Thesis

The Development of the Air Brake

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Course I 1904.
There is probably no part of the equipment of an up-to-date railroad more interesting and important than the braking equipment. The railroads are the largest common carriers and their field of action penetrates every part of the world. It is necessary in handling trains that the engineer should have absolute control of his train. The safety of life and property is demanded by the traveling public.

When one notices the ease with which trains are handled today and compares the number of accidents to the number of people carried, his natural impulse is to inquire into the methods of train handling. The efficiency of train handling today is largely brought about by the air brake. Of course there are other elements entering...
into the subject of train handling. This Thesis deals only with the air brake, and traces its development from its introduction to the present date. The Westinghouse air brake has been taken as a model, because it more nearly, according to best authority, represents the perfect air brake than any other used.
PLATE A.

ARRANGEMENT OF THE AIR-BRAKE EQUIPMENT ON THE ENGINE, TENDER AND PASSENGER CAR.
The air brake is a brake worked by compressed air. The first form was the straight air brake, and was invented in 1869 by George Westinghouse. The parts necessary to operate the straight air brake were an air pump, a main reservoir, a valve called the three way cock used to control the application and release of the brakes, a train pipe and brake cylinders. The main reservoir, pumps and engineer's valve were located on the engine, while the train pipe and brake cylinders were on the car. The braking power in this system was stored in the main reservoir on the engine. The brakes were applied by changing the position of the three way cock on the engine, so as to allow the main reservoir pressure to flow into the train line.
The tram line, connected directly with the brake cylinder, allowed air to pass into the cylinder, forcing out the piston and applying the brake.

This style of brake was unsatisfactory for several reasons. First, the tendency of the brake was to apply soonest at the head of the tram. When the application of the brakes was sudden, the slack in the tram running ahead would cause severe shocks and damage.

In case of bursting hose, the brakes could not be set as the air would pass through the opening into the atmosphere. Think! In a long tram the main reservoir pressure would equalize with the tram line pressure and brake cylinder pressure. The resultant pressure would be very low owing account of the large space to be filled. This
made it necessary for the engineers to allow the air pump to compress air into the train line and brake cylinders, so that before the maximum braking power was obtained, the train would be stopped.

Fourth: The effect of friction on the flow of air from the main reservoir through a long train line made this brake slower.

The air brake as described, made several gains over the hand brake previously in use. With a train of fifty air brake equipped cars, a full and harder set brake was obtained on the whole train more quickly than a hand brake could be set on a single car. Since trains handled on heavy grades have to be slowed down for the purpose of recharging,
the air supply, the wheels are
given a chance to cool. With hand
brakes on heavy grades, the shoes
grind against the wheels all the
way down, heating the wheels to
so high a temperature that they
often break. Air brakes there for
give no increased speed with
greater safety.

The second form of air brake
was the automatic brake. This was
also invented by George Westinghouse
in 1873. The difference in the equip-
ment of the straight air and auto-
matic brake, was that the automatic
had beside the train line and
brake cylinder, a plain triple-
valve and an auxiliary reservoir.
There were two games made in the
automatic brake over the straight
air brake.

First: The necessary braking power for each car regardless of the length of the train, was stored in the auxiliary tank under each car. Thus the brakes could be set very quickly compared to the action of the straight air brake.

Second: If the train parted, the triple valves would automatically apply the brakes. This could not be done with the straight air brake.

The essential feature of the automatic was the triple valve, known as the plain triple. It was located on the car at the junction of the train line, auxiliary, and brake cylinder. The valve was called a triple because it automatically did three things namely: charge
the auxiliary, apply the brakes and release them.

Then an engine was coupled to a car not charged, the triple valve was coupled to the main train line by a hose. The pressure from the train line passed through the triple and into the auxiliary. The air would flow into the auxiliary until the pressures in the train line and auxiliary were equalized. To set the brakes the train line pressure was reduced. This caused the piston in the triple valve to move down and open a port into the brake cylinders. Another reduction of pressure then had to be made to set the brakes harder. These reductions could be made until the pressures in the brake cylinder and auxiliary
were equal, at which point the brakes would have their maximum power.
To release the brakes it was necessary to pump air into the train line. This forced the triple piston up to a joint where it released the pressure on the auxiliary. This auxiliary pressure being lowered, the brakes were released.

With the old style triple valve, the auxiliary could be charged in about seventy seconds to seventy pounds pressure.

The main objection to the plain triple was that it often took some time to release the brakes, as the air pump would not charge the auxiliaries equally.

