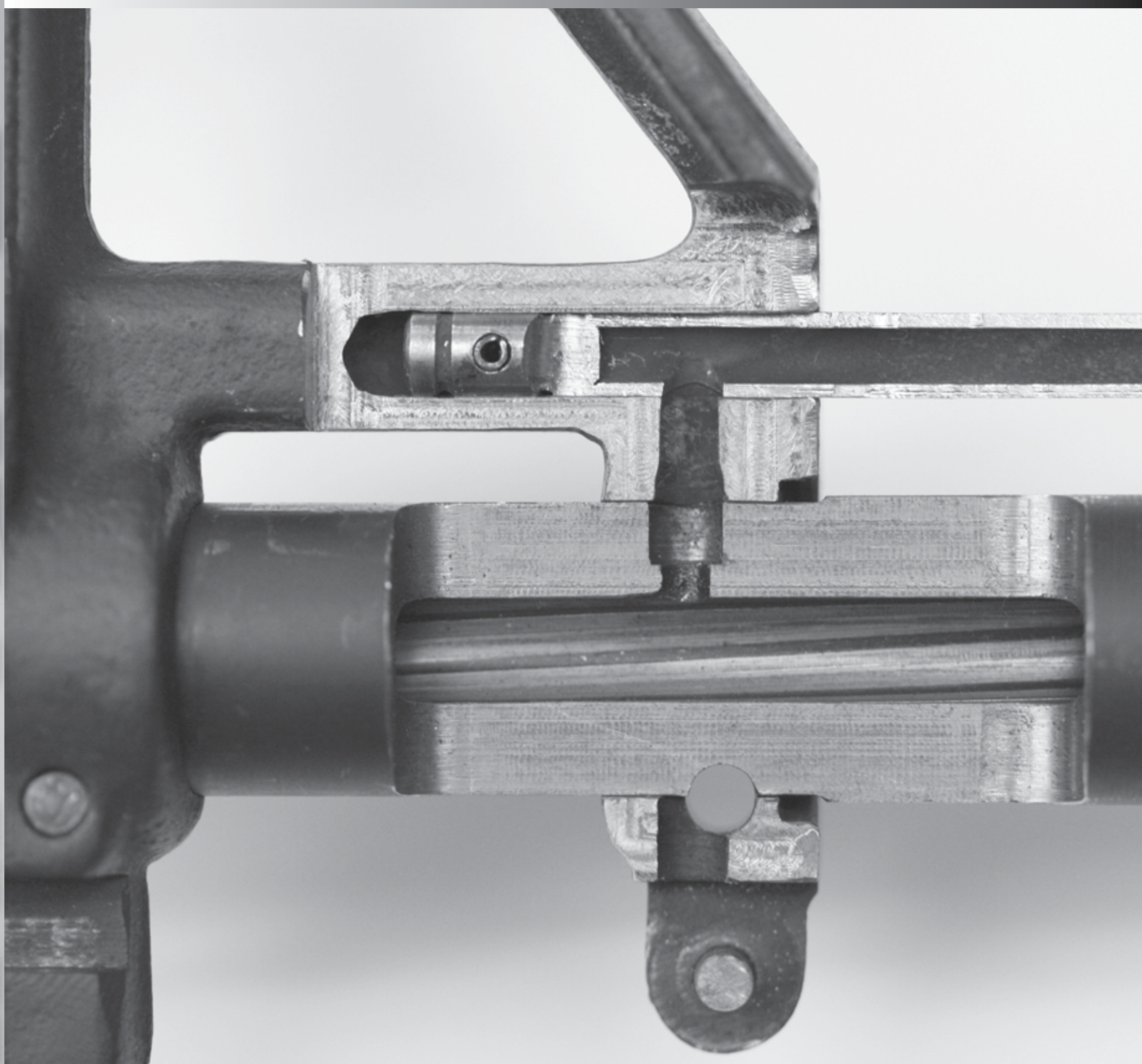
Gun Digest® Book of THE AR-15

Volume 3

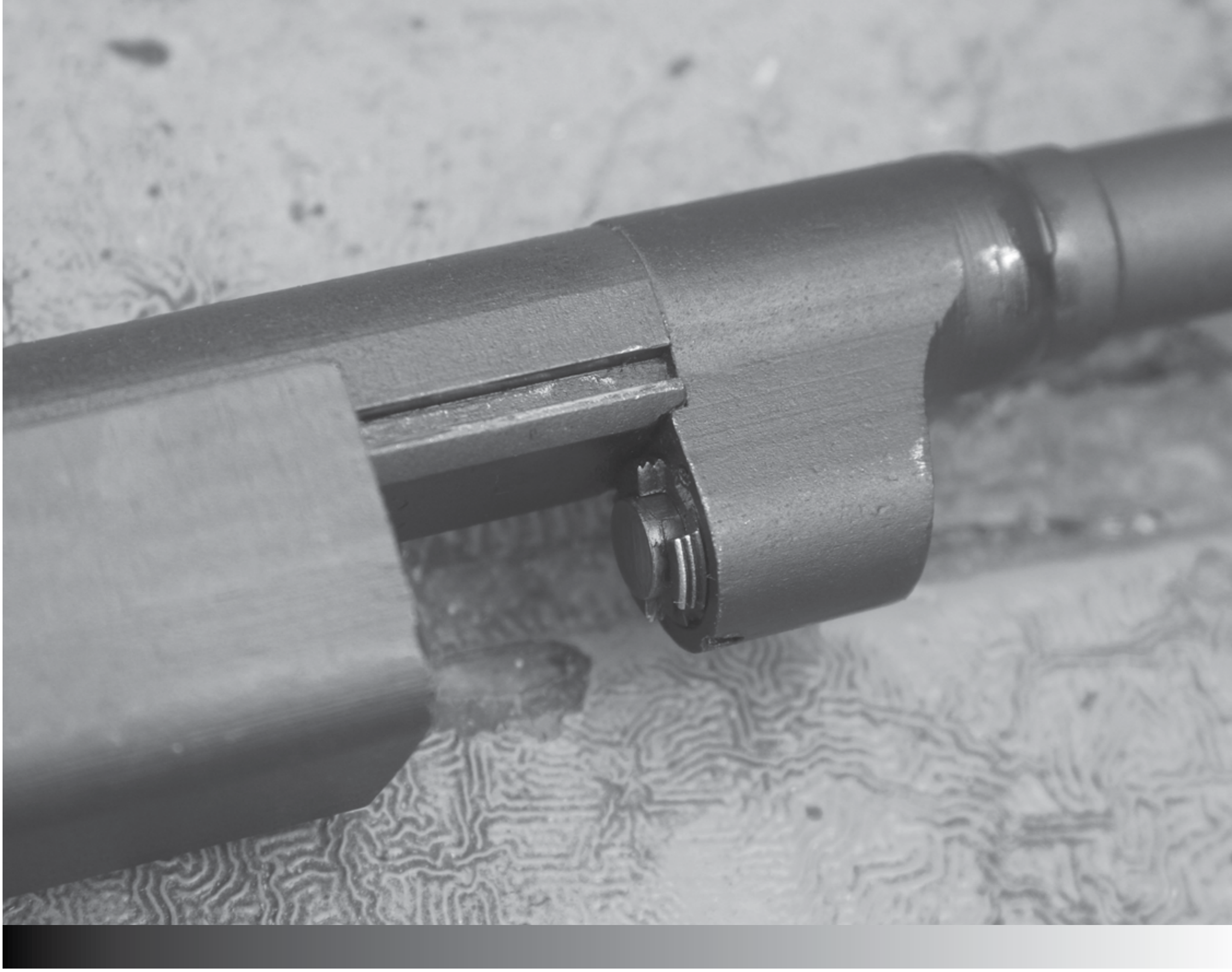
PATRICK SWEENEY

WHAT IS THIS PISTON STUFF, ANYWAY?

CHAPTER 2



The direct gas impingement system vents gas out of the barrel and back to the receiver, with no intermediate parts.



The M1 Carbine is a short-stroke piston design.

Before we can discuss the piston systems available, you have to have some background. And before we can discuss the piston systems with any chance of clarity and common understanding, you have to know a lot more than the average AR owner or GI knows about the Stoner system. The AR was designed around a system known as "direct gas impingement." The barrel has a gas port under the front sight. When you fire a round, the gases pushing the bullet get sluiced off (a small amount, anyway) and travel back to the receiver through that shiny, hollow tube called the gas tube. There, they pressurize the interior of the carrier (the big steel cylinder that the bolt rides in) and blows it back off the bolt. The bolt, constrained by the cam pin, rotates and then follows the carrier back.

