Student Workbook **TP2005**

Pressure Equalization Applied to Air Brakes

Wabtec
CORPORATION

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Pressure Equalization

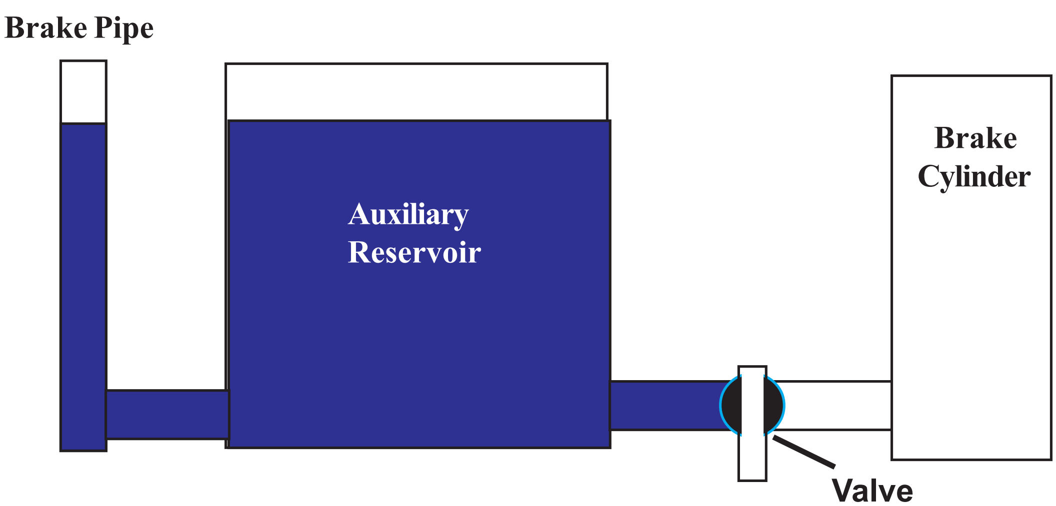
Contents:

Part 1: Principles of Pressure Equalization

A. A Simple Illustration of Equalization

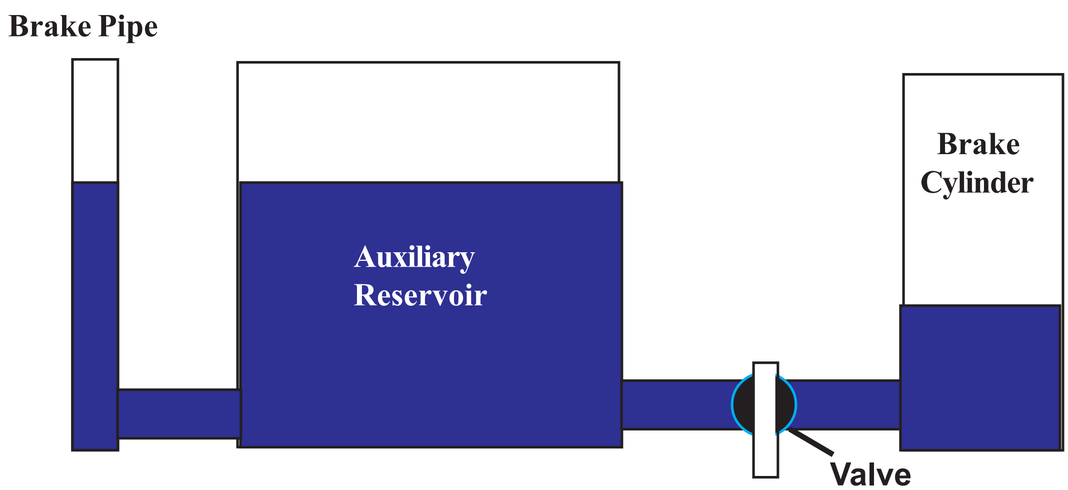
In order to illustrate the principle behind pressure equalization, we will use vessels containing water and extend the principles to compressed air. Air does not behave in quite the same manner as water but close enough for the principles relating to the brake system. The major difference is that water in its liquid state cannot be compressed, so we must use a little imagination.

In the drawing below we have a large tank representing the auxiliary reservoir and a small tank to represent the brake cylinder. The tanks are connected by a pipe and a valve (representing the control valve). On the side of the large tank is a level gauge, which we will use to represent the brake pipe. It is also connected to the large tank with a straight pipe connection. Because there is a direct connection the level in the auxiliary reservoir is the same height as the water level in the brake pipe.



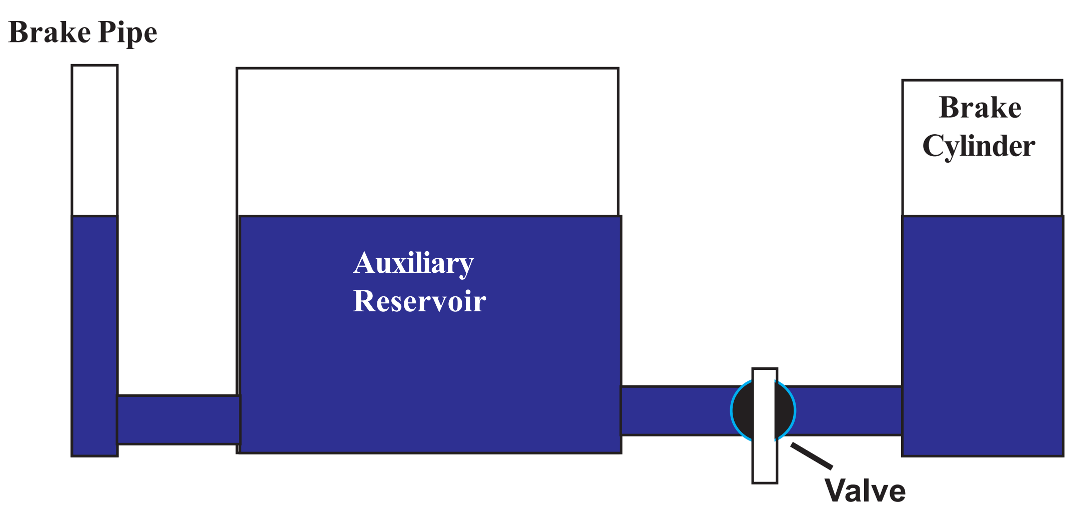
* FULL CHARGE

In this case because both tanks or vessels are connected and full of water, we will call them fully charged. At this time the brake cylinder has no liquid in it, therefore the brakes are not applied.



* PARTIAL APPLICATION

In a partial brake application we will allow water to flow from the auxiliary reservoir to into the brake cylinder vessel, causing its level to rise. Thus we have made a brake application. The amount of water allowed to enter the brake cylinder vessel is relative to the amount of brake pipe reduction.
In the case of air pressure – the brake pipe would be reduced and the control valve would allow air to flow from the auxiliary reservoir to the brake cylinder. The reduction in the auxiliary reservoir would match the brake pipe pressure reduction.

