Air Brakes for Dummies

Not that anyone volunteering on the Sumpter Valley Railway is a dummy. However, some might have received some dumb information about air brakes back down the line or may have been psychologically traumatized by some misdirected (albeit well intended) presentations about the intricacies and inner workings of air brakes without first having essential knowledge of the basic components of a train's air brake system and how they work to control movement of a train. The following is an edited version of BNSF Engineer Al Krug's article on Simplified Air Brakes <http://www.trainlife.com/articles/275/air-brakes-simplified>.

Here is a (very simplified) description of how North American train brakes work and some answers to other frequently asked questions.

Basically, there is a reservoir (air tank) on each car which is charged with (nominally) 90 psi (70 psi on the SVRY) of compressed air, supplied by the compressor (air pump) on the locomotive and sent to every car through the train's brakeline. (That's the hose you see linking the cars – the one that goes "kapoosh!" when the train uncouples.) Once the reservoirs on all the cars are charged, the engineer can set the brakes on the entire train by bleeding air out of the brake pipe, using a valve in the locomotive cab. The reduction of air pressure in the brake pipe causes a valve on each car to connect that car's reservoir air to the brake cylinder on that car, applying the brakes.

To release the brakes, the engineer moves the valve to the Release position, which once again sends compressed air back through the train. The increase in pressure in the brake pipe causes the valve on each car to vent the air in the brake cylinder to the atmosphere. A spring in the brake cylinder of each car causes the brakes to move away from the wheels. The brakes apply whenever the air pressure in the brake pipe drops. If the train accidentally uncouples, the brakes will automatically apply fully-since all of the brake pipe pressure will be vented to the atmosphere through the disconnected pipe. (This is why they are called automatic air brakes.)

Because air pressure from the car's reservoir tank flows into the brake cylinders to force the brake shoes against the wheels, it is important to note that a train has no air brakes until each car's reservoir is initially charged from the locomotive. In other words, no air in the reservoir means no brakes. There is nothing new about this system. It was invented by George Westinghouse in the late 1800s (and first practically applied to passenger trains in 1868, to freight trains in 1887) and has been in use ever since with minor improvements.

Train Control

The engineer can "graduate" the brakes on. That is, control the braking force in the "more brake" direction, but any release can only be a full release. He or she can't graduate a freight (or passenger train on the SVRY) train's release as a car driver does by easing up on the brake pedal. This is one of the many characteristics that make running a train different from driving a car or truck. The engineer must not set too much brake, or he will stop short. Too little brake and he can set some more, if there is time. If there isn't time, he is fired-or dead!
Locomotives have two air brake systems—one operates in concert with the train brakes, and the other as an independent brake exclusively for the locomotives. The independent brake is faster-acting and offers graduate-on graduate-off control. This locomotive-only brake is usually used only during switching, light engine moves, or for holding a stopped train on level track.

**Freight Train Brakes**

Fine, you say, but exactly how are brakes controlled?

That is the job of the so-called triple valve on each car. Basically, this valve constantly compares the brake pipe pressure with its car's reservoir tank pressure. If the brake pipe pressure is higher than the reservoir pressure, the triple valve moves to the release position. Any brake cylinder air is vented to the atmosphere, thus releasing the brakes. The valve will also open a passage between the brake pipe and the reservoir tank, re-charging the tank.

This sequence happens when a train sits in the yard, "pumping up its air" prior to making a brake test: The boiler is supplying steam to operate the compressor, pumping air through the engineer's brake valve into the brake pipe and, finally, through the triple valves of each car into the reservoirs. This takes a lot of air. It may take several minutes to charge a train, depending on its length and how leaky the air hose couplings are.

The standard brake pipe pressure is 70 psi on the SVRY. Once the cars' reservoirs are charged to the same pressure as the brake pipe (70 psi), the triple valve on each car moves to the neutral, or Lap, position. The brakes are now ready for use, either on the road or for an air brake test. To set the brakes, the engineer moves the brake valve handle from the Release & Charge position to the Application position. This disconnects the locomotive's air compressor from the brake pipe and opens a small hole, allowing brake pipe air pressure to vent to the atmosphere. This venting causes the brake pipe pressure to drop slowly. On each car, the triple valve monitors both the brake pipe pressure and the reservoir pressure and senses when pipe pressure is lower. This signals the triple valve on the car to move to the apply position, connecting the reservoir air pressure to the brake cylinder, pushing a piston in the cylinder out, and applying the brake shoes.

Meanwhile, up in the cab, the engineer is watching the gauges. When the brake pipe pressure lowers to where he wants it, he puts the brake valve in neutral or Lap. Lap simply seals the brake pipe, letting no air out nor letting air from the compressor in.