The plain triple valve could also be used as an emergency brake. By suddenly reducing the pressure, the triple piston opened a large port.
into the brake cylinder, which set
the brakes immediately. The braking
power in emergency was no greater
than in service application. Plain
triple valves are very little used
today except on engines and tenders.
Their use on cars is confined prin-
cipally to those equipments put on
before the introduction of the quick-
acting triple valve.

The plain triple was satisfactory
so long only as it was used in service
application. It was most unsatisfactory
with emergency application on a
long train. In the emergency appli-
cation the head brakes were set so
much sooner than those in the
rear, that the slack of the train
ran ahead and often did great
damage. It was therefore necessary
that some improvements be made, so that the brake could be depended on in both service and emergency application. To this end the quick acting brake was introduced.

The quick acting triple valve was invented in 1887 by George Westinghouse Jr. Two advantages were gained by this invention over the plain triple valve:

First: It enabled the engineer to set the brakes throughout the train before the slack had a chance to run ahead and do damage.

Second: It not only enabled the engineer to set the brakes quicker, but it enabled him to set them harder, thus permitting a quick stop and consequently a higher safe speed for trains.
In service application there was no difference in the action of the plain triple and quick-acting triple valves, except the additional ports placed in the slide valve of the quick-acting triple, and which are only used in emergency. It is therefore evident that these two kinds of valves scattered throughout a train would work perfectly together.

A check valve was added to the quick-acting triple. This might be called an emergency valve. It acted only in case of a break in the hose coupling or tram pipe, in which case it caused all brakes to be set instead of allowing the air to escape into the open.

It has been said that in the case of the quick-acting triple the brakes
were set harder in emergency. It would therefore seem that they would be correspondingly harder to release. This is true in the case of the quick acting triple, but not true for the plain triple.

With the quick acting triple air from the train line helps set the brakes in emergency, and the pressures equalize higher. Therefore the train line pressure must be made higher to overcome the auxiliary pressure and force the triple piston to release position.

There has been some question as to whether the emergency will work after a partial service application has been made. It is much harder to get quick action after the service application has been made. The
quick action depends on the amount of reduction that has been made in
service and upon the piston travel.
In no case can we gain as much
after a small service reduction has
been made, as we could if a sudden
reduction were made when the aux-
iliarys were fully charged and the
brakes released. After a light reduction
again over the pressure obtained
in full service can be made by
going to the emergency position
if the piston travel is of fair length.
By using the emergency after a partial
service application, we would get
full service more quickly, even
though we made no gain in pressure.
In order to throw the trip into
quick action the reduction on the
trainline must be made so that
the train line pressure will get
into the brake cylinder before the
pressure from the auxiliary. The
auxiliary pressure gets in a small
amount as the service port in the
slide valve passes the port leading
to the cylinder. However, the air from
the train line reaches the cylinder
first. The size of the ports used
in emergency to let auxiliary
pressure into brake cylinder and that
of those used in service application
are different, the service ports being
larger. This is so as to hold back the
auxiliary pressure in emergency
and allow as much air as possible
to enter the brake cylinders from
the train line.

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preceded that the triple valve is a
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the team even in the case of general
trumpets being out of order the brakes would still work, so efficient and sensitive are the valves.

Should the engineer fail to make reductions in the air pressure after once starting to set the brakes, the air coming ahead from the back of the tram would kick off the head brakes. Water in the tram line often causes trouble as it freezes the pipes. It comes from leaks in the air pump.

The triple valve depends largely for its usefulness on the springs used. A weak spring might fail to close the valve and all valves would go into quick action, setting the brakes on the entire tram. This is true in the case of short trams, but not necessarily so in long ones. On a short tram with gradual tram line reduction, air is
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drawn from the tram line faster than the auxiliary pressure can get into the brake cylinders through the service port in the slide valve. When the auxiliary pressure is enough greater than that in the tram line, it forces the triple piston into an emergency position, as there is no graduating spring to stop it. On a long train it takes longer to make a corresponding reduction on account of the larger volume of air in the tram line. This gives the auxiliary pressure longer to pass into the cylinder, and as a result the tram line and auxiliary pressures keep about equal, and the triple piston will not move to emergency, unless a sudden reduction is made.

Probably the most common cause of brakes being set accidentally is a
sticky valve. The valve when sticky
will not respond to a light reduction
of pressure. When it does move, it
jumps and the sudden blow compresses
the graduating spring and makes
the valve quick-acting. This sets
all the valves on the train, regardless
of their position in the train.