The bolt and carrier travel back, compressing the action spring, which when it has fully absorbed the work, pushes the parts back towards the muzzle. The bolt strips a round off the magazine (unless the magazine is empty or faulty) and chambers it, closing and locking.

Obviously, the pressurized gases, when they vent out of the carrier, splatter hot gas and powder residue into your lovingly cleaned receiver interior. That is the origin of the phrase "pukes where it eats." (I've heard other, more colorful terms used, but my Editor won't let me use them. Not that I would, for a guy who has spent a

The M1 Carbine piston snaps back and forth maybe a quarter of an inch. That's all it needs to do to drive the system.

lifetime learning very hazardous skills, I'm remarkably restrained in using expletives.) Even a little bit of shooting will produce an AR remarkably slathered in carbon residue from the combustion of gunpowder.

What the critics will tell you is that the residues are bad. Yes, but not the life-shortening, hair-losing, interest rate inflating bad. Just grubby. With proper lubricant, you can reliably shoot an AR (as long as you scrub the chamber now and then) that is so filthy that chunks of carbon fly out when you shoot it. Bad for the left-handed shooters, but still reliable.

You'll also hear about the high-pressure gases that the system spews. Well, yes and no. The gas port pressure of the AR differs depending on the barrel length and the load used, but the typical 20-inch AR with M-193 ammo will have a port pressure of some 12-14,000 PSI. The carbine will have a port pressure of 18-20,000 PSI. However, by the time the gases have gotten back to the receiver, they have been reduced in pressure by an order of magnitude. (A quick math update for those who have been distracted by advertising fluff and language. An "order of magnitude" means you add or drop a zero. 100 becomes 10 or 1,000. If someone tells you their comp "reduces recoil by an order of magnitude," move on – they either don't know what they are talking about, or they are blowing smoke.)

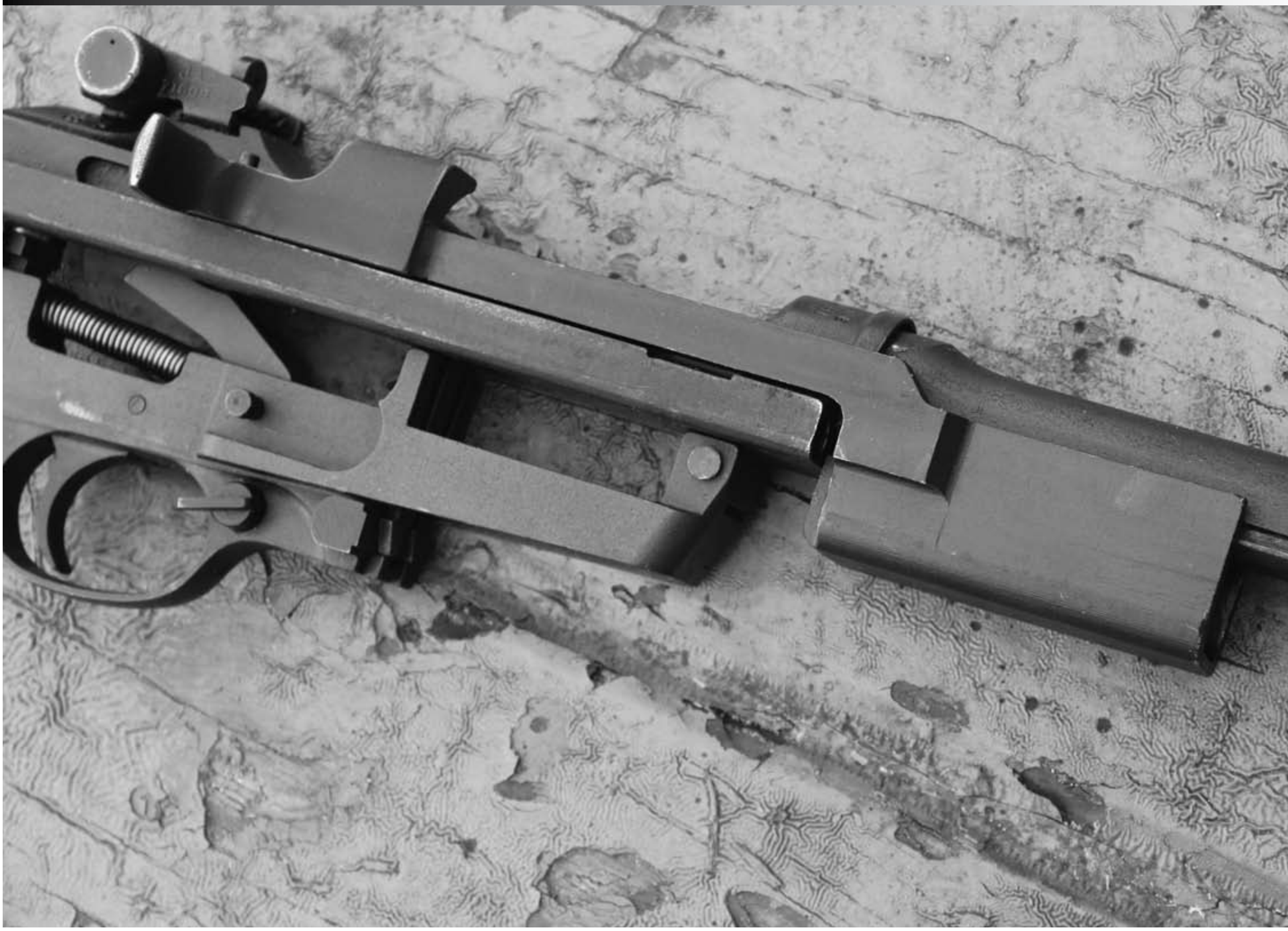
But I digress. The pressure drops from the 12K/20K at the gas port to 1.2K/2.0K in the carrier. Now, 2,000 PSI is not nothing. But a fully-charged SCUBA bottle runs more than that. So you aren't exposing your carrier and bolt to the open flame of a propane torch on every shot. You're just splattering it with grubby, hot gases.

