# Freight Train Air Brakes of North America

## The General Concept

Each freight car has an air tank on it called the SERVICE RESERVOIR. This reservoir is charged with compressed air from the locomotive's air compressor via the train line BRAKE PIPE. (The air hoses you see at the couplings between the cars are part of this brake pipe. Perhaps you have heard them go Kapowssssh when the cars are uncoupled. That sound is the compressed air escaping from the brake pipe). After the initial charging of the reservoirs on the cars the brakes can be set (applied) by REDUCING the pressure in the brake pipe. When the brake pipe pressure is reduced the CONTROL VALVE on each car causes the compressed air from each car’s reservoir to be directed into that car's BRAKE CYLINDER where it pushes on the brake cylinder PISTON to apply the brakes on the car. Note that the air pressure, which creates the force on the brake piston, comes from the reservoir on that car. If you have no air in the reservoir then you will have no brakes. If you are moving at that time then you have a run away.

Now if you are not technically oriented or don’t understand the meaning of psi (pounds per square inch air pressure) you may as well give up right here and be satisfied with the above description. If you understand compressed air and have a high boredom threshold then read on.

## The Basics

### Control Valve

How are the brakes controlled? That is the job of a control valve commonly referred to as the "triple valve" on each car. This valve compares brake pipe air pressure and car auxiliary reservoir air pressure. It is called a triple valve because of its three basic states.

- If the brake pipe pressure is HIGHER than the reservoir pressure the triple valve moves to the RELEASE position.
- If the brake pipe pressure is LOWER than the auxillary reservoir pressure the triple valve moves to the APPLY position.
- If the brake pipe pressure is EQUAL to the auxillary reservoir pressure the triple vale moves to a neutral or LAP postion.

### Release and Charge

If the brake pipe pressure is HIGHER than the reservoir pressure the triple valve moves to the RELEASE position. In this position the triple valve vents any brake CYLINDER air to atmosphere thus releasing the brakes. It also connects the BRAKE PIPE to the RESERVOIR so brake pipe air pressure can begin recharging the reservoir. This is the situation you are in when you are CHARGING the brake system sitting in the yard waiting for a brake test ("pumping up the air").

So now the locomotive’s diesel engine is turning an air compressor that is pumping air thru the engineer's brake valve into the brake pipe of the train. The air flows back along the train and thru the triple valves of each car into the reservoirs. It takes a lot of air to charge (fill) all those reservoirs on the cars. It takes anywhere from 15 minutes to an hour to charge a train depending on its length and how leaky the air hose couplings are.

**Lap**
On the railroad I work for the standard brake pipe pressure is 90 psi. Once the cars' reservoirs are charged to the same pressure as the brake pipe (90 psi), the triple valve on that car moves to the neutral or LAP position. In the lap position the triple valve closes all connections.

- The brake pipe is no longer connected to the reservoir.
- The brake cylinder is no longer open to the atmosphere.
- The reservoir is not connected to the brake cylinder.

The whole system is "in limbo" so to speak. The brakes are now ready to be used, either on the road or for an air brake test.

**Setting the Brakes**
To set the brakes move the engineer's brake valve handle from the RELEASE & CHARGE position to the APPLICATION position. This disconnects the loco's air compressor from the brake pipe and opens a small hole to vent brake pipe air pressure to atmosphere. This venting of brake pipe air causes the brake pipe pressure to drop slowly.

On each car the triple valve is "watching" the brake pipe pressure and the reservoir pressure. Remember when the system was completely charged, both reservoir and brake pipe were at 90 psi. Now with the brake pipe pressure dropping, the triple valve senses that the brake pipe is LOWER than the reservoir. This difference in pressure moves the triple valve to the APPLY position. In the apply position it connects the RESERVOIR air pressure to the BRAKE CYLINDER. Air will flow from the car's reservoir into the car's brake cylinder. This air pressure pushes the brake cylinder piston out and applies the brakes.

Meanwhile, up in the cab, the engineer watches his gauges. When he gets the brake pipe pressure lowered to where he wants it he puts the brake valve handle in the neutral, or LAP, position. The lap position of the engineer's brake valve is similar to the lap position of the car triple valves. Lap simply seals the brake pipe, letting no more air out and not letting any air compressor air into it.