The Westinghouse freight equipment
is somewhat different than the pas-
senger equipment. In the first place
it is smaller. The auxiliary reservoir
is connected directly to the brake
cylinder. While the appearance of
the freight equipment is different
the principle is about the same as
in the passenger.

Of late years the call by the
traveling public for higher train
speed, rendered it necessary to insure
the safety of life and property.
To meet this demand, the high-speed brake was introduced and adopted. This brake is about thirty percent more efficient than the ordinary quick-action brake. It is used on such trains as the Empire State Express, the Black Diamond and the Congressional Limited. The average percent of braking power to light weight on a passenger car equipped with the quick-action brake is about ninety. With the new high-speed brake this percentage is about one hundred twenty-five. It might seem that such a high braking power would flatten the car wheels. However, these brakes are only used when the train is moving at a very high speed. There is an
automatic reducing valve used with the high-speed brake, which gradually reduces the brake cylinder pressure so that when the speed of the train is decreased, the brake cylinder pressure has also been correspondingly decreased to the sixty-pound limit as used by the ordinary quick-action brake.

It is safe to use a higher braking power with the train running fast, because the faster the wheels turn, the greater the inertia of the wheels, which friction of the wheels has to overcome before they will stop revolving.

There were some tests made in England, called the Heatmghouse Galton tests, which proved that the faster the tread of the wheel moved
against the brake shoe, the less
the friction between the two. As the
speed decreases the friction increases.
The friction of the wheel and rail
remains constant regardless of the
speed of the train. The track line
and auxiliary pressures carried
with the high speed brake are
about 110 pounds. The auxiliary
and brake cylinder when set in
emergency equalize at about 85
pounds pressure. This 85-pound
pressure is reduced to the safe
pressure of 60 pounds for slow speed,
by means of an automatic reducing
valve which will be explained
later.

It may be well now to take up
in detail the other necessary parts
of an up-to-date air brake equipment.
The main reservoir is located on the engine between the frame back of the cylinder saddle. It should be located if possible at the lowest point in the air brake system, so as to have all dirt and oil in the system drawn into it, as it is easier to remove it there.

The air leaves the pump it goes to the main reservoir. The main reservoir pressure begins at the pump and ends at the engineer's valve. It is usually kept at about 90 pounds pressure, except in mountainous country and in high speed brakes, where it of course runs higher. The reservoir should have a capacity of not less than 7000 cubic inches. In any case it should be large enough to equalize the pressure m
the tram line, so that it will
insure the prompt and certain
release of the brakes after they are
set. And, for the service larger reservoirs
are required, as there are more auxiliaries to be charged. A large main
reservoir is most essential after an emergency application, and especially so
after a break in the tram. The main
reservoir acts as the storehouse, in
which to keep a reserve pressure to
release the brakes and charge the
auxiliaries. If the main reservoir is too
small, the pump will get too hot.
Small reservoirs mean high pressures,
and the higher the pressure the more
the heat generated in compressing
the air. Again, the pump has to work
closer to charge the auxiliaries. Then
it works too fast, it does not have time
to take in a full cylinder of air at each stroke, and hence loses its efficiency.

The engineer's valve is a sort of a transfer station for the compressed air. The air is stored in the main reservoir and its future action is controlled by the engineer's brake valve subject to the needs of the service. The brake valve controls not only the main reservoir air supply, but all air that may be stored in the auxiliaries and transmission. The original engineer brake valve was the three-way cock. This was used with straight air, with the plain automatic, and for some time by a good many roads with the quick-acting brake. It was however not sufficiently sensitive, and there was great danger of throwing the brake into emergency at times least
desired.

Reductions in pressure were then made by instinct or sound. An
engineer having a long train today
and a short one tomorrow, could not
do good braking, as the valve was
nothing more than a plug valve.
If the reductions were a trifle too
heavy, the triple valves would be
thrown into quick action. The reductions
could not be made too slowly, or
the air would blow through the escape
valves into the brake cylinders. If the
air escape from the train line was
suddenly checked, the air from the
rear of the train would ahead and
kick off the head brakes. What
was bleded, was a valve which
would mechanically make the
desired reduction in train line.
pressure, regardless of the length of the train.