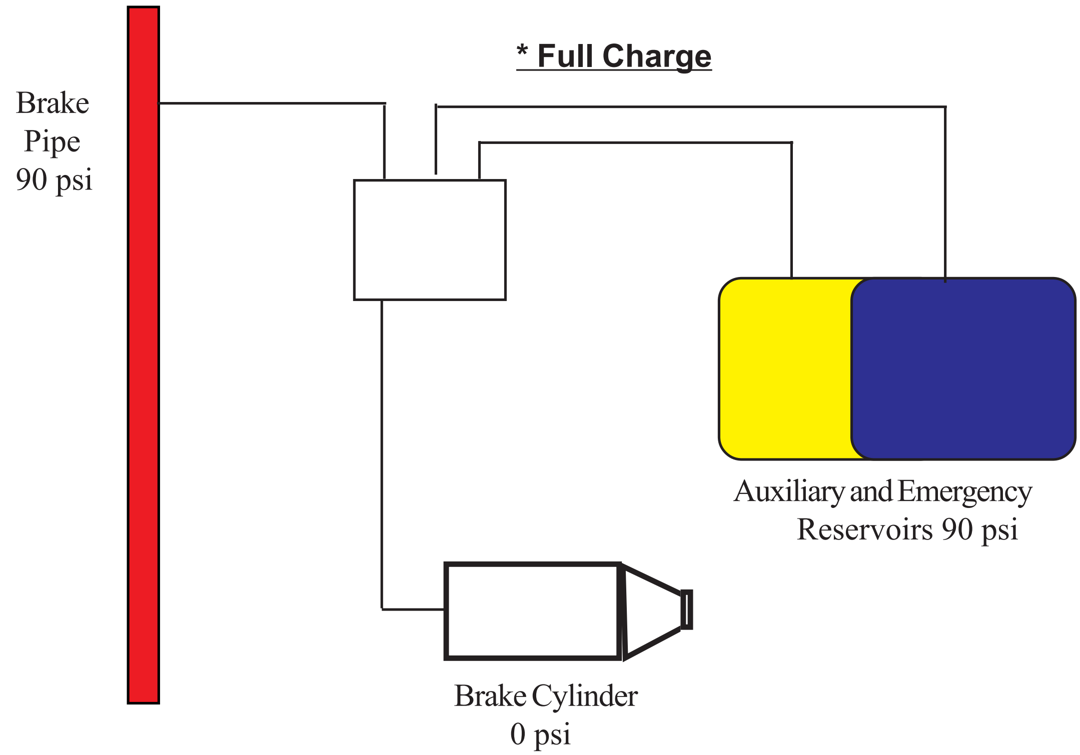


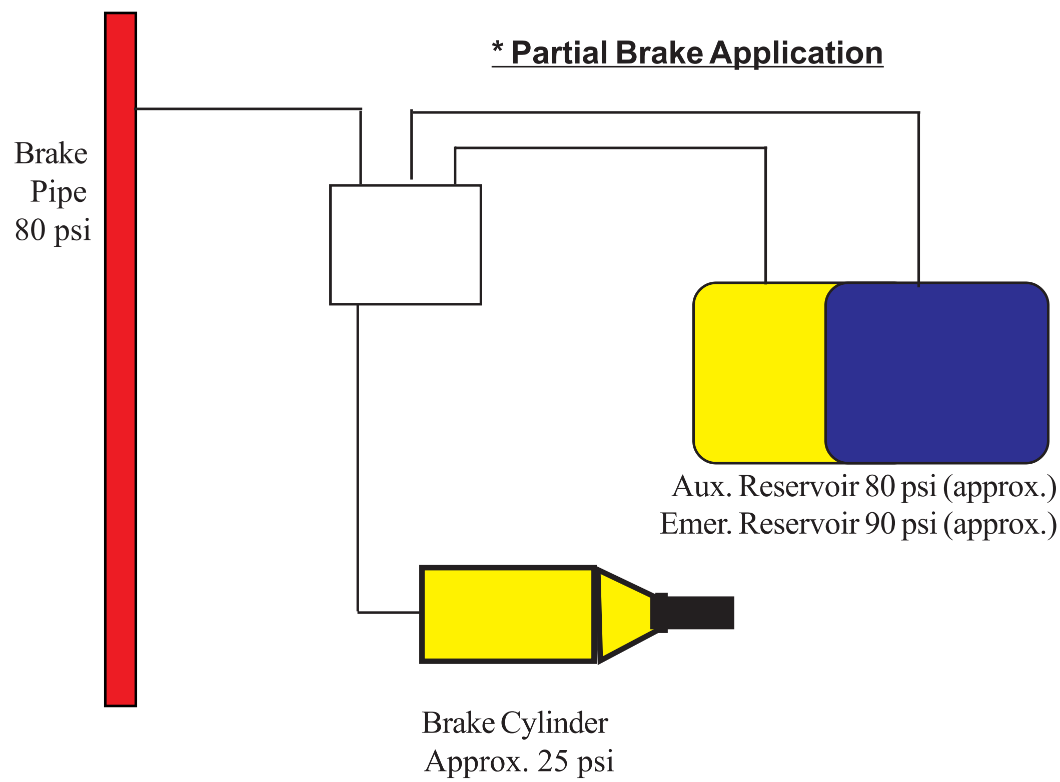
* FULL SERVICE (EQUALIZATION)

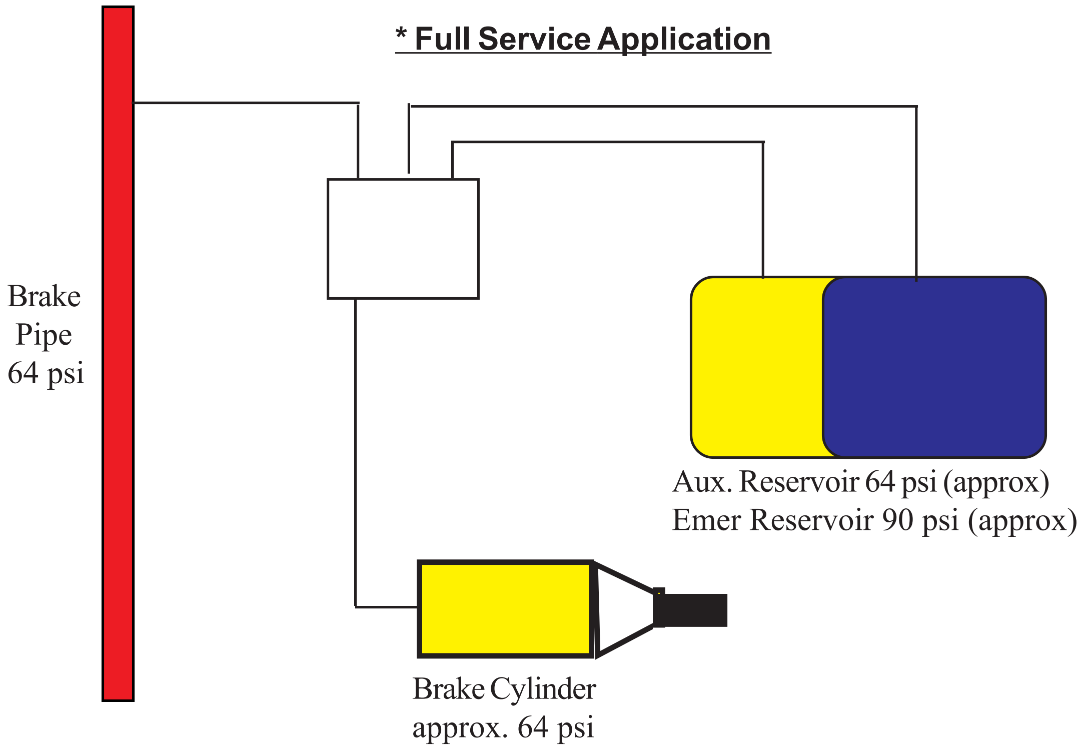
In a full application we would open the valve until water is allowed to flow into the brake cylinder until it is at the same level as the level in the auxiliary reservoir. At this point we have reached an equalization. No more water can be forced into the brake cylinder without outside influences.
This is very similar to air pressure. We cannot force more air into the brake cylinder from the auxiliary reservoir because it is at the same pressure as the brake cylinder. By reducing the brake pipe we simply vent that air to atmosphere.