Let's say he "makes a 10 pound set". This means he reduces the brake pipe air pressure from 90 psi to 80 psi then "laps" his brake valve. The triple valve on the car is "watching" the brake pipe air pressure and, as soon as the brake pipe pressure drops below reservoir pressure, the triple valve moves to the APPLY position and allows reservoir air to flow into the brake cylinder. This flow of air from the car reservoir to the cylinder will of course lower the pressure in the car reservoir. Remember that the triple valve always watches the pressure in the brake pipe and the reservoir. It allows air to flow from the reservoir into the brake cylinder UNTIL THE RESERVOIR PRESSURE LOWERS TO THAT OF THE BRAKE PIPE PRESSURE. Now once again the reservoir and brake pipe are equal pressure so the triple valve returns to its own LAP position. Both the brake pipe and the car reservoir now have 80 psi.

All the air that flowed from the reservoir to the cylinder is pushing on the piston and 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 90 to 80, enough air flowed from the reservoir into the cylinder that it put 25 psi in the brake cylinder. (2.5 times the 10 psi reduction = 25 psi). Simple isn't it?

The engineer now has three choices concerning his air brakes.
1. He can leave the brakes applied to control speed or stop.
2. He can make another reduction to get increased braking.
3. He can release the brakes.

**Increasing the Braking**

Let's say he wants to slow down faster than he is so he wants more braking. He moves his brake valve to the application position again and lowers the brake pipe pressure another 5 psi from 80 to 75 psi. The triple valves on the cars sense once again that the brake pipe (75psi) is LOWER than the reservoir (80psi). So they move to the APPLY position. This allows more reservoir air to flow into the cylinder until the reservoir is the same pressure as the brake pipe (75psi). The brake cylinder pressure goes up and so the braking effort goes up. Because of the 2.5 ratio of reservoir volume to cylinder volume this 5 psi reduction results in (2.5 times 5psi =) 12.5 psi more braking pressure. This is on top of the 25 psi already there for a total of 37.5 psi brake cylinder pressure.

**Fail Safe**

Notice that if this air brake system has been fully charged, it is "fail safe". That is, anytime the brake pipe air reduces, the brakes apply. Thus if a train comes uncoupled or an air hose bursts, the brakes apply fully, automatically. The amount of braking depends upon the amount the system is charged however.

**Releasing the Brakes**

When the engineer no longer needs the brakes he can release them. This is done by moving the engineer's brake valve to the RELEASE & CHARGE position. As before, this simply connects the locomotive air compressors to the brake pipe and pumps air back thru the brake pipe raising its pressure back to 90 psi. The cars' triple valves sense that the brake pipe (90psi) is HIGHER than the reservoir (75psi) and move to the RELEASE position. This connects the brake cylinder to the atmosphere, releasing the air pressure in the cylinder and thus releasing the brakes. It also connects the brake pipe to the reservoir to begin recharging the reservoir from the brake pipe. Notice there is NO PARTIAL release, the release is a complete release.

**The Second Application**

You now know the basics of air brakes. But as always in life there are complications. First of all, note that when the brakes released on the train cars, the brake pipe was at 90 psi but the reservoirs were at 75 psi. Upon releasing, the reservoirs BEGIN to recharge but the recharging takes time. So for several minutes after releasing the brakes, the reservoirs are not fully charged and thus you do not have full braking available.

Suppose the engineer had made a total reduction of 15 psi as in the above example. This reduced the brake pipe and reservoirs from 90 to 75 psi. He then released the brakes by raising the brake pipe back to 90 psi. Suppose 1 minute later he wants to set the brakes again. The brake pipe is at 90 psi but the reservoirs may have only re-charged from 75 psi to 79 psi! Now if he makes a 10 psi reduction of the brake pipe from 90 to 80 what does the car triple valve see? It sees 80 psi in the brake pipe and 79 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!

If he reduces a further 5 psi to bring the brake pipe down to 75psi, the triple valve sees the brake pipe LOWER than the reservoir (79) so it goes to APPLY position. This once again allows reservoir air to flow into the brake cylinder until the reservoir pressure lowers to the brake pipe pressure. The brake pipe is at 75 psi and the reservoir was at 79 psi so the reservoir lowers 4 psi. The 2.5 volume ratio between the reservoir and brake cylinder means he got 10 psi in the brake cylinder. (2.5 times 4 = 10). Very little brakes where before with the same 15 psi reduction he got 37.5 psi in the cylinders!