A new valve was designed so that it would ensure a volume and pressure in the main reservoir sufficient to release all brakes. To this end the valve was designed so that it would keep twenty pounds more pressure in the main reservoir than in the train line. This improved valve was naturally called the twenty-pound cock instead of the three-way cock. Instead of a plug and socket, the valve consisted of a valve body in which there was a top valve and spring and a main valve and spring, the purpose of the springs being to hold the valves in place. The top valve controls the opening to the
atmosphere. The main valve controls the openings from the main reservoir to the tram pipe. With the handle in release position, the main valve allows the passage of air from the main reservoir to the tram pipe through two large ports. When the handle is turned to the first notch, all air must pass the feed valve and go through two small openings into the tram pipe. The valve should be set in this position while tram is running. The rest of the work done by this brake valve is in principle the same as the three-way cock. When the handle is turned to the third notch, it opens the tram pipe and allows the air to escape into the atmosphere, setting the brakes. There is one position of this
valve, which closes all ports. This is used in case the train breaks in two, or when the brakes have been set from the conductor's valve, so that the air will not escape from the main reservoir.

A new device for automatically assisting the engineer to apply the brakes moderately and with more skill, is the engineer's brake and equalizing discharge valve. This valve closely resembles the engineer's brake valve just described. The chief difference is that the valves in this brake valve are held to their seats by air, instead of springs. The main purpose of this new valve is to insure a more easy and uniform application of the brakes throughout the entire length of train.
By a gradual reduction of pressure from the train pipes, the air did not rush violently from the rear cars and kick off the head brakes. In place of the main valve and top valve of the twenty pound cock, a rotary valve was substituted. Below the rotary valve is the air chamber, or valve body, to which is attached a small air tank, to add capacity. The rotary valve controls the ports. When the handle is turned to release position, the air is given a free passage from the main reservoir to the train line. When the handle is in the second notch or position, the air flows to chamber, and small auxiliary reservoir, and also on top of the piston valve, keeping it to its seat.
Another position of the handle relieves the air from the train pipe and sets the brakes. This valve is very useful in double heading and on mountain grades.

There is a device on every car which enables the conductor to stop the train. This is known as the conductor valve. The device consists of a valve and spring enclosed in a case. The spring holds the valve to its seat. The valve is worked by a lever, to which a chord may be attached and hung in the car where it is most convenient. By pulling the chord and moving the lever the valve moves from its seat and allows the air from the train pipe to escape, setting the brake. In consequence, as soon as the chord
and lever are released the spring automatically places the valve on its seat and shuts off the flow of air from the train pipe. In applying the brakes, the conductors’ valve should be held open until the train comes to a stop. Conductor’s valve is only used in case of possible accident.

In connection with the high speed brake equipment the reducing valve was spoken of. This reducing valve consists of a piston and spring. Any air in the brake cylinder is free to reach the top of the piston in the reducing valve. As long as the tension in the spring is greater than the brake cylinder pressure on top of the piston, the valve will not move. When brakes are full set, the pressure is greater than the
tension in the spring. The piston is therefore forced down, and carries the slide valve with it, which opens a port allowing the brake cylinder pressure to escape into the atmosphere. The reducing valve is very useful, as by simply adding it to the present quick-acting equipment, we can turn this equipment into high-speed brakes. Certain additions have to be made on the engines however. A duplex pump is used and two tractive governors are added. Reducing valves are connected to the tender and driver brake cylinders. These are arranged with cutout cocks so that the engine may be used with "high speed" brake or with the ordinary quick-action brake.

Another interesting and very
useful piece of mechanism is the air pump. It is located on the engine and consists of an engine and pump, that is, an air cylinder and a steam cylinder. These two cylinders are connected by a casting to which both are bolted. A piston passes through the center piece connecting the steam and air cylinders. The casting is fitted with a packing box so that when properly packed, there can be no flowing of steam into the air or of air into the steam cylinder. The steam working the the piston, is regulated by a piston valve called the main valve and which is located in the walls of the steam cylinder. The main valve is in turn regulated by a reversing piston, which is located above it. After the pump is started,
the main piston, as in any steam engine, regulates the valve motion. Steam to work the pump, is admitted to the main valve on one side of the steam cylinder and is exhausted after use on the opposite side. The exhaust is carried to the atmosphere through the smoke stack of the locomotive. The air pump consists simply of a piston acting as a plunger. The movement is identical with the steam piston. Two sets of valves, self-acting, control passages of air to the main reservoir and atmosphere. They are called the upper and lower discharge valves and receiving valves. When the air piston moves away from the upper end of the cylinder, the upper receiving valve opens and air
follows the suction or the vacuum, formed, until the piston commences its return stroke, when the upper valve closes and the air is forced into the main reservoir through the upper discharge valve. As the receiving valve closes automatically when the air is being discharged into the main reservoir, so the discharge valve acts in the same manner in retaining the pressure in the main reservoir.

