens when conditions change.

Beer temperature and the CO₂ pressure applied through the coupler influence the amount of CO₂ dissolved in any keg of beer. At any temperature, a specific pressure must be applied to a keg to maintain the carbonation established by the brewery. If temperature or pressure varies, carbonation levels will change. Here's an example.

Beer in a keg at 38°F needs a pressure of 11 psi to maintain 2.5 volumes of CO₂ as the beer is served. So long as the temperature and pressure remain constant, the beer maintains the same carbonation level.

		CO ₂ pressure		
		9 psi	11 psi	13 psi
Temp	34 °F	2.5	2.7	2.9
	38 °F	2.3	2.5*	2.7
	42 °F	2.1	2.3	2.5

* Pressures rounded for purposes of illustration.
Do not use these charts for system adjustment.

If the temperature of the beer changes, so does the required internal keg pressure. Here we see that if the pressure remains at 11 psi but the temperature of the beer rises to 42°F, carbonation will begin to move from the beer to the headspace. Over a few days and as the keg empties, the overall carbonation in the beer drops to 2.3 volumes of CO₂.

		CO ₂ pressure		
		9 psi	11 psi	13 psi
Temp	34 °F	2.5	2.7	2.9
	38 °F	2.3	2.5*	2.7
	42 °F	2.1	2.3	2.5

Alternately, if the temperature remains at 38°F, but the CO₂ pressure increases to 13 psi, then the carbonation level of the beer in the keg will increase as the beer slowly absorbs additional CO₂.

		CO ₂ pressure		
		9 psi	11 psi	13 psi
Temp	34 °F	2.5	2.7	2.9
	38 °F	2.3	2.5*	2.7
	42 °F	2.1	2.3	2.5

The “ideal gauge pressure” for a beer is the pressure at which CO₂ is not diffusing from beer into the headspace and excess CO₂ is not absorbing in the beer. This value varies from account to account depending upon factors such as temperature, altitude and carbonation level of the beer. Because beer carbonation can vary with the temperature of your cooler and the pressure applied to the keg, you must take care to maintain steady values suited to your system and beers.

You can determine ideal gauge pressure for pure CO₂ from the chart shown in the table below and in Appendix B. If you do not know the carbonation level in the beer, you can estimate it using the procedure found in Appendix B.

System Balance

So far we’ve seen what happens to a beer’s *carbonation* in the keg as the result of *applied pressure* and *temperature*. But of course beer must travel from the keg to the glass and along the way it encounters the fourth measure we introduced, namely *resistance*. The beer line and changes in elevation impart resistance to the flow of beer from the keg to the faucet.

The pressure applied to the keg overcomes this resistance and drives the beer through the system and to the customer’s glass. To achieve proper flow and beer quality, the pressure applied to the keg must equal the total resistance of the draught system.

We have already seen that the pressure applied to the keg needs to be matched to the carbonation level

Draught System Balance

When applied pressure equals resistance, a draught system will pour clear-flowing beer at the rate of 2 ounces per second.

Determination of CO₂ application pressure given volumes of CO₂ 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	PSI	PSI	PSI	PSI	PSI	PSI	PSI	PSI	PSI	PSI	PSI
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

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

of the beer. This means we have two different factors to consider when deciding the pressure to apply to a keg. This creates a problem when the resistance of the system calls for more—or less—pressure than is needed to maintain the carbonation of the beer. To prevent conflicts, draught technicians design system resistance to match the pressure applied to the beer.

Designing For Resistance

While the individual components in any draught system have a fixed resistance value, draught system designers select from a variety of choices to create systems with a target total resistance value. For instance, a 20-ft. run of 1/4" internal diameter vinyl beer line gives a total resistance of 17 psi while 5/16" barrier tubing of the same length only generates 2 pounds of resistance.

Thus, any draught system can be designed to operate under a range of applied pressure values. Whenever possible, the operating pressure will be set to maintain the carbonation of the beer being served.

Nitro Pour Pressure

Most nitrogenated beers are poured through a special faucet that, because of its added restriction, requires the beer to be dispensed between 30 – 40 psi.

Unfortunately, in some systems this doesn't work. Consider the resistance created by long beer lines and climbs of two or more floors. Even with the lowest resistance components, the applied pressures for these systems often exceed that needed to maintain beer carbonation. These systems must use mixed gas or beer pumps to overcome the problem.