B. Pressure Equalization with "AB" Equipment

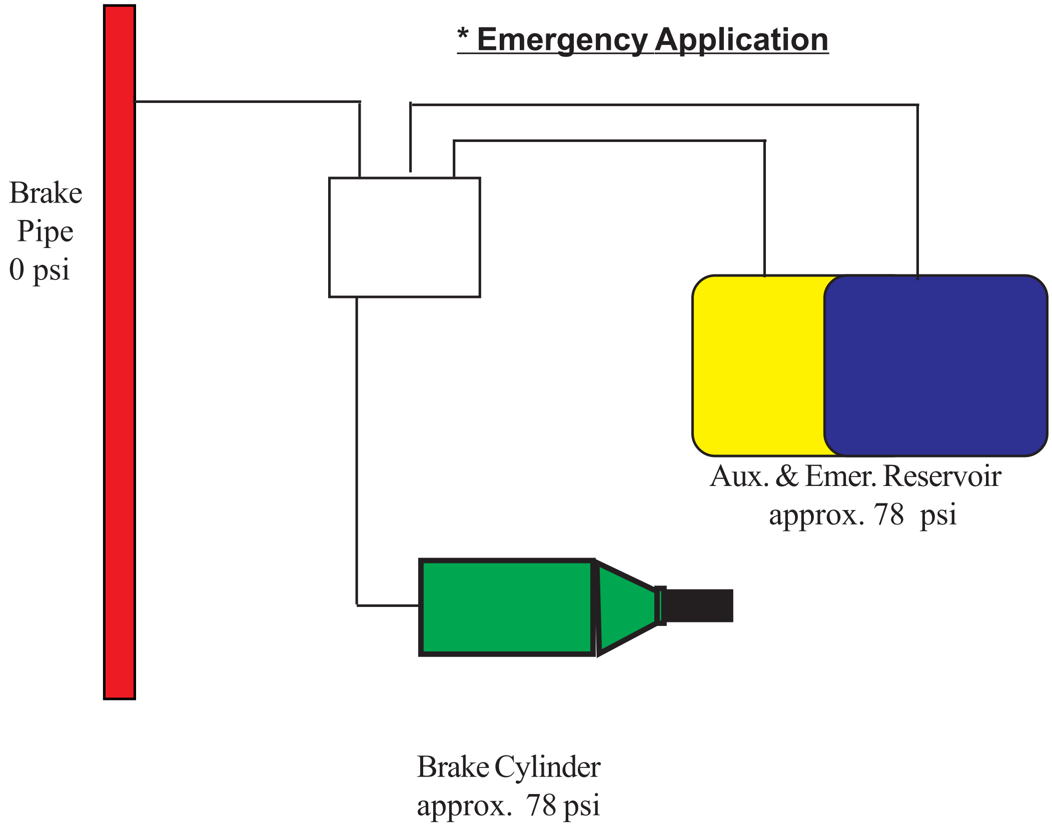
The following diagrams represent a little more closely the situation that actually exists in the operation of the AB control valve and equipment.







In this diagram the auxiliary reservoir and the brake cylinder are at the same pressure. They are EQUALIZED. No additional braking is available in a service application – the brakes are "on full". The 64 psi equalization is in direct proportion to the 90 psi original charge pressure. Starting at a lower pressure will result in a lower equalization point. Starting at a higher initial pressure will result in a higher equalization. In a service application the pressure in the emergency reservoir has not reduced, it remains at the original pressure.



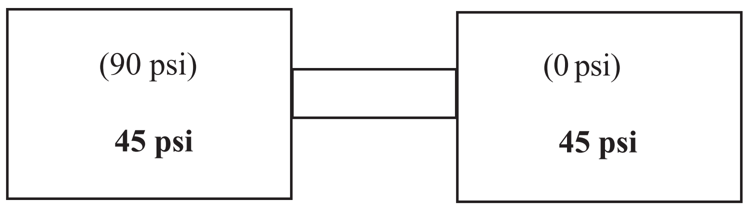
When an emergency brake application is initiated, the emergency reservoir is connected to the auxiliary reservoir through the AB control valve and equalization now occurs in the auxiliary and emergency reservoirs and the brake cylinder. In order to generate an emergency application, it is necessary to reduce brake pipe pressure very rapidly to zero.

Part 2: Equalization and Piston Travel

A. Equalization with Various Volumes

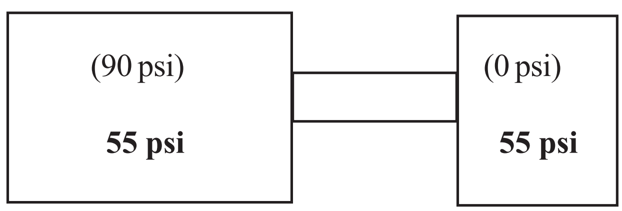
When compressed air in a reservoir is allowed to flow into a second reservoir, the air expands to fill the second volume and as a consequence, reduces in pressure. Let us assume we have two reservoir of the same size, with a pressure of 90 psi in one of them. If we connect them, air will flow from the high pressure volume to the empty volume and will equalize about half-way, that is approximately 45 psi.

EQUALIZATION PRESSURE = 45 PSI



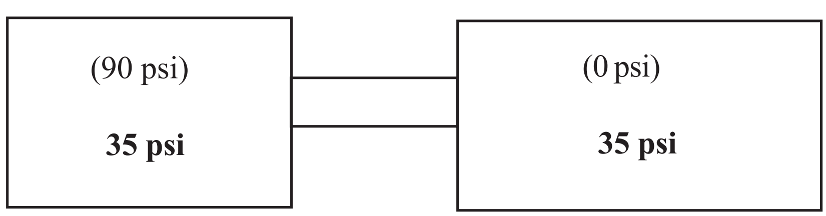
If the empty pressure volume is smaller than the high pressure volume, it is not going to take as much air to fill it, so the pressure on the high pressure side will not drop as much. Consequently, the pressures will equalize at a higher pressure than that in the first case.

EQUALIZATION PRESSURE = 55 PSI



If the empty volume is larger than the high pressure volume, it will take more air to fill it and the high pressure will drop much more. Thus the system will equalize at a lower pressure than the first case.