Enter the piston system. The idea is not new: you shift the gas splatter to some other location, so it doesn't get squirted into your receiver. OK, before we can go on, you need a bunch more background.

Gas systems come in two flavors, with each of them having two variants. The flavors are long-stroke and short-stroke, and the variants are vented and non-vented. (There is another, throttled short-stroke, that we'll get to in a bit.)

Now, this is not to be confused with the long and short-stroke recoil systems. The classic long-stroke recoil system is the Browning Auto-5 shotgun. A 12 gauge (originally 12, it later came in others) shotgun, the system works by having the bolt and barrel locked together when fired, and both recoil simultaneously, locked together, for the full stroke of the system. When it reaches the rear of the receiver, the bolt latches in place, unlocks from the barrel, and the barrel runs forward, driven by its own spring. When the barrel gets forward, it releases a shell from the magazine, which when it feeds out unlatches the bolt, which gobbles up the shell, chambers it and locks to the barrel.

The short-recoil system is exemplified by a number of machine guns from the late 19th and early 20th century.



The piston launches the carbine op rod, which turns and cycles the bolt, returns and chambers and locks. All very simple.

In the short-recoil system, the barrel and bolt recoil for a short distance (typically less than the length of a cartridge) then the bolt unlocks and the barrel stops, and the bolt continues onward, as the system then extracts, ejects, feeds, chambers and locks closed.

Why all this folderol? Simple: corrosive primers. Any gas-operated system had to deal with the corrosive primer problem, and once you added the extra parts so a system wasn't exposed to the powder residue except in the bore, the result was a design too heavy for use as a personal weapon, until John Moses Browning designed the BAR. (The light machine gun, not the hunting rifle.) It, however, had to be cleaned after firing, as the piston was exposed to the primer residue and could rust.

In the long and short recoil system in gas operation, the difference is not how far the bolt and barrel move, because the barrel doesn't move. The difference is simple: is the part actuated by the gas flow permanently attached to the bolt group?

The classic long-stroke piston system is the M1 Garand. The gas port delivers gas to the operating rod, which is a single piece long enough to reach back to the bolt. The gases thus work directly on the rod, which has a cam track that turns the bolt and cycles it back and forth. Alas, the simplicity of the Garand is not without drawbacks. The long rod is unsupported for nearly its

The M1 Garand is a long-stroke piston system. The gas works on the muzzle end of the op rod, which works the bolt. No parts in between.

entire length. I'm sure John Garand spent many a day trying to figure a way to support the rod and still make it easily disassembled by the soldiers it was issued to, so they could clean it after firing corrosively-primed ammo. That he could not and made the rifle work anyway is a testament to his genius.