Mixed Gas

As we have seen, beer readily absorbs carbon dioxide. Any change in CO₂ pressure on a beer results in a change in the carbonation of the beer. Nitrogen is different. Beer does not absorb nitrogen gas to any significant degree. This means we can apply nitrogen pressure to beer without changing the properties of the beer. Thus, in high resistance draught systems, we use a mixture of CO₂ and nitrogen to achieve two objectives: 1) maintain proper beer carbonation and 2) overcome the system resistance to achieve a proper pour.

The exact mix of CO₂ and nitrogen depends on all the factors we have discussed: beer temperature and carbonation, system resistance and the total applied pressure that's required. Those interested in the details of these calculations can see Appendix C. While some systems use a premixed blend, other installations may require a custom mix created from separate nitrogen and CO₂ tanks by an on-site gas blender.

Dispense Goals

A balanced draught system delivers clear-pouring beer at the rate of two ounces per second. This means it takes about eight seconds to fill a pint glass and about one minute to pour one gallon of beer.

Some high-volume settings benefit from faster pours. If you try to achieve faster pours by increasing the gas pressure you will create over-carbonated beer, foam at the taps and get slower pours. If you need faster pour flows, your draught technician can alter the system resistance to achieve this result. Gas pressure, once set for a particular beer, remains constant and should never be adjusted to alter the flow rate of the beer.

Balancing Draught Systems

Having reviewed all the concepts behind draught system balance, let's examine three example systems to see how these variables are adjusted to create balanced draught systems in several different settings. ■

Example 1: Direct-Draw System

- Beer Conditions:
 - Beer temperature: 38°F
 - Beer carbonation: 2.8 volumes of CO₂ per volume of beer
 - Dispense gas: 100% CO₂
 - Gas pressure needed to maintain carbonation = 14.5 psig
- Static Pressure:
 - Vertical lift = 5 ft. (Tap 5 ft. above the center of the keg)
 - Static resistance from gravity = 5 ft. x 0.5 pounds/foot = 2.5 pounds
- Balance
 - Applied pressure of 14.5 psi must be balanced by total system resistance
 - Since static resistance equals 2.5 psi, a total of 12 pounds of system resistance will be needed:
Restriction = 14.5 – 2.5 = 12 pounds
 - To achieve this: 4 ft. of 3/16" polyvinyl beer line (choker) @ 3 pounds per foot = 12 pounds

Example 2: Long-Draw, Closed-Remote System

- Beer Conditions:
 - Beer temperature: 35°F
 - Beer carbonation: 2.6 volumes of CO₂ per volume of beer
 - Dispense gas: 65% CO₂ / 35% nitrogen blend
 - Gas pressure needed to maintain carbonation = 22 psig
- Static Pressure:
 - Vertical lift = 12 ft. (Tap 12 ft. above the center of the keg)
 - Static resistance from gravity = 12 ft. x 0.5 pounds/foot = 6.0 pounds
- Balance
 - Applied pressure of 22 psi must be balanced by total system resistance
 - Since static resistance equals 6 pounds, it has a total of 16 pounds of system resistance
 - Restriction = 22 – 6 = 16 pounds
(120 ft. of 5/16" barrier @ 0.1 pounds per foot = 12 pounds & 1.25" choker = 4 pounds)

Example 3 of Forced-Air, 10-ft. run

- Beer Conditions:
 - o Beer temperature: 33°F
 - o Beer carbonation: 2.8 volumes of CO₂ per volume of beer
 - o Dispense gas: 100% CO₂
 - o Gas pressure needed to maintain carbonation = 10 psig
- Static Pressure:
 - o Vertical fall = 10 ft. (Tap is 10 ft. below the center of the keg)
 - o Static resistance from gravity = 10 ft. x -0.5 pounds/foot = -5.0 pounds
- Balance
 - o Applied pressure of 10 psi must be balanced by total system resistance of 15 pounds
 - o Since static resistance equals -5 pounds, the system has a total of 15 pounds of resistance
 - o Restriction = 10 – (-5) = 15 pounds
 (10 ft. of 1/4" barrier @ 0.3 pounds per foot = 3 pounds & 4 ft. of choker = 12 pounds)
 = 3 pounds + 12 pounds = 15 pounds

Direct Draw Draught System Balance

At 38°F

Carbonation (Volumes CO ₂)	2.3	2.4	2.5	2.6	2.7	2.8	2.9
psig Applied CO ₂	9.2	10.3	11.3	12.4	13.5	14.5	15.6
3/16" Vinyl beer line length	3'3"	3'5"	3'9"	4'2"	4'6"	4'10"	5'7"