Let's say the engineer makes "10 pound set." This means he's reduced the brake pipe air pressure from 70 psi to 60 psi then lapped the brake valve. The triple valve on the car was monitoring the brake pipe air pressure, and as soon as it dropped below reservoir pressure, it moved to the apply position and allowed reservoir air to flow into the brake cylinder. This flow of air will, of course, lower the pressure in the car reservoir tank. Remember, the triple valve always compares the pressure from the brake pipe to the pressure in the reservoir. It allows air to flow from the reservoir into the brake cylinder until the reservoir pressure lowers to match that of the brake pipe. When the pressures match (that's 60 psi in this example), the triple valve returns to Lap.
But now all that air that flowed from the reservoir to the cylinder has applied the brakes on that car. The volume of the reservoir is about 2.5 times the volume of the brake cylinder. So, to lower the reservoir 10 psi, from 70 to 60, enough air flowed from the reservoir that it put 25 psi (2.5 multiplied by the 10 psi reduction equals 25 psi) in the brake cylinder.

Simple, isn't it?

The engineer now has the choice of leaving the brakes applied, making another reduction to get heavier braking, or releasing the brakes. Let's say he's on a moving train and wants to slow down quickly. He moves the brake valve to the Application position and lower the brake pipe another 5 psi from 60 to 55 psi. The triple valves on the cars sense, once again, that the brake pipe (now 55 psi) is lower than the reservoir (60 psi). Once again, the valve moves to allow reservoir air to flow into the brake cylinder until the reservoir matches the 55 psi. The brake cylinder pressure goes up, and the braking effort correspondingly increases. Because of the 2.5 ratio of reservoir-to-cylinder volume, this 5 psi reduction results in 12.5 psi more braking pressure, in addition to the 25 psi already there, for a total of 37.5 psi brake cylinder pressure.

This air brake system, when fully charged, is fail safe: Anytime the brake pipe air reduces, the brakes apply. If a train comes uncoupled, or an air hose bursts, the brakes apply fully and automatically. But the amount of braking force always relies on the amount of charge present in the system.

When the engineer no longer needs the brakes, he can release them by moving the brake valve to the Release position. As before, this connects the locomotive air compressors to the brake pipe, raising its pressure back to 70 psi. The cars' triple valves sense that the brake pipe (now 70 psi) is higher than the reservoir (still at 55 psi) and moves to Release position, connecting the brake cylinder to the atmosphere, releasing the pressure in the cylinder and thus releasing the brakes. It also connects the brake pipe to the reservoir to begin re-charging the reservoir from the brake pipe.

Congratulations! You now know the basics of air brakes. But, as always in life, there are complications.

When the brakes released on the train's cars, the brake pipe was at 70 psi, the reservoirs were at 55 psi. Upon releasing, the reservoirs begin to recharge—a process that takes time. So for several minutes (30 seconds to two minutes on the SVRY, depending on train length and condition of the brake pipe) after releasing the brakes, the reservoirs are not fully charged, and an engineer does not have full braking power available.

In the example, the engineer had made a total reduction of 15 psi (reduced the brake pipe and reservoirs from 70 to 55 psi). Suppose, less than a minute later, he wants to set the brakes again? The brake pipe may be at 70 psi, but the reservoirs may have only recharged from 55 psi to 59 psi. Now, if the engineer makes a 10 psi reduction of the brake pipe (from 70 to 60), what does a car's triple valve see? It sees 60 psi in the brake pipe and 59 psi in the reservoir. The brake pipe is higher than the reservoir, so the triple valve stays in the release position! He gets no brakes! Nada! Zip! But, if he reduces a further 5 psi, bringing the brake pipe down to 55 psi, the triple valve sees the brake pipe lower than the reservoir (59 psi), so it goes to apply position. The brake pipe is at 55 psi and the reservoir was at 59 psi, so the reservoir lowers 4
psi. The 2.5 volume ratio between the reservoir and brake cylinder means he will get (2.5 multiplied by 4 psi) 10 psi in the brake cylinder. That's very little brakes compared to a minute earlier when the same 15 psi reduction resulted in 37.5 psi braking power! **This is how runaway trains happen.**

Imagine, while going down a long mountain grade, a dumb engineer makes several heavy sets and releases in a short time. He or she soon will have no brakes because there will be very little air left in the reservoirs. Railroaders call this "pissing away your air." (Now before you go and tell the press at the scene of a runaway train wreck that a dumb engineer must have been at the controls, please understand that runaways can also occur in ways that are not the engineer's fault.)

Another complication of this simple brake system is that a long train has a long brake pipe, containing a lot of air. When the engineer wants to make a brake application by reducing the brake pipe pressure, it takes time to vent enough air to do so. This is not a problem under normal braking conditions, but what happens in an emergency?

Solution: an emergency vent valve has been added to each car. This valve monitors the brake pipe air pressure. If the pressure drops slowly, the emergency valve does not react, no matter how low the pressure goes. But if it drops quickly, the emergency valve opens the car's brake pipe to the atmosphere. This quickly dumps the brake pipe air to the atmosphere at the car. In other words, all the air does not have to go through the entire brake pipe, up to the engineer's valve, and out to the atmosphere.