The long-stroke piston system that you may be familiar with in another application is the AK-47 (and the AK-74). The system is highly reminiscent of the M1 Garand, with the op rod and piston mounted on the top instead of on the bottom of the rifle. Did Kalashnikov "steal" it from Garand? Good question. While there were probably not a lot of Garands that made it to Russia, the method was not unknown outside of the US. The genius of Garand wasn't that he conceived the long-stroke system, but that he made it work with the .30-06, perhaps the second most unsuited self-loading rifle cartridge in existence. (The Russian 7.62X54R takes that honor.)

The classic short-stoke piston system, also called the "tappet" system, is the M1 Carbine: there, a small piston rests in the lug under the barrel. When the carbine is fired, the piston slaps the front end of the operating rod, which hurls back. The piston, however, is trapped in the barrel lug, and after traveling a fraction of an inch, it stops and gets pushed back in place when the operating rod moves forward as it closes the bolt.

Another short-stroke piston system from the classic era is the M14/M-1A. The piston rides in the piston housing under the barrel, and when you fire a round the piston pushes on the operating rod. Like the M1 carbine the M14 piston lacks a return spring; it is pushed back into place by the returning op rod.

Now, while all these are fun, there are variations on a theme. The M1 Garand and the AK are both vented long-stroke piston systems. On the Garand, the operating rod has clearance between the piston head and the gas cylinder. Too much, and it short-strokes. Checking piston and gas cylinder diameters is one of the gauging operations when M1 Garands were overhauled. The

The LWRCI piston system: a short-stroke with a piston that travels farther than the M1 Carbine, but is not as lengthy as the Garand.

armorers would mike the (or gauge) the operating rod head and the gas cylinder, and if they were too small (piston) or too large (cylinder) they'd be rejected and scrapped. Those that passed would then be subject to further inspections before being refurbed or used to rebuild rifles. The venting is built-in, not provided via ports, so some might argue the point and declare it to be an unvented system. Fine, whatever floats your boat.

The AK has vent holes in the gas piston tube. Once the head of the piston has traveled to the vent holes, they allow excess gas to escape. I'm not sure the AK has specs on the piston head size, but if it does I'm sure they are pretty generous. Venting allows for a larger variation in gas pressure while still ensuring safe and certain function.

In the short-stroke systems, the M1 Carbine is not vented. The gases fill the expansion chamber in the barrel lug and slap the piston, and that is that. The M14 is not vented either, but it instead is throttled. On the M14, the piston does not get gas on one end and push the op rod on the other, like the M1 carbine. Instead, the gas travels into the piston, which essentially expands, pushing away from the front of the gas system, the only direction it can travel. The piston receives gas from the barrel port only for a short distance. Once the piston has traveled a certain distance, the gas port in the piston has slid out of alignment with, and far enough to no longer receive gas from, the barrel port. Over-pressure rounds shunt the piston faster, cutting off gas flow sooner, and low pressures slow gas shut-off, working longer. In theory, it should be a lot more forgiving of gas pressure variations. In practice, it worked pretty much like all other gas systems.

The FAL is all those and more. It is a venting short-stroke system, but it also has a piston return spring and a user-adjustable gas regulator. The gas port runs gas against the front of the piston, which is a long thin rod above the handguard. It pushes the bolt carrier back, but does not travel with it for more than an inch. Then the op rod returns, pushed by its own spring, as the bolt and

The AK is a long-stroke piston system, as the piston is connected to the op rod that works the bolt. Basically, an upside-down Garand, with an M1 Carbine-style bolt in it.

Like the Garand, the AK piston is not a tight fit, and gas blowby on the piston head is built into the system and calculated for function.

Once the AK piston has traveled far enough, it passes the vent holes, which bleed off gas. This works to prevent over-driving the system.

carrier work on theirs for their part of the action. The gases are vented directly up from the piston head, and by rotating an angled cover plate, you restrict the vent port (or not) to determine how much gas is used to push on the piston. On the Garand, AK, M14 and Carbine, the user had no control over the amount of gas used. On the FAL, you can change the gas available to the system by adjusting the numbered wheel right behind the front sight. While useful in theory, the usual result is an over-gassed rifle.

In summary, what all this means is that the hot, grubby gases are vented or used at some location away from the chamber. It does not mean that the dirt and heat have been negated, or transported to another dimension or location. The heat and powder residue still exist, they are just allowed to exist in a different location. More on that in a bit.

So, our basic gas piston overview has four types: long stroke, vented and unvented, and short-stroke vented and unvented. But there are a lot more variants that can be designed, conceived or made.