To get effective braking the engineer must reduce the brake pipe farther still. If he reduces the brakepipe to 64 psi he can finally get the same 37.5 psi in the brake cylinder that he got the first time. That is because with the reservoirs at 79psi if he reduces the brake pipe to 64 psi the brake pipe is now 15 psi below the reservoirs. (79 - 64 = 15). The pressure in the brake cylinders will be 2.5 x 15 = 37.5 psi. Note that with the system fully charged to 90 psi a 15 psi reduction to 75 psi produces 37.5 psi in the brake cylinders. But with a system only partially recharged to 79 psi it requires a 26 psi reduction (90 to 64 psi) to get the same 37.5 psi in the cylinders and thus the same braking effort

**Run Away**
When the engineer moves his brake valve handle to release the brakes will release and begin recharging. But this time they are starting from a much lower value, 64 psi instead of 75 psi. If he needs air brakes shortly after releasing this second set he is going to have to make a very large reduction. This scenario is how most classic run-aways occur. Imagine going down a long mountain grade an engineer makes an air brake set and he sets a bit too much. The train is going to make an unwanted stop on the down grade so he releases the brakes. Remember that there is no partial release. It is not like your automobile where if you apply the brakes too hard at first you can just let up a bit on the pedal. If he releases the brakes they fully release. The train immediately begins to pick up speed on the steep grade so he makes a second set. He has to go lower this time to get effective braking. If the engineer is not very experienced he may once again get too much braking. If he is smart he will let the train stop and handle the situation with hand brakes and/or retainers. But if he is a dumb engineer he might make several heavy sets and releases of the air brakes in a short period of time. With each set he has to go deeper and deeper to get effective braking. Each set and release lowers the pressure in the cars auxilary reservoirs. Depending upon how much he sets each time, by the third or fourth application he finds he has no brakes because there is very little air left in the reservoirs. This is known as "pissing away your air". Now before you go tell the press at the scene of a run away train wreck that it had a dumb engineer allow me to state that there are other ways runaways can occur that are no fault of the engineer.

## Adding "Extras"

**Emergency Braking**
Another complication of this simple brake system is that a long train has a long brake pipe and all that pipe contains a lot of air. When an engineer wants to make a brake application by reducing the brake pipe pressure, it takes TIME to vent enough air out through his brake valve to lower the pressure to where he wants it. This can be managed by an experienced engineer by planning ahead under normal braking conditions, but what about emergencies? They solved that by adding an emergency vent valve to each car. This valve watches the brake pipe air pressure. If the brake pipe pressure goes down SLOWLY the emergency valve does nothing, no matter how low the pressure goes. But if the pressure drops QUICKLY the emergency valve senses this and 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 thru the entire brake pipe up to the engineer's valve in the loco for emergency. All he has to do is START the emergency application by venting brake pipe air at the head end QUICKLY. This causes the first car's emergency valve to sense the fast drop and move into emergency. This 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 next and so on. Within seconds the entire train is in emergency, dumping all the brake pipe air at each car. You get a fast and full application of the brakes through out the entire train.

If you are standing near a train when the loco uncouples you can hear these emergency valves vent the brake pipe pressure locally on the car you are next to. That car will go "Psssssht". If you are standing some distance off to the side of the train you can hear each car trigger in succession as the "psssht, psssht, pssht, pssht" goes rapidly back the train.

These emergency vent valves stay open for about 2 minutes after triggering. This ensures the train is stopped before you can release the brakes.

Note that ANYTHING that causes a QUICK drop in brake pipe pressure at any car, will trigger that car which in turn triggers adjoining cars and thus puts the whole train in emergency. This initial trigger could be the engineer, the conductor pulling his emergency valve in the caboose, the brakeman pulling his valve in the cab, the train or air hoses coming uncoupled, or an air hose bursting.

**Emergency reservoir**
This is all well and good in theory but what about that doofus engineer described above that "pisses" away his air so there is little air in the reservoirs? He still gets very little braking in emergency, he just gets it quicker. To ensure that there is always air pressure on each car for an emergency application, they modified the basic system. They added a second reservoir to each car! The original reservoir we've discussed up to this point is called the auxillary reservoir or SERVICE RESERVOIR because it is the one used in normal service braking.

The new reservoir is called the EMERGENCY RESERVOIR because it is only used in emergencies. This 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 has 90 psi in it. This air is never used during normal braking. However, if an emergency application is initiated by any cause making a QUICK reduction of the brakepipe, each car emergency valve triggers as explained above, but now it also connects the emergency reservoir air to the brake cylinder in combination with the service reservoir air. This ensures that there will be air pressure for an emergency stop.

By the way, when I make a service application of the brakes, I vent the brake pipe air thru a SMALL HOLE in my brake valve. This lowers the brake pipe air pressure slowly. When I want an emergency application of the train brakes I move my brake valve over to the emergency position. This is just a BIG HOLE that allows air to escape QUICKLY and that triggers the emergency valves on the train cars. That is where the terms "big hole 'em" and "He went to the big hole", meaning an emergency application, come from. Also the term "Dump the Air" means go into emergency. It comes from the fact that you initiate an emergency application and cause each cars' emergency valve to "dump the air" locally. Regular service applications of the brakes are referred to as "set 'em up", "set the brakes", "set the air", "squeeze the breeze".