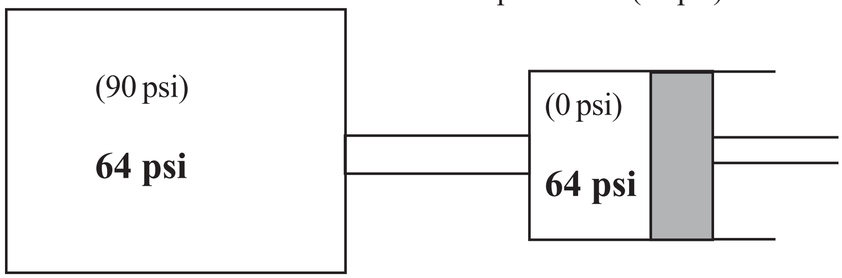
EQUALIZATION PRESSURE = 35 PSI



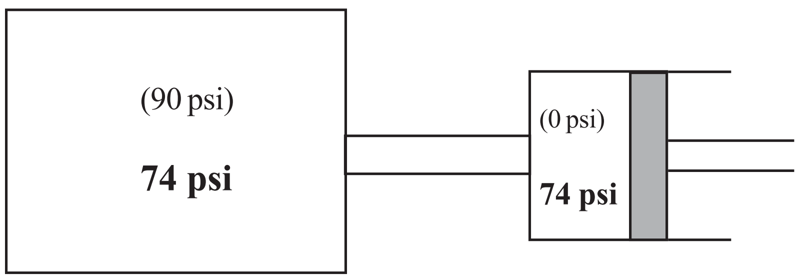
B. Equalization and Piston Travel

Piston travel and equalization pressures are very important to the braking of each car. Using the examples from the previous page and substituting a brake cylinder in place of the smaller volume, our pressure relationships would look similar to the examples shown below.

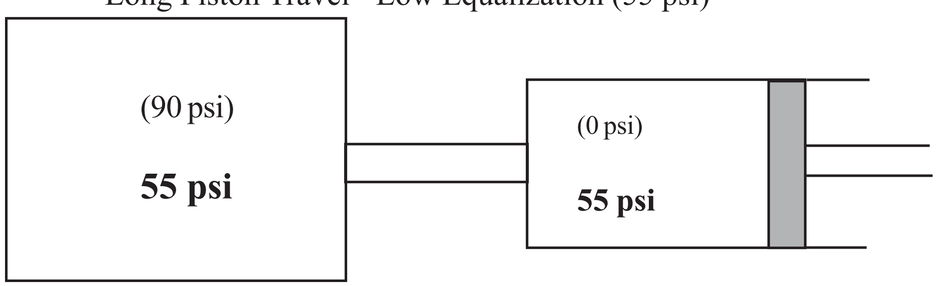
Correct Piston Travel - Correct Equalization (64 psi)



Short Piston Travel - High Equalization (74 psi)

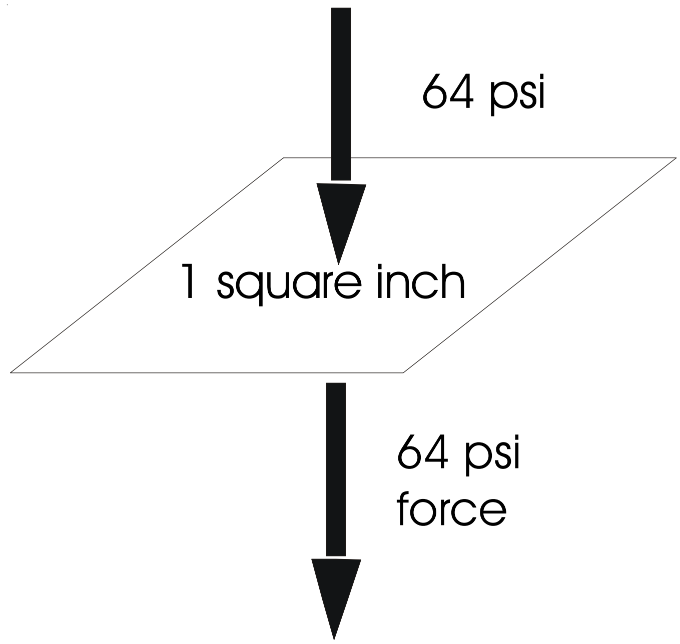


Long Piston Travel - Low Equalization (55 psi)

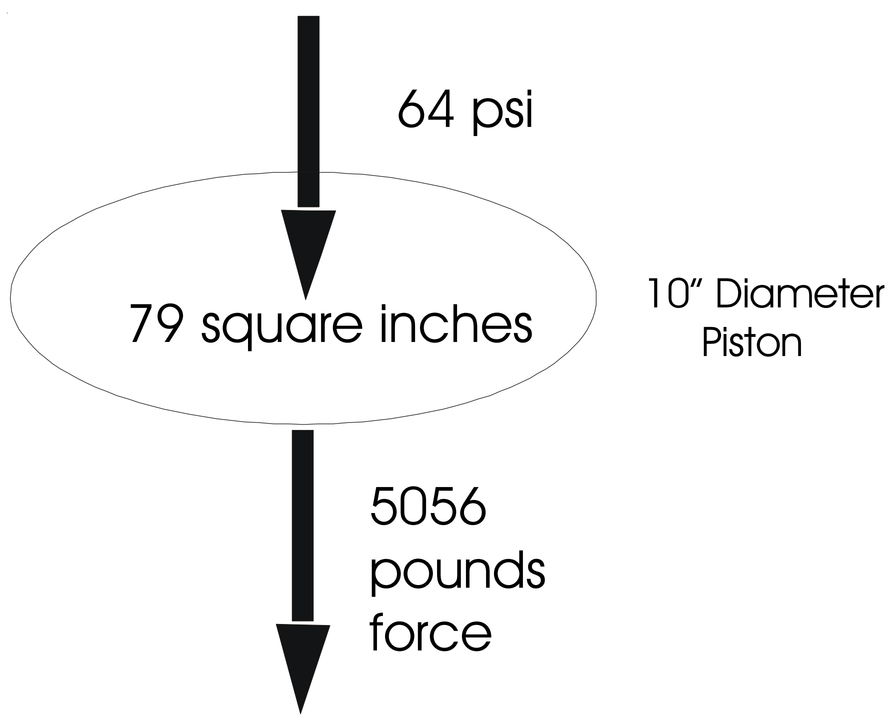


C. Piston Travel and Braking Force

The pressure at which the AB brake equipment equalizes has a direct effect on the braking force developed at the car. The pressure of air on the piston produces the force to apply the shoes to the wheels – the higher the force, the greater the braking action.