All the engineer has to do is start the emergency application by quickly venting brake pipe air at the head end. The first car's emergency valve senses the fast drop and vents all brake pipe air at that car quickly; the next car senses a fast drop and also goes to emergency, then the next, and so on. Within seconds, the entire train is in emergency, dumping all the brake pipe air at each car. The engineer gets a fast and full application of the brakes throughout the train. If you are standing near a train when the locomotive uncouples, you can hear these emergency valves vent the brake pipe pressure locally as the car you are next to makes the tell-tale "psssssst." If you are standing some distance off to the side, you can hear each car trigger in succession, rapidly down the train. These emergency vent valves stay open for about two minutes, ensuring that the train will be stopped before the engineer can release the brakes.

Anything -- the train coming uncoupled, a bursting hose, the engineer, the conductor—that causes a quick drop in brake pipe pressure at any car will trigger that car, which in turn triggers adjoining cars and puts the whole train in emergency.

All well and good in theory. But what about that doofus engineer who used up all his brakes, leaving little pressure in the reservoirs?

*Note: On the SVRY, most cars do NOT have an emergency reservoir. The following two paragraphs are included so that the reader will understand a basic difference between our brake systems and those of modern freight trains.*

If he puts his train into emergency, he will still get very little braking-in effect, he will just get what is available more quickly. To ensure that there is always air pressure on each car for an
emergency application, the basic system was modified by adding a second-or emergency-reservoir to each car.

The emergency reservoir is charged with compressed air from the brake pipe, just like the service reservoir. After the initial charging time in the yard, it contains 90 psi (70 psi on the SVRY). This air is never used during normal braking. However, if the engineer initiates an emergency application by making a quick reduction, each car's emergency valve triggers, just as described above, but now it also connects the emergency reservoir air to the brake cylinder in combination with the service reservoir air.

So how to handle an emergency braking situation on the SVRY in which you have a lower brake pipe pressure? First of all, definitely place the automatic brake valve in emergency to get whatever braking ability is left. Then, in the case of the Heisler, fully apply the engine brake. In the Mikado, don't bail the independent or fully apply it if it's already been bailed off. If the train is still not under control, whistle for the crew to start tying down hand brakes.

Just like the cars, locomotives have air brakes that apply when brake pipe air pressure is reduced. This is not always desirable, especially when "stretch braking" with the throttle open and car brakes set to control slack action. At these times, an engineer can prevent the locomotive brakes (this applies to the Alco, not to the Heisler) from applying by depressing the independent brake handle and holding it down-sometimes called "bailing the air." On the SVRY this is the required method for descending the grade from Sumpter to McEwen in order to give the smoothest ride and not crash light-weight passenger cars into a heavy locomotive which has the independent applied.

As I mentioned, locomotives also have an independent "straight air brake," so called because air pressure goes directly from the locomotives' compressor reservoirs to the locomotives' brake cylinders. This brake is controlled by the independent brake handle and is generally used to apply the locomotive brakes during switching or for holding a stopped train on level track.

You are now an expert on train brakes. There will be a quiz on Wednesday.

Quiz. (Is it Wednesday already?)

Question: You have made a 10 psi brake pipe reduction on a fully charged train. The brakes have applied, but one car has a leak in its service reservoir. What happens to the brakes on that car? What happens to the brakes on the entire train?

Answer: (no peeking)

The key is to remember how the triple valve works. It senses the difference between the brake pipe pressure and the service reservoir pressure. If you have made a 10 psi reduction, from 70 to 60 psi, and the brakes have set, the reservoir and brake pipe are both now at 60 psi. As the reservoir slowly leaks, the pressure drops, from 60 to 59 to 58 to 57 etc. As soon as the reservoir pressure leaks from 60 to 59 psi the triple valve "sees" that the brake pipe (60 psi) is higher than the reservoir (59 psi) and will release the brakes on that car. Whoa! That is not good! But you still have brakes on the rest of your train. Hopefully.
Equalizing Reservoir

As stated earlier that the engineer makes a service application of the brakes by moving his brake valve handle to the application position, opening a small hole, which reduces brake pipe pressure slowly. He watches the brake pipe pressure fall on the air brake gauge. When he gets the amount of reduction he desires, he moves the brake handle to the Lap (blocked-off) position.

Actually, this is only true with the very early air brake systems *(yes, ones even older than those on the SVRY)*. As trains got longer, and had more brake pipe volume, it took too much time for the air to travel through all the cars to vent at the engineer's brake valve. Compromising safety, his attention was fixed on the air brake gauge for an inordinate time. So another small reservoir, known as an equalizing reservoir was installed; its size allows pressure to be reduced almost instantaneously. The engineer's brake valve now reduces the air in the equalizing reservoir instead of the brake pipe. He can get the desired reduction (say 10 psi) very quickly and then can take his eyes off the equalizing reservoir gauge to look out ahead. An equalizing valve is connected between the equalizing reservoir and the brake pipe; it is this valve that vents the brake pipe air to the atmosphere until it matches the equalizing reservoir pressure.