**Quiz #1**
You are now an expert on train brakes. There will be a quiz on Wednesday.

Quiz: (Is it Wednesday already?)
You have made a 10 psi brake pipe reduction on a fully charged train. The brakes have applied. 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 the brake pipe is higher than the reservoir the valve moves into release position. If the brake pipe is lower than the reservoir it moves into the apply position. If you have made a 10 psi reduction from 90 to 80 psi and the brakes have set, the reservoir and brake pipe are both now at 80 psi. As the reservoir slowly leaks the pressure drops, from 80 to 79 to 78 to 77 etc. As soon as the reservoir pressure leaks from 80 to 79 psi the triple valve "sees" that the brake pipe (80) is HIGHER than the reservoir (79). IT WILL MOVE TO THE RELEASE POSITION and release the brakes on that car!!! Whoa! This is not good. But you still have brakes on the other 109 cars of the train, hopefully.

**Quick Service**
Because, during a normal service application, all the brake pipe air has to vent thru the loco's control valve it takes a long time to get the brakes set through out the train. The pressure first drops near the front of the train and then drops further and further towards the rear. This causes the brakes to set up on the front part of the train before they set on the rear portion. This causes the rear end to run into the front end (slack action).

So some smarty comes up with the idea of modifying the triple valve on the cars so that when a car first senses a drop of pressure, it opens a passage from the brake pipe to a small reservoir (a third reservoir called a "quick service reservoir"). This reservoir is sized such that it has the proper volume in relation to the car's brake pipe volume that filling it with air from the brake pipe will reduce the brake pipe 6 psi. That means when an engineer makes a 10 psi reduction, 6 psi worth of it is done at each car. This results in a faster (but not fast enough to trigger emergency) more even application of the brakes thru the train. It only works the first time, however, since after that the small quick service reservoir is filled and remains so until the brakes are released.

**Quick Release**
Because of the long brake pipe of a train and all those cut off valves at the ends of each car and other restrictions, it takes time to pump air back through the train to release the brakes. As a matter of fact, as each car goes into release it begins recharging its reservoir from the brake pipe, consuming air from the brake pipe further slowing down the build up of pressure towards the rear. This results in the head end releasing first and causes problems with slack action as the front portion running free runs away from the rear portion still braked.

In the early days they solved this problem by putting chokes in the pipes that carried air from the brake pipe to the reservoir on each car. A choke is just a restriction. A plug with a small hole drilled through it. This allowed a more rapid build up of air pressure in the brake pipe all the way to the rear of the train since each car reservoir was consuming brake pipe air at a slower rate due to the choke restriction as it recharged following a release. But as trains got longer and heavier even this was not enough and the chokes slowed down the initial charging of the trains in the yard and the recharge on the road. So along comes Mr. Smart again. Like a Congressman and the social security fund, he can't stand to see a surplus go unused.

Remember that emergency reservoir they put on each car? It was initially charged to 90 psi and never used if the engineer did not need an emergency application. All that air there. They modified the triple valve again so that when a car goes into release it:
1. Vents the cylinder air to atmosphere releasing the brake as before,
2. Connects the brake pipe to the reservoir to begin recharging as before, and now
3. Connects the 90 psi emergency reservoir to the BRAKE PIPE to boost the brake pipe up quickly at each car. This results in fast releases through out the train length, but it depletes part of the emergency air available if you need it right away before it can recharge.

**Quiz #2**

You have made a 10 psi brake pipe reduction on a fully charged train. The brakes have applied. One car has a leak in its service reservoir. With a whole train of this type of equipment what happens to the brakes on that car? What happens to the brakes on the entire train?

Answer:

Same as before. The brake will release on the leaky car. However, with this type of equipment that one leaky car, when it moves to the release position, will put its 90 psi emergency reservoir air into the brake pipe. This action will raise the brake pipe pressure on that car AND THE CARS NEXT TO IT! When the cars next to the leaky one see the brake pipe rise slightly above their service reservoir pressure, their valves interpret this as a release signal AND THEY ALSO MOVE TO RELEASE! Now they also dump their emergency reservoir air into their brake pipes and that triggers the cars next to them to release. Because of that one leaky service reservoir the entire train will release. It is for this reason that it is against the rules to "bottle the air", close the angle cock on the train, when uncoupling the engines.

**Retainers**

On long steep grades it may be necessary to set and release the brakes several times due to grade changes etc. But, if you release the brakes on a steep hill the train immediately accelerates. If you immediately reset the brakes you get less braking than before because the car reservoirs have not had time to recharge. Because of the long recharge time on long freights a way was needed to keep the brakes applied on the cars yet allow them to recharge. Enter the retainer valve.