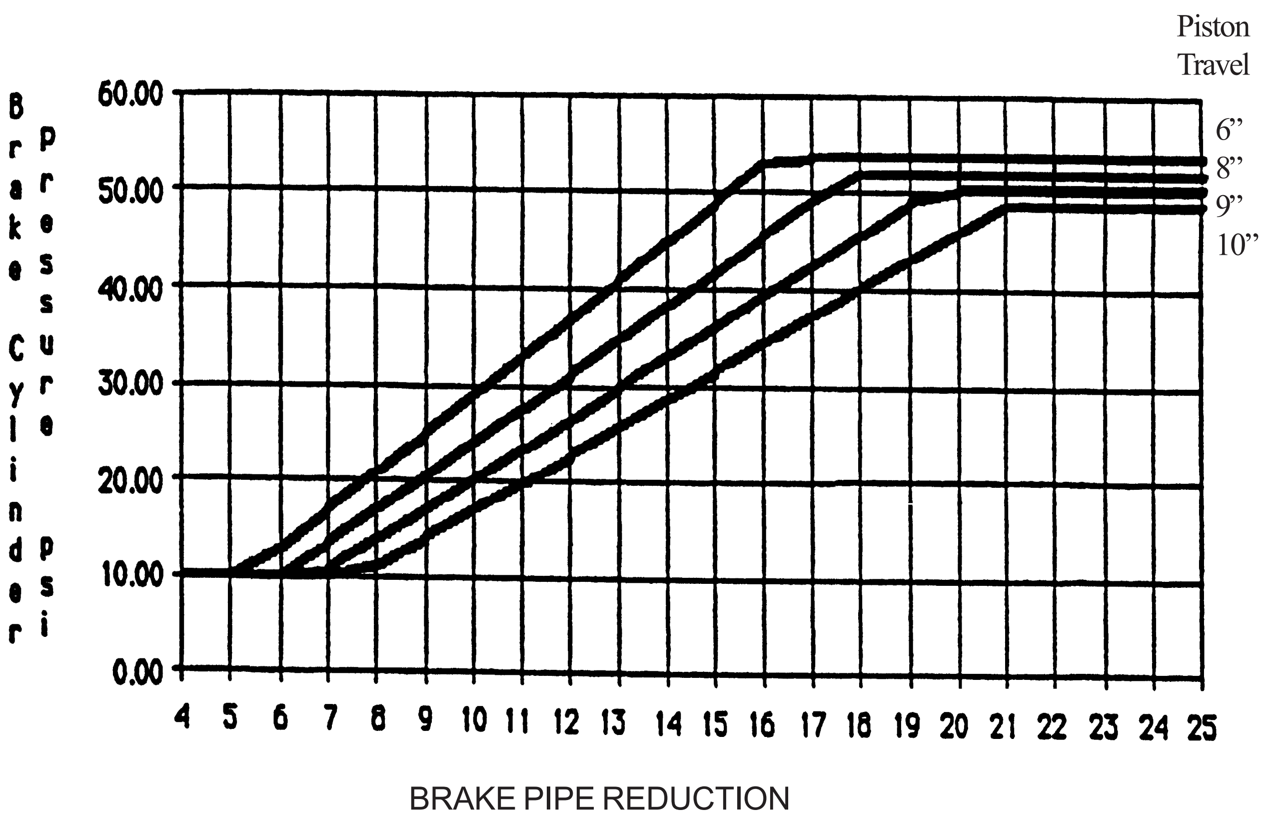
For a standard 10 inch brake cylinder, the diaphragm area is approximately 79 square inches. Multiplying 79 sq.in. times 64 psi (equalization from 90 psi) will be 5056 pounds force. This pressure is multiplied by the brake rigging to give the required force at the brake shoes.



As shown on the previous page, the force developed at correct equalization pressure with a 10" cylinder is about 5056 pounds. At 50 psi equalization this falls to 3900 pounds and rises to 5530 pounds at 70 psi equalization. These extremes cause complications for good train handling and control of coupler slack.

The following chart shows the brake cylinder pressures developed for various piston travels and brake pipe reductions. In this chart equalization was from a 70 psi initial brake pipe pressure. Therefore, proper equalization would be at approximately 50 psi.

10" ABU Brake Cylinder Pressures



Part 3: Multiple Cylinders and Relayed Equipment

A. Review of Piston Travel and Equalization

In the last section it was shown how piston travel has a direct bearing on equalization pressures and how it is necessary to maintain the correct piston travel. The use of a “standard” AB type reservoir (2500 cubic inch auxiliary reservoir) with a “standard” 10 inch ABU cylinder and the correct 8 inch piston travel gives the required equalization pressure of 64 psi from an initial 90 psi brake pipe pressure. However, for many reasons, it may not always be possible to use a standard, single 10 inch cylinder. For instance when converting a car to high friction shoes or when using WABCOPAC truck mounted brakes the volume displaced by the piston may be larger or smaller than that of a 10 inch diameter, 8 inch stroke displacement volume. Note: Piston travel is set at 8 inch for equalization purposes per AAR S-401. Piston travel must be set to proper length in accordance with AAR S-486 before car is allowed into service.

B. Car Conversion to High Friction Shoes

Composition shoes have a much higher coefficient of friction than metal shoes – that is why they are called “high friction shoes”. This means the braking force applied at the brake beam must be much lower than what is required for a metal shoe to obtain the same braking action. If the same force was applied to a high friction shoe as that applied to a metal shoe, the wheels would surely slide. To lower this braking force, either the rigging can be changed, a modulating valve may be applied (not a Wabtec component), or the brake cylinder diameter may be reduced in size.

The volume displaced by a standard 10 inch cylinder with 7 1/2 inch piston travel is the area of the packing cup multiplied by the piston travel or

78.5 square inches x 7.5 inches = 589 cu. ins.

The force supplied by this cylinder is:

78.5 square inches x 64 psi = 5024 lbs force

If the cylinder size is reduced to 8 ½ inches, then the force developed is:

56.8 square inches x 64 psi = 3635 lbs force

This is the force required for COBRA® high friction composition brake shoes. The problem now is the volume displaced by the smaller piston with the same piston travel is:

56.8 square inches x 7.5 inches = 426 cu. in.

This is considerably less volume than what is required for correct equalization of the auxiliary reservoir with the brake cylinder. The result would be much higher equalization pressure with an 8 ½ inch cylinder than with a 10 inch cylinder. To compensate for this the 8 ½ and 7 ½ inch cylinders have an extra “compensating” volume at the back of the brake cylinder. This ensures the equipment will equalize at 64 psi with an initial 90 psi brake pipe pressure, even though the piston diameter is smaller.