However, there is more to know. The basic gas laws of chemistry and physics explain everything, if you're willing to slog through the details. We have Boyle's Law and Charles' Law and they describe the situation from different perspectives. Robert Boyle postulated and then demonstrated that if you decrease the volume of a gas, you increase pressure. Jacques Charles postulated and then demonstrated that when you take a given volume of gas, and change its temperature, the volume will change (hotter means more volume) even as the pressure remains constant.

What does this mean for us? Simple. When the gas volume changes, temperature changes (the other

The M14/M1A piston has a vent hole in it. When it lines up with the gas port, gas flows. As the piston moves it closes off the gas flow, thus acting as a self-limiting system.

consequence of Charles' law.) Gas leaving the bore of your AR at 14,000 PSI goes into the gas tube, expands and cools. So, the gases that reach the carrier are cooled not just by the cooler metal they contact along the way, but also because of the expansion that happens along the way. Also, when they leave the barrel, the pressure of the entire system (the bullet still seals the bore at this point) drops, as there is a lot more volume to pressurize.

However, cooling does not mean condensing. The gas tube on the AR is remarkably self-cleaning. If buildup occurs, the pressure drop of the expansion doesn't occur to the same extent. Pressure slowly builds until the system blows the collected residue free. That doesn't keep the drill instructor from insisting that you clean the gas tube. But it does mean that in the real world, cleaning the gas tube (unless something is really lodged in there) is a waste of time.

So, do not listen to your friend who asserts that the pressure your carrier experiences is the same as that existing in the bore at the moment the bullet uncovers the gas port. It is a lower pressure and lower temperature gas, although it's still hot and grubby.

One last gas law to keep track of: the Bernoulli principle. That tells us that as gas velocity in flow increases, pressure decreases. This is usually used to explain the lift of an aircraft wing, but it also describes the flow of fluids or gases in pipe or tubing. As the pressure drops, the gas flow velocity increases.

The FAL gas system has a return spring and depends on the user for proper gas flow.

This law also explains the apparent self-cleaning nature of gas tubes. Carbon can't build up, as the dynamics of gas flow don't permit it.

What does this mean for our piston gun? I repeat: you can't make the carbon go away, you just change where it gets left and how it builds up. In any venting system, the carbon will leave a hot, high-pressure area, and upon expanding, cool rapidly.

OK, a real-life example of what we're talking about: water vapor. There is water vapor in the air you breathe. The amount of water vapor the air can hold, and not lose, is called the saturation point. The absolute amount it can hold depends on the temperature and pressure of the air. Warmer air can "hold" more water vapor than cold. Imagine a muggy, oppressively humid day. Suddenly the temperature drops. What happens? As the temperature goes down, the amount of water vapor the air can hold decreases. When the amount it can hold falls below the amount that is there, water leaves its vapor state. It can become dew (the "dew point" weathermen talk about) or it can form fog.

The hot gases of your burned powder contain the particulate and vaporized elements of the combustion. When the gases cool, those constituents of the gases cannot stay in suspension, and they precipitate out. Since they are in the process of jetting out of the port, they get laid down as a hard deposit right near the vent port or ports. If your hand is there, they get deposited as hot carbon on your hand, which rapidly cools and is tough to scrub off.

That is why the carbon inside your receiver on your direct impingement gun is relatively soft (that, and the lube you slathered in there) and can be cleaned off – and why the carbon you'll see on your piston gun is hard, baked-on and has to be chipped away.

I had a Physics professor who summed up the Three Laws of Thermodynamics so succinctly that I still remember them:

1) You can't win.

2) You can't break even.

3) You can't get out of the game.

The gas settings of the FAL require a reasonably skilled operator to set properly. Otherwise, the system either short-strokes or is over-driven.

So, when someone tells you that their piston system is "revolutionary" and requires "no maintenance" and "no lubrication," ask them how they've suspended the laws of physics and gotten around the laws of thermodynamics.

It can't be done. And it is exactly this attitude toward the AR-15 in the earliest days that got the armed forces in such a pickle. Because the demo rifle Armalite had been shooting all over Asia had never been cleaned, and never malfunctioned, the DoD "Whiz Kids" whom Robert McNamara put in charge of the program insisted that not only did the rifle not have to be tested by Army Ordnance, it could not be changed and didn't need cleaning equipment. So rifles arrived in Vietnam lacking any cleaning equipment at all. And since the existing rifles and machine guns were .30 caliber, their cleaning gear wasn't going to work on the .22-caliber M16.