When a triple valve moves to release, it connects the reservoir to the brake pipe to begin recharging the reservoir from the brake pipe. It also vents (exhausts) the brake cylinder air to atmosphere to release the brakes. The retainer valve is mounted on the exhaust pipe of the brake cylinder and can restrict or close off that exhaust. This restriction holds some of the air in the brake cylinder, thus keeping the brake applied even though the triple valve is in release where it allows recharging of the reservoirs.

Retainer valves are completely manually operated, i.e. the train must be stopped (usually at the top of a long downgrade), the engineer releases the brakes, and a crewman must walk back along the train. He turns the retainer valve on each car to the restricting position. Usually only a percentage of the cars are "retainered", just enough cars to keep the train from running away down the hill when the brakes are released and recharging during the run down the mountain. When the crewman is back aboard the train may proceed down the mountain. The air brakes work normally until they are released. Then the cars with the retainers closed will hold their brakes applied, slowing train acceleration while the reservoirs on all cars recharge for the next brake application. The train must stop at the bottom of the grade and a crewman again walk back and return the retainers to their open (direct release) position.

The retainer valves have four positions:

1. Direct release (normal)
2. Slow release
3. Low pressure hold
4. High pressure hold.

There are very few places in the U.S. today where retainers are used on a regular basis as dynamic brakes serve much the same purpose, controlling the train acceleration while the air brakes recharge. Since the dynamic brakes slow down the rate of acceleration the air brakes have longer to recharge before they are needed again. Also the retarding effort of the dynamic brakes allow the engineer to use lighter air brake applications to control train speed, thus the car reservoirs are not depleted as much and require less time to recharge. However if a train should happen to go into emergency due to a burst air hose or such and stops on a long steep grade you would NOT want to release the train brakes after fixing the hose. The brakes would release completely and you will have almost no air remaining in the car reservoirs to reapply the brakes. If you don't have dynamic, or it is not sufficient to slow the train once it is moving, then you'd have a run away. The solution is to walk back before releasing and turn on the retainers to hold the brakes on some cars. Then release the brakes and roll down the hill with these "retained" cars controlling the acceleration while the entire train recharges.

**Load/Empty Sensors**

Traction between the wheels and the rail is directly proportional to the weight on the wheels. The amount of traction determines the amount of braking that can be applied without sliding the wheels. Sliding wheels develop flat spots within a few feet. Train cars have a large weight difference between the loaded condition and the empty condition, especially modern coal hoppers and grain cars.

The maximum braking effort of a car must be designed so that when in emergency (when the highest brake cylinder pressure is obtained) the EMPTY car will not slide its wheels. Unfortunately this means a heavily loaded car is under braked even in emergency. A way was needed to allow higher brake cylinder pressures on loaded cars than on empty cars.

One way of accomplishing heavier braking on loaded cars than on empty cars is to put a slightly larger auxillary reservoir on the cars. This increases the 2.5 to 1 volume ratio between the auxillary reservoir and the brake cylinder. This produces a higher cylinder pressure for any given brake pipe reduction. The higher cylinder pressure means heavier braking on that car. This is what you want on a loaded car but just the opposite of what you want for an empty car. To reduce the volume ratio of auxillary reservoir to cylinder you can attach a small reservoir to the brake cylinder. (Yes another reservoir). This small reservoir effectively increases the volume of the brake cylinder. That reduces the volume ratio between the auxillary reservoir and the brake cylinder. This means that for any given brake pipe reduction you will get a lower cylinder pressure which is what you want for empties.

On an empty car you want the passage between this new little reservoir and the brake cylinder to be open so part of the brake cylinder air can flow into the little reservoir to lower the cylinder pressure. On loaded cars you want that passage closed so all the air is in the brake cylinder. The closing or opening of the passage between the new little reservoir and the brake cylinder is controlled by a load/empty sensing arm. The valve is mounted on the car frame just above the truck frame. One end of an arm is attached to the close off valve and the other end rests on the truck frame. If the car is EMPTY the car body rides high on the springs and the arm moves the close off valve to the open position allowing part of the cylinder air to flow into the small reservoir. A LOADED car rides low on the springs and the arm is pushed up, moving the close off valve to the closed position, thus preventing any of the cylinder air from flowing out into the small reservoir. This method of load/empty regulation has the advantage of higher brake cylinder pressures on loaded cars for any given brakepipe reduction and lower brake cylinder pressures on empty cars for that same brakepipe reduction. This produces a more even retardation of loaded and empty cars while at the same time prevents the sliding of empty car wheels.