C. WABCOPAC Truck Mounted Brakes

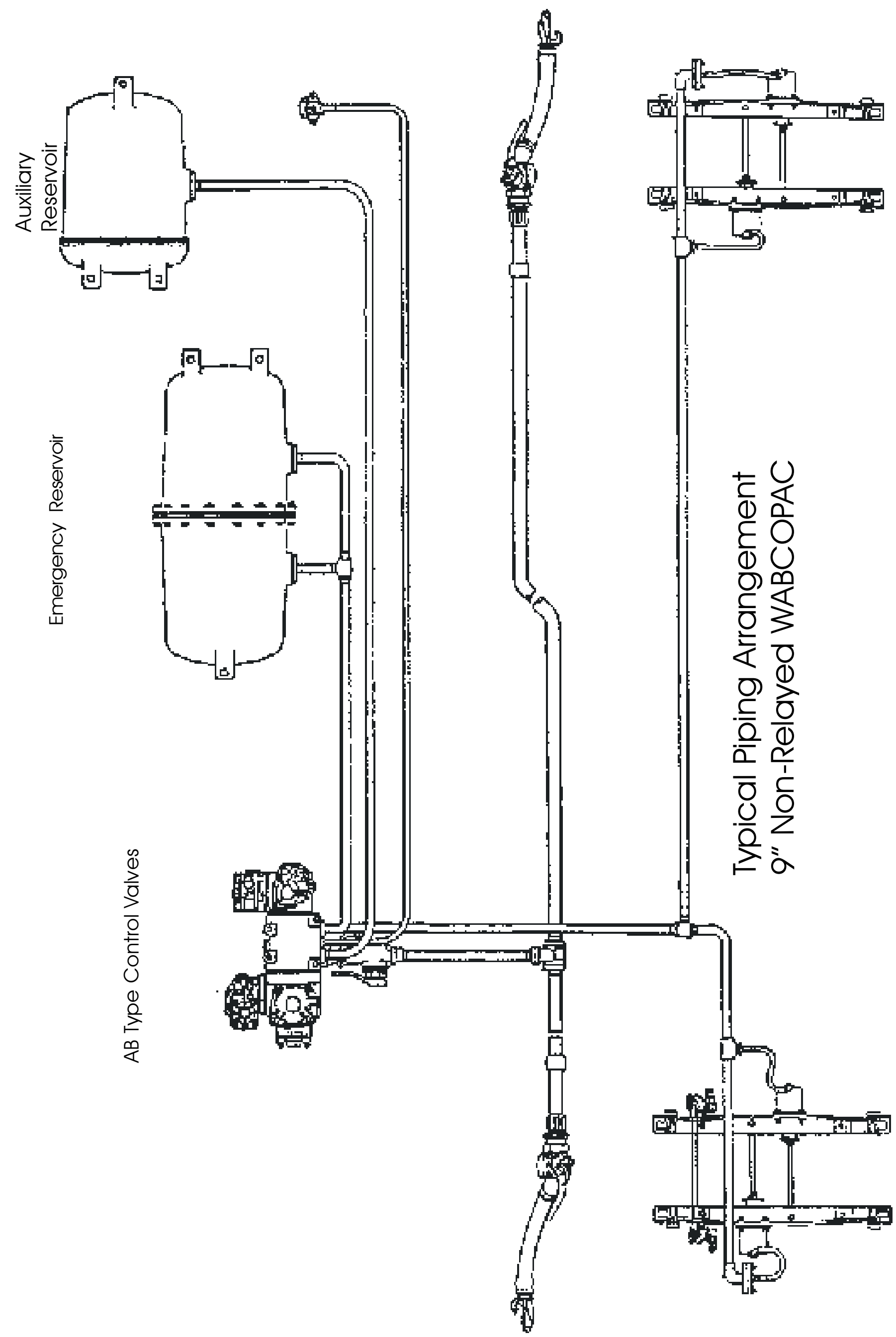
The first WABCOPAC Truck Mounted Brake came in four sizes and the design was based on using two cylinders at each truck, four cylinders per car. The cylinder sizes were available in 7 ½, 8 ½, 9 and 10 inch diameters depending upon the car brake configuration.

WABCOPAC II Truck Mounted Brakes introduced the use of only one brake cylinder per truck . Any cars converted from WABCOPAC to WABCOPAC II required an additional volume to compensate for the loss of brake cylinder volume. This was accomplished by increasing the size of the piping to the brake cylinders. WABCOPAC II brakes also incorporated the use of an automatic slack adjuster mounted in place of one push rod for piston travel adjustment.

The **8 ½" WABCOPAC** provides the required equalization pressure of 64 psi at a nominal 2 ¼" piston travel. For the **7 ½" WABCOPAC**, equalization will be a little higher, and today's tighter specification my require that steps be taken to reduce this equalization pressure on cars built new or rebuilt.

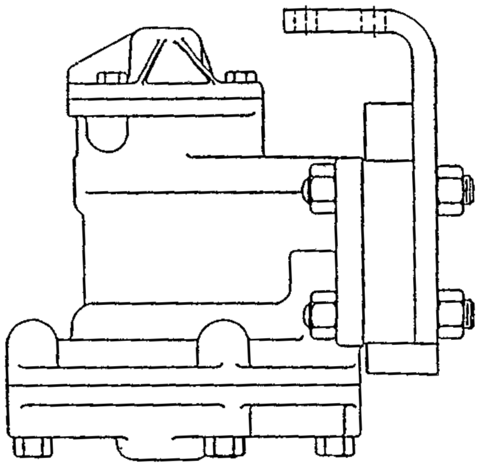
For the **9" WABCOPAC**, the equalization pressures with extended piston travel falls too low and the use of the standard auxiliary/emergency reservoir is no longer possible. For this situation the non-relayed 9" WABCOPAC equipment was developed. The piping and equipment arrangement is show on page 13. This equipment uses a 3500 cubic inch auxiliary reservoir (2500 is the normal size) and a 6000 cubic inch emergency (normally 3500 cu. in.). A special pipe bracket is required to ensure that there will be no deterioration of emergency brake cylinder pressure build up times. To ensure the brakes function properly all other brake equipment is standard.

The **10" WABCOPAC** arrangement requires such a large volume of air to achieve the correct equalization pressures that it is necessary to use a "relayed equipment" arrangement. Relayed equipment is required wherever there is a requirement for more than one 10" cylinder, for instance on six wheel trucks and special heavy duty cars. Relayed equipment requires the use of a special supply reservoir and a J-1 Relay Valve or "J" type empty and load equipment. Operation of J-Type empty/load brake equipment is covered in the Wabtec publication Empty/Load Brakes (TP2004).


Auxiliary Reservoir
Emergency Reservoir
AB Type Control Valves
Typical Piping Arrangement
9" Non-Relayed WABCOPAC

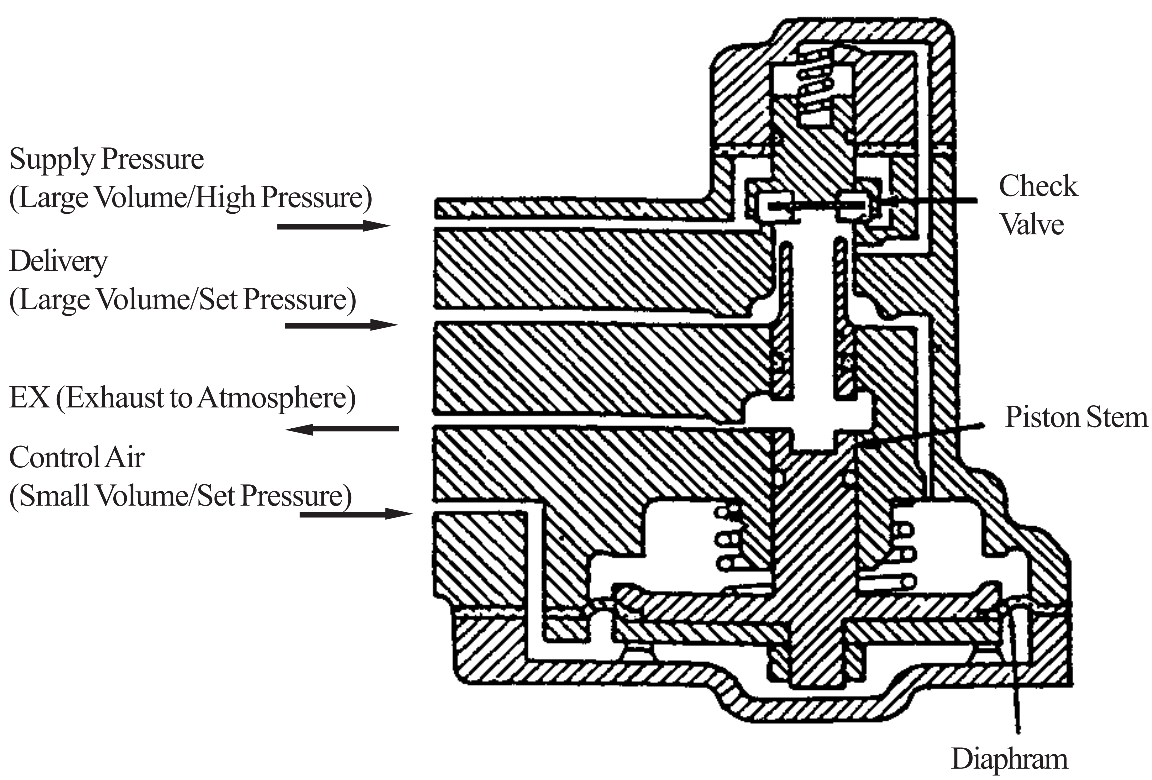
Part 4: The J Relay Valve

A. The "J-1" Relay Valve



The function of the J-1 Relay Valve on freight equipment is to provide an efficient brake application on cars equipped with multiple large brake cylinders. The J-1 Relay Valve is a diaphragm operated valve that utilizes a low volume air signal at a set pressure to direct a large volume of air at the same pressure to the point of use (brake cylinder). The requirement for sufficient air volume to achieve equalization is achieved by using a large supply volume, connected to the brake cylinder through the J-1. With this arrangement it is possible to develop the correct brake cylinder pressure at the required pressure regardless of the displacement volume or number of brake cylinders.