Piston Systems: Pros and Cons

The big drawback to the DI system is the gas blown back into the receiver. It does, however, have several manifest advantages, advantages you should not discard simply because all your buddies say you should. First of all, it is light. All the system needs is a hollow tube leading from the gas port back to the receiver. Unless you make your piston system out of unobtainium, it isn't going to be that light, not ever. When you are laden with a whole lot of gear, lighter becomes very attractive.

Also, the hollow tube does not press on or bind the barrel, and so the barrel is essentially free-floated. If you use a free-float handguard, secured to the receiver at the barrel nut (and to the barrel not at all), the barrel is free-floated, and you can thus wring all the potential accuracy out of it that it has.

With a good barrel, an AR can be as accurate as a lovingly-blueprinted bolt gun.

The piston system removes all those advantages. First, it adds weight. Granted, some systems not so much, but they all add something. Second, part of the weight is a more secure (and often heavier) gizmo bolted on the barrel up front. That weight makes the barrel harmonics of firing a different thing than the DI system. You see, every time you fire, your barrel gets hit as if by a hammer. It vibrates. Accuracy is the bullet leaving the muzzle at the same point in the barrel harmonics on each shot. If the barrel harmonics vary, so will accuracy.

The piston system, working in or on the barrel block the new system requires, adds mass and potentially vibration, and also can potentially bind the barrel as the barrel heats. (Binding depends on how securely the piston system is held by the barrel/receiver geometry.) A superb barrel will have few or no stress lines in it. A bad barrel can have many. The stresses can be from the original steel bar, or be added in the machining or straightening process. As the barrel heats up, the stress lines "unkink" and the barrel points differently. It also changes the harmonics, and thus, potentially, accuracy. (A brief aside: hammer-forged barrels have the stress lines pounded out of them, and cryogenically-treated barrels have the stress lines relaxed.) If the piston is a firmly-held object between block/barrel and receiver, it can lever the receiver as the barrel heats up and unkinks.

The extra piston parts can hold heat. Also, as the barrel expands as it heats, the piston parts heat up at a different rate, and add another potential binding or pressing on the barrel.

The piston itself can also influence accuracy. When the M1 Garand was the king of the target range, everyone knew that if the op rod got bent, accuracy went all to hell. Bending op rods usually happened when someone used the wrong powder, one outside the burning rate range the Garand would accept, and the rod was over-worked. But once bent, it was "goodbye accuracy" and the situation could be restored only with a new, correctly-dimensioned op rod.

When the M14 became the target king, it did so only after armorers figured out that the barrel could not be free-floated and had to be pre-stressed. The USAMTU match specs call for welding the gas system and front plate together, and using that as a lever to pull the barrel down as it is locked in the stock. The barrel starts out pre-loaded downwards, dampening the harmonics. If the bedding goes, the pre-load changes, and accuracy goes kerflooey. However, no need to replace parts there; "simply" re-bedding will do. However, every time the action was removed from the bedded stock, the bedding suffered a bit. Match shooters using the M14 became adept at cleaning their rifles without removing them from the stock.

The AR can be free-floated, even with a piston system, but the piston has to neutrally influence the barrel, or your accuracy, zero or both will change as the barrel heats up. With the DI system, not so much – nay, hardly at all, especially with a good barrel in it.

And, on top of all that, the piston system brings with it another problem: tilt. (Actually, two, but I'll detail that in a bit.) When the DI system pressurizes the carrier, it basically pushes the carrier rearward axially. That is, the direction and location of the thrust is on, and in line with, the center of the carrier itself. Enter the piston system, which taps or pushes on the carrier up where the gas key used to be. The carrier tries to tilt in the upper and is restrained from doing so only by the buffer tube.

The buffer tube, being made of aluminum, is not at all happy with the steel carrier slamming down and gouging it. Now, the gouging isn't all that bad, at least not what I've seen of it. And not all (even the early ones) piston systems tilt or gouge. Me, if I really felt the need to use a piston system, and found that it gouged the buffer tube, I'd perform a simple calculation: will the buffer tube last as long as the barrel? If it did/would, I'd simply view the cost of a replacement buffer tube as part of the cost of a new barrel, and not sweat it. If the tube wouldn't, then a barrel replacement becomes a 2X or 3X buffer tube cost. At the moment, a plain old USGI-dimension, six-position carbine buffer tube costs $25. A good barrel (there isn't much point in buying a cheap barrel) starts at about $200, and that is for a steel tube lacking sight, gas block (you're going to take off the one for your piston system, right?), nut and such.