## Air Pressure Variations

The engineer can change the maximum pressure of the brake pipe by adjusting the FEED VALVE at his control stand. I have used 90 psi as the standard pressure to which the brake pipe is initially charged and subsequently recharged. On the railroad I work for, 90 psi is the standard. Some railroads use 80 psi as a standard. Some mountain grade railroads use 100 psi in mountain territory on loaded coal and grain trains.

What is the significance of these different pressures? During normal service braking operations there is none. A 10 psi REDUCTION from a 100 psi brake pipe, a 90 psi brake pipe, or an 80 psi brake pipe all result in 25 psi in the brake cylinder and thus equal braking effort. Remember that 2.5 to 1 ratio between service reservoir volume and brake cylinder volume.

But what happens if you make a 26 psi reduction from a 90 psi brake pipe? 90 minus 26 = 64 psi in the brake pipe. Remember the triple valve moves to the apply position and allows service reservoir air to flow into the brake cylinder until the service reservoir pressure lowers to equal the brake pipe pressure. As the service reservoir pressure flows into the brake cylinder the brake cylinder pressure rises. Because of the 2.5 to 1 ratio of volumes, when enough air has flowed into the brake cylinder to lower the service reservoir 26 psi the BRAKE CYLINDER PRESSURE IS 64 psi !!! (2.5 times 26 = 64). This air came from the service reservoir which is NOW AT 64 psi ALSO. Since the reservoir pressure and the brake cylinder pressure ARE EQUAL no more air will flow into the brake cylinder.

This condition is called a **FULL SERVICE** brake application because even reducing the brake pipe further, below 64 psi, WILL NOT INCREASE the amount of brake cylinder pressure. Even if you reduce the brake pipe pressure to zero psi the reservoir and brake cylinder pressure will still be 64 psi, the same as it was with only a 26 psi reduction. This full service or "equalization of pressures" occurs at 64 psi for a 90 psi charged system. It occurs at 71 psi for a 100 psi charged system resulting in higher full service brake effort. It occurs at 57 psi for an 80 psi charged system resulting in lower full service braking effort. The corresponding brake pipe REDUCTIONS are 26 psi for the 90 psi brake pipe, 29 psi for the 100 psi brake pipe, and 23 psi for the 80 psi brake pipe. The chart below shows the full service reduction and equalization pressures for various brake pipe settings.

| Brake Pipe Setting | Full Service Reduction | Equalization Pressure |
|---|---|---|
| 100 psi | 29 psi | 71 psi |
| 90 psi | 26 psi | 64 psi |
| 80 psi | 23 psi | 57 psi |
| 70 psi | 20 psi | 50 psi |

An engineer who makes a reduction greater than these values is just wasting time, no higher braking effort results. This is all academic however since normal train operations seldom require a brake application greater than a 15 psi reduction and any reduction greater than 12 psi is considered heavy braking.

So why would mountain grade railroads use 100 psi in the brake pipe? Two reasons.
First, as we just saw, the full service braking effort IS higher if it is needed.
Second, suppose a 10 psi reduction is made from a 100 psi charged system (100 - 10 = 90). This results in 25 psi in the brake cylinders. (10 psi times 2.5). Part way down the mountain the grade lessens and the train speed drops. The engineer releases the brakes and the brake pipe returns to 100 psi. The train immediately begins to accelerate down the grade. He immediately resets the air brakes by making another reduction. But the car reservoirs have only just begun to recharge so they have only 90 psi in them. If he makes a 10 psi reduction of the brake pipe (100 - 10 = 90) he will get no brakes. This is because the brake pipe will be at 90 and the reservoirs are also 90. But if he makes an additional 10 psi reduction, a total of 20, (100 - 20 = 80psi) he will get the same braking effort as the original set, 25 psi in the cylinders. So you can see that the 100 psi charged system AFTER one 10 psi set & release is in the exact state a 90 psi charged system is in when fully charged. This means the 100 psi charged system gives him one additional 10 psi set and release before he begins to run out of air compared to the 90 psi charged system.

So why not use 100 psi everywhere? There are penalties that go along with that extra pressure. One is that any weak hoses or valve gaskets may fail at the higher pressures. Another is if the train should go into emergency for any reason the higher braking effort may be enough to lock up and slide car wheels, especially on empty or lightly loaded cars. This will cause wheel damage at the very least and possibly a derailment from failed wheels later. A third reason is it takes longer to charge a train initially to 100 psi instead of 80 or 90 and the higher pressures cause more leaks in the system.