B. Single Diaphragm J-Relay



"J-1" RELAY VALVE PORTION

Part 5: Relayed Brake Equipment

A. Relayed Brake Equipment

When the standard “AB” reservoir is too small to supply a sufficient volume of air to obtain correct equalization pressure, it becomes necessary to fit the car with some type of relay equipment. The relay equipment uses a supply reservoir of sufficient volume to achieve correct pressures with full service or emergency applications.

In the previous section, it was shown how a small volume pilot signal at the desired pressure actuates the J-1 Relay Valve to supply a large volume of air at the same pressure as the pilot signal.

The diagram on page 16 shows one method of fitting this equipment to a freight car. This car is fitted with the “standard” AB type equipment, a large supply reservoir, a J-1 Relay Valve and a second ABU brake cylinder.

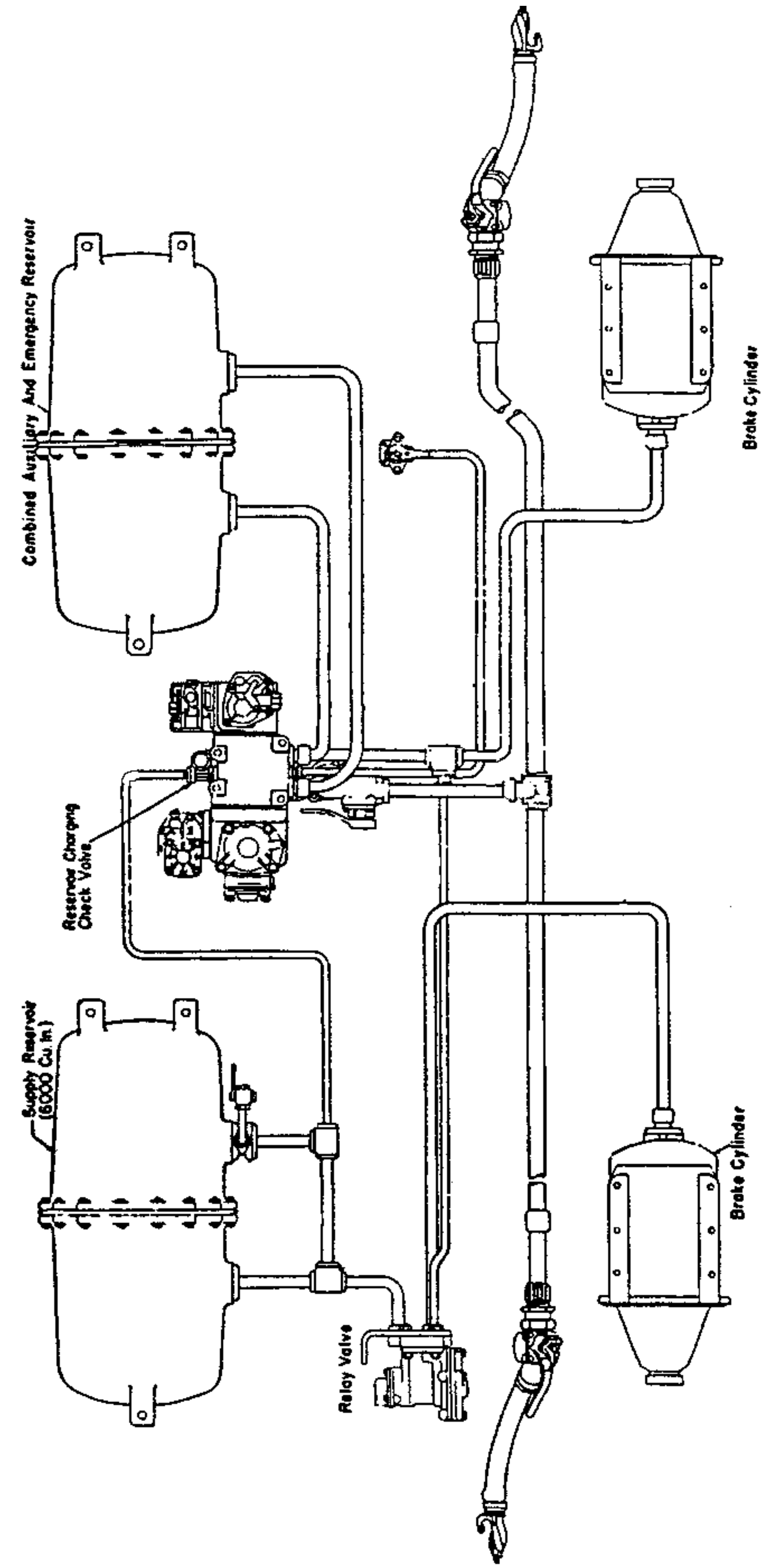
The standard AB reservoir is designed to supply only one 10” cylinder, so the air supply for the second cylinder is provided by the Supply Reservoir, controlled by the Relay Valve. Brake cylinder pressure developed in the “control” cylinder is passed to the Relay Valve, which allows air to flow from the supply reservoir to the second cylinder. As the pressure in the second cylinder rises to match the pressure in the first cylinder, the J-1 will lap off, and the pressure will be the same in both cylinders. When the brakes are released, pressure in the control brake cylinder and pilot pressure in the J-1 is reduced, causing the J-1 to move to the release or exhaust position. This releases the brake in the second cylinder.

There is one drawback to this arrangement. Should the control cylinder piston travel be incorrect, the pressure developed in the “control” cylinder is incorrect and the second cylinder pressure will also be incorrect.

If the car is fitted with a cylinder of “non-standard” dimensions, that is, one that will not produce the correct equalization pressure at its design piston travel, it will have a detrimental effect on the braking forces. For instance, it is not possible to use one cylinder as a reference pressure on a car fitted with 10” WABCOPAC brakes since correct piston travel for these cylinders is 2 ¼ inches.

The preferred method of establishing the pilot pressure for relayed equipment is by means of a fixed “dummy” volume used in place of the control cylinder. In this arrangement, all the cylinders will be supplied with air from the supply reservoir. For standard AB equipment a dummy volume of 800 c.i. is used. In this case correct pressures will always be obtained in the brake cylinders since the pilot pressure is always developed in a fixed volume of correct size.

The supply reservoir must be sized to provide sufficient air to register emergency pressure of 15 to 20% in the brake cylinder, above a full service brake application. On a freight car the supply reservoir is charged from and to the same pressure as the brake pipe through a one way check valve attached to the front of the AB pipe bracket.