So, as long as it doesn't cause a functioning problem, replacing the buffer tube is a fraction of the total cost to replace a shot-out barrel.

Oh, and the second problem with a piston system? Cost. If you use a replacement kit, you'll be replacing the existing carrier with a piston-compatible carrier. If you buy a full-up rifle/carbine, you'll be paying an extra for the design and fabrication costs of the new parts. Either

Piston systems do not make gas go away. They merely vent it in different locations. Here, the gas is venting directly behind the front sight, as it is meant to.

way, your new piston-equipped rifle is going to cost a bit more than a plain old DI-running one.

So, should you go piston or not? That depends. One group who benefit greatly from a piston system are those who own suppressors. The delayed gas flow (that's how a suppressor works: it delays the gas flow out the muzzle, to reduce noise) means more gas and gunk blown back into the receiver on a DI rifle. Depending on minor variables in each rifle, running with a "can" can mean a gun that looks like a 4th of July charcoal grill after a few magazines, or simply a more-difficult cleaning job after a day of shooting. A piston system on a rifle with a suppressor (especially a piston system with an adjustable flow valve) can make shooting with a "can" a pleasant time.

Another group that finds favor with piston systems are those with SBRs. The short barreled rifle crowd often find that a short-barrel DI system is just too touchy, or in order to be reliable, has to run too violently. Let's take a look at the math involved.

Our bullet screams past the gas port, and thus allows gas to flow into the system. The bullet continues onward, and the system remains sealed until the bullet leaves

the muzzle. How long is that? The time period is called the “gas dwell time,” by the way. Well, on a twenty-inch rifle, we have a 55-grain FMJ bullet leaving the muzzle at some 3200 fps. That means that the distance from the gas port to the muzzle, some 6.5 inches, produces 0.00017 seconds of sealed-bore gas dwell time. (Those who know their mathematics realize that it is not simple arithmetic, but a calculus application, but I’m fine with rounding the numbers for this demonstration.) So, .17 milliseconds of time, which is less than the duration of a typical camera flash at its peak.

On a CAR with a 16-inch barrel, that dwell time is .24 milliseconds, an improvement, but from there it goes backwards. The M4, with its 14.5-inch barrel, gives us .19 milliseconds, and an 11.5-inch SBR produces a miniscule .11 millisecond dwell time. To ensure that the short-barreled rifle works, you have to open the port to get more of the gas working for you.

Piston systems are much less touchy. You see, you can hammer the system with as much gas as you need, and use a built-in gas bleed, or a self-limiting piston, to control over-driving it. Use a piston system and the SBR becomes a far less touchy creature, working with a wider array of ammunition, bullet weights and loads, and doing so with greater reliability.

So, those of you with SBRs may find a piston system advantageous. The rest of us? Not so much.

Finally, cost. Part of the cost of a piston system is the piston system itself and the R&D that went into developing it, as well as the tooling costs to fabricate the piston parts. However, a fondness for the good old days clouds the issue. There are still a number of shooters who remember fondly the $600 AR they bought “back when [fill in the blank].” Inflation aside, let’s look at the “$600 AR” they bought. It probably had plain plastic handguards, maybe the A2/M4 type, maybe not. They certainly weren’t railed, free-float handguards. The stock was either an A1, an A2, or an old-style CAR stock. Not one that holds batteries or offers a solid cheek weld.

The sights were either A1 or A2, no flat-top, and no place to mount a scope except in the carry handle. Which sucked. And the barrel? Maybe it was a 1:12 twist “pencil” barrel, and maybe it was something heavier. But wasn’t the premium tube we now expect, in this age of the sub-MOA AR. In fact, it wasn’t a rifle many of today’s shooters would pay $600 for, and that is with less-valuable inflated dollars. Adjusted for inflation, that 1986 AR you paid $600 for would run you $1,186.54 in Obamadollars. So, before you go grumbling about “how expensive ARs have gotten,” consider what it takes to upgrade the $600/$1187 AR with a new stock, railed handguard, better barrel and flat-top upper. All of a sudden, an “expensive” AR doesn’t seem so bad, does it? Throw in a piston system and they are almost reasonable.

So, go to a piston if you want. Stick with a direct impingement if you want. Add all the features you want or don’t want, but don’t grumble about the cost. For what we get today, the AR has never been a better deal.