So why the 80 psi system? Long ago, like in the 1920s, the brake pipe was 70 psi. That was fine for the 40 ton cars of the day. By the 1940s the coal cars had grown to 55 tons and the brake pipe pressure pushed to 80 psi. In the 1950s the cars were 70 tons and in the 1960s had grown to 100 tons. Still 80 psi brake pipe pressure handled the braking chores OK. By the 1970s coal & grain cars had climbed to 135 tons and the 80 psi brake pipe had little margin for error. Especially on unit coal trains of 15,000 gross tons, even on 1.25% grades. In addition the emergency stop distances for heavy trains was growing longer and longer.

During the 1970s our railroad rules dictated an 80 psi brake pipe for all trains EXCEPT loaded unit coal and grain trains which were to use 90 psi. This gave the engineer one extra 10 psi set and release compared to an 80 psi brake pipe and it also shortened emergency stop distances for these heavy trains, but it created other problems. For instance when the trains were unloaded the pressure had to be reduced. If a coal train using a 90 psi pressure gave cars during switching operations to a freight using an 80 psi brake pipe, the "over charge" condition had to be reduced. This didn't always get done properly resulting in stuck brakes on some cars and over heated wheels. As the weight of lumber, tank, and other cars caught up to the coal and grain cars and load/empty sensors were applied the railroad simply mandated a 90 psi brake pipe for all trains. However, railroads that don't operate unit coal trains or don't have steep grades still use 80 psi since it is adequate for their type of operations. Some yard and transfer operations that operate at low speeds still use 70 psi, taking advantage of the shorter charging times.

## Locomotive Brakes

The locomotives have air brakes just like the cars and they will apply when the brake pipe air pressure is reduced just like the car brakes. This is not always desired, especially when stretch braking with the throttle open and car brakes set to control the slack action. The engineer can prevent the loco brakes from applying at these times by depressing the independent brake handle and holding it down. This is called "bailing off the air", or more correctly, "actuating off the air".

**Independent Brakes** Locos also have "independent" brakes that you can apply on the locos only. This is straight air where the air pressure comes straight from the air compressor main reservoirs on the locos to the locos' brake cylinders. It is controlled by the position of the independent brake handle. The locomotive brakes alone could eventually stop a train on level track or a small train on a grade. But applying heavy braking to the locomotive wheels for the required time would over heat them. So it is forbidden to use independent brakes to control train speed on the road except in emergency. The independent loco brakes are used only for switching, moving locos by themselves, or for holding a stopped train on level or low grade track.

**Multiple Unit Hoses** Each loco has an air compressor and main air reservoirs on it. They are all connected by hoses to the lead loco so all units can help supply air. These main reservoir hoses and independent brake control hoses are the hoses you see between loco units. Looking at the end of a loco from out in front of it you see there is a set of three hoses on each side. From the outside in they are:

1. The independent brakes Application & Release line.
2. The independent brakes Actuating line (Bail off).
3. The Main Reservoir Equalizing line.

The brake pipe is the large hose under the coupler.

The big electrical jumper between units is a 27 wire cable that has control wires for trailing units' throttle, headlights, reverser, compressor control, generator field control, dynamic brake set up and control, engine alarm bell, sanders, etc.

## Equalizing Reservoir

I 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.

This method is true only for very early air brake systems. As trains got longer, thus more brake pipe volume, it began to take too long for the air to travel thru all the cars to vent at the engineer's brake valve. His attention was fixed on the air brake gauge far too long to be safe. So the locomotives had another small reservoir installed called an EQUALIZING reservoir. This reservoir is very small compared to the brake pipe volume of a long train and thus its pressure can 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 and it is this valve that vents the brake pipe air to atmosphere at a service rate until it reduces to be equal to the equalizing reservoir pressure.

## Self Lapping Brake Valve

Since the late 1950s or early 1960s the engineer's brake valve has been of the self lapping type. That is, he no longer has to move the brake valve back to the LAP position after making a reduction. The position of the brake valve handle determines the amount of reduction made.

## Dynamic Brakes

Dynamic brakes are easy. Basically you just turn the traction motors into generators and turn the electric power they produce into heat and dissipate it. Contrary to popular belief the motors are NOT put into reverse!

Normally, while pulling (motoring) the traction motors are your standard DC motors. The output of the main generator is applied to the traction motor armatures and fields and they "motorvate". However when you change to dynamic braking, heavy duty contacts "re-wire" the motors. The ends of the field windings are connected across the main generator output so that the main generator is applying power only to the fields. The ends of the armature are connected across iron resistance grids. As the train moves down the track the wheels turn the traction motor armature. Since the armature is turning in a magnetic field, created by the field windings powered by the main generator, the armature generates electricity. This electricity flows thru cables up to the resistance grids. The grids get hot using up the electricity just like the resistance wires in your electric toaster but on a much larger scale. Large blower fans cool the grids to keep them from melting. In principle, the whole thing works similarly for AC drives but the details are different.