The air pump is controlled by a pump governor. The object of the governor is to automatically shut off the supply of steam to the pump when the air pressure in the train line and reservoir has reached the allowable limit, forming the basis for which the maximum power of the
brake is designed. Excessive pressure which may result in the sliding of the wheels is thus avoided.

The link between the different appliances which form the air brake equipment is the main line, or main air pipe. This starts at a connection with the main reservoir, runs to the engineer's brake valve, from whence it goes under the tender to each of the cars. The connections between cars are made with flexible rubber hose and air tight couplings. The main pipe is tapped under each car by pipes to the triple valve and conductor's valve. Some roads put a device on each car to apply the brakes in case the car jumps the track. This consists of a valve with a long handle pointing downward, the end of the handle
being about two inches above the
ties. Then, the car jumps the track
the handle strikes the ties, opens the
valve in the train pipe and in letting
the air escape, sets the brakes.
At each end of the car is a stop cock.
These cocks are for the purpose of
confining the air to the appliances on
the car, when necessary to uncouple
cars in service. These cocks should
always be open when the train is
completed and in service. A dummy
coupling is located at the end of
each car, so that when the hose is
not coupled to another hose, it can
be connected to the dummy, keeping
it free from dust and cinders.
This for air brake equipment
on cars only has been considered
there are also brakes in locomotives.
Opinion differs regarding the economy of using driver brakes for general service and on many roads they are considered an emergency brake. The usual outcome of using them for emergency only, is to strip off the tires, which necessitates sending the engine to the shop for repair. The driver brake with straight air is bad practice, as it has to be worked independent of the train brake. Some driver brakes have been applied by pipe connection to the triple valve of the tender so that the auxiliary in tender would furnish braking power for both engine and tender. This generally proved a weak inefficient method. The best way of working driver brakes is to have them on the same system with the car.
brakes, which make them act in conjunction with the car brakes. This ensures a moderate, but not too hasty application of the brake. There are many reasons for having the engine exert a percentage of the braking power, in proportion to its weight compared with the total weight of the train. Since this is the case, the tender brakes should become part of the continuous train brake, and exert braking power for all stops. Each engine should therefore be equipped with its own triple valve and auxiliary reservoir.

The cost of equipping a locomotive with a complete air brake appliance is about two hundred seventy-five dollars: tender, sixty dollars: passenger car, one hundred dollars and freight
car forty-five dollars.

It will be seen from the above figures that the equipment is rather expensive. It has been suggested that the brake mechanism be simplified and the cost reduced correspondingly. The demand however has not been so much for cheaper mechanism but for greater results. As the development of air brakes has been progressive in results, it would not be wise to accept a poorer brake for the sake of saving a few dollars.

There were a number of tests made some years ago, which show how quickly air brake trains can be stopped with quick-acting brakes. The train used in these tests consisted of fifty 60000 pounds capacity box cars. The light weight of each car was
30,000 pounds. The tests were ten in number. The following is the description of the tests:

1. Emergency stops train running at twenty miles an hour.
2. Emergency stops train running at forty miles an hour.
3. Applying brakes while train was standing still, to show rapidity of application.
4. Emergency stops train running at forty miles an hour.
5. Service stops and time of release. Exhibition of smoothness of ordinary stop and time of release.
6. Hand brake stops at twenty miles per hour, with five brakemen on train.
7. Breaking train in two.
8. Emergency at twenty miles per hour.
the brake leverage having been increased to give the quickest stop possible.

9. Emergency stop at forty miles per hour, using same leverage as in (8).

10. A train of twenty freight cars and a train of twelve ordinary passenger cars, running beside each other along parallel tracks, each being about the same weight and length of train and the brakes applied at the same time. This shows the relative stopping power of the old and new brake.

The summary of the results of these tests is given on the next page.
### Summary of results of tests

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<th>Third</th>
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<th>Fifth</th>
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<sup>Summary of results of tests</sup>
The following figure gives an idea of the advancement in air-braked appliances. The three figures represent to scale stops made by the same train, rate of speed but equipped as indicated. It takes twice as long to stop a train going at 40 miles an hour, three times at 50 and five times at sixty, as it does if the speed of the train be 30 miles an hour.

1886 Plain Automatic Brake

1887 Quick Action Brake

1896 High Speed Brake
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