It takes lots of power to turn those armatures to generate all that electricity being thrown away as heat. This power comes from the rolling train thus retarding it. Because the armatures must turn a minimum speed to generate power, you can not stop a train with dynamic brakes. You can only control its speed or slow it down. As you near 12 mph the armatures are turning slowly enough that they generate little power so braking effort drops off rapidly. At higher speeds the amount of braking is controlled by me, the hogger. I move the dynamic brake lever and that in turn controls the output of the main generator which is supplying the traction motor field current. The stronger the fields the more power generated by the rotating armature so the more braking effort you get. Simple ain't it?

Actually that is a pretty good description of how it works but in reality it is a little more complicated. Life always is isn't it. I don't really control the output of the main generator directly. My lever controls a rheostat that controls transistors that control the field of the exciter generator. The output of the exciter goes to the field of the main generator and that controls the output of the main generator, which goes into the traction motor fields so the rotating armatures can generate the electricity producing braking effort. Wheeze! Got it? Also various sections of the resistance grids are switched in and out of the circuit to provide different amounts of electrical load thus different braking forces.

About the only part of dynamic brakes you can see are the resistance grids and their cooling blowers. On EMD locos they are along the top of the roof of the long hood about in the center of the loco. That is the "bulge" along the roof line with one or two 36" blower fans on top. Older GEs (U25, U30 era) have the dynamic brake grids mounted in the radiator cooling air intakes on the side of the hoods. You can see them if you look thru the screens. The grid cooling air is supplied by the single large radiator fan on these GEs. Newer GEs and EMDs have a boxy affair mounted high immediately behind the cab. These have their own grid cooling blower. You can tell when any loco is in dynamic braking going down hill because these blowers suck a lot of air and whine. Once in a great while a grid cooling fan will fail or a grid will short circuit. This results in the iron grids actually melting, accompanied by white hot molten slag blowing from the unit and all sorts of arcing and pretty sparks. A great show at night.

# FOOTNOTES

## 1. Quick Service

The Quick Service feature is an 1895 requirement of the Master Car Builders' Association (now called the AAR). Early triple valves didn't have Quick Service. The feature was first introduced with the K freight brake of 1900 (or 1901) and has been a requirement for all braking systems since. Triple/control valves accomplish quick service in one of three ways, depending upon the model of the valve: put the air into the brake cylinder (K does this), throw the air away (AB/ABD does this), or save it in a reservoir for use if an emergency is called for later (a modification to ABD/ABDX for some designs of TOFC, auto rack, articulated container cars, and others). This third method is the reservoir mentioned.

It takes only about 1 to 1½ psi pressure differential across the face of the triple/control valve operating piston to move it. Once it moves, it goes to Quick Service, with no choice offered and reduces the brake pipe by 6 psi. If the engineer makes an initial reduction that is greater than 6 psi, Quick Service action within the valves will be bypassed. If he makes one that is less, the valves on the cars will make sure it becomes a 6 psi reduction. The Inshot Piston is a device inside the Emergency Portion of an AB control valve and it is used to regulate the flow of air into the brake cylinders into two stages during an emergency application in order to get a modicum of control over slack action in the train during the emergency application

## 2. Equalising Valve

There are a few automatic brake valves (mostly special passenger ones) that vent both the Equalizing Reservoir and the Brake Pipe to atmosphere at the same time. This is done to eliminate the delay between the movement of the brake handle and the onset of reduction of brake pipe pressure, essentially ensuring "instant" automatic brake applications.

revolves around the economics and practicalities of air consumption and replenishment and the geometry of the foundation brake rigging on the cars.

## 3. Air Pressure Variations

US automatic brake systems are still designed around the ratio of 2:5:7 and the 50 foot freight car. When automatic brakes were first introduced, 70 psi was the operating pressure and this pressure was used by some railroads right up until almost 1960. Taking 2/7 of this pressure out of the brake pipe results in a brake cylinder pressure of 5/7 of this value; a 20 psi reduction produces a 50 psi brake cylinder pressure. This is the notorious "Point of Equalization" where further decrease of brake pipe pressure won't produce an increase of brake cylinder pressure. When the base operating pressure was raised to 90 psi (current US standard for freight), the numbers became 26, 64, and 90 ; for 110 psi (the current passenger standard) they become 32, 79, 110. The ratio doesn't have units. If you threw away the British based gauges used in the US and substituted metric ones (kgs per sq cm), used a self-lapping automatic brake valve to apply the brakes and measured the full service pressures, you will find that a full service reduction is still 2/7 of the base operating pressure. The reason for the original 50 psi brake cylinder pressure standard