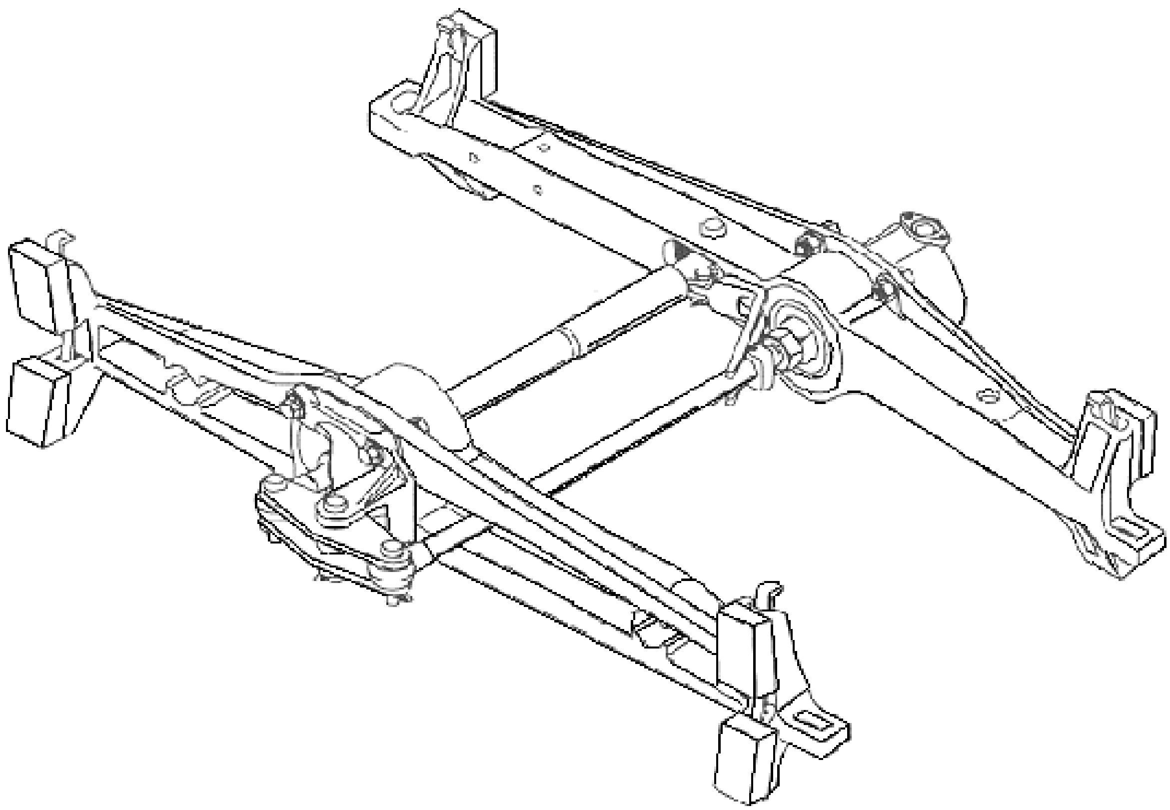


ABDW Control Valve Assembly Using
J-1 Relay Valve and Dual Brake Cylinders

B. Truck Mounted Brake Assemblies

1. WABCOPAC II

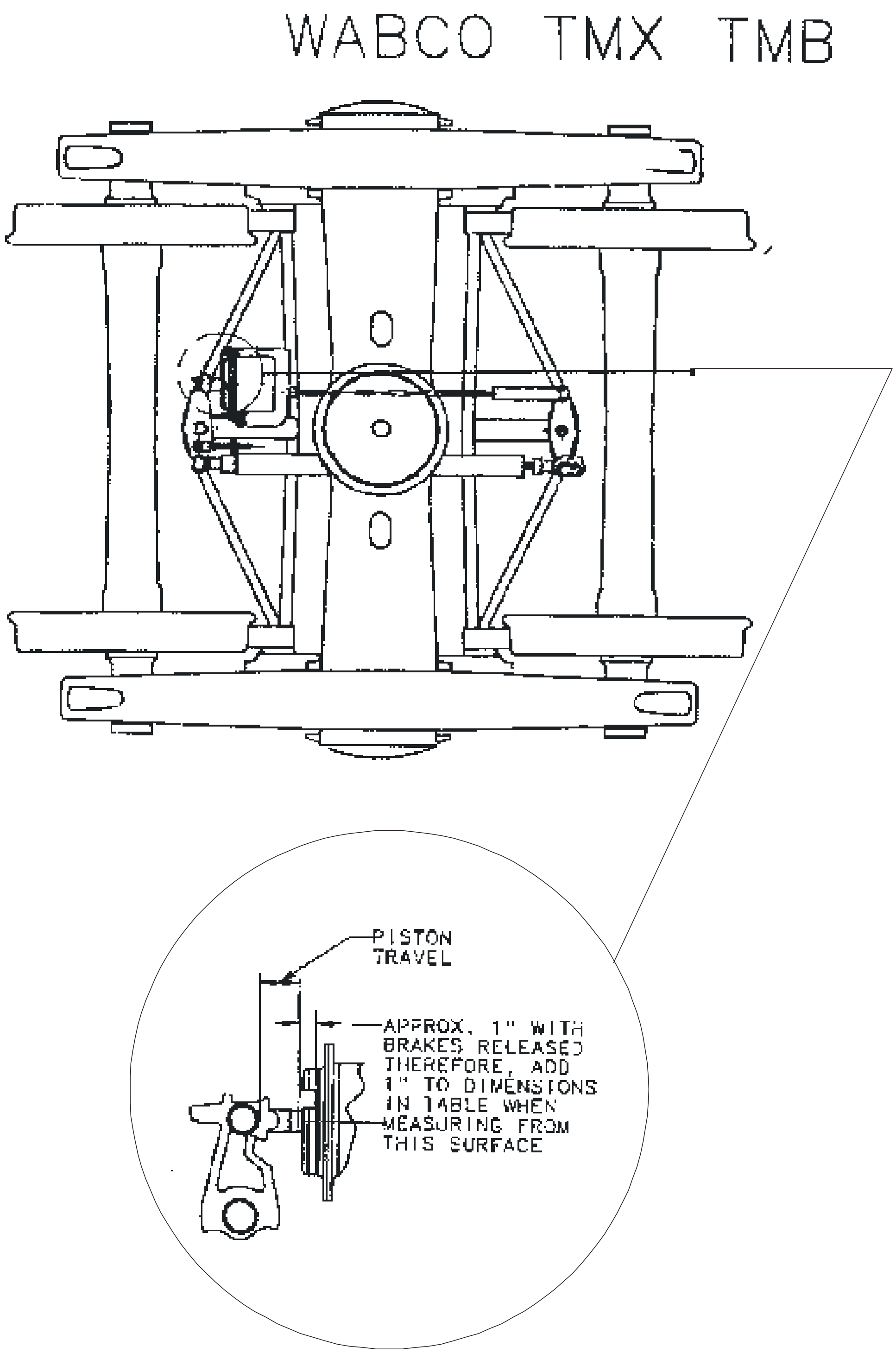
The WABCOPAC II and TMX Truck Mounted Brake assemblies also require volume adjustments in the brake cylinder piping to keep equalization pressures standard. The WABCOPAC II uses only two cylinders in place of the four normally found with the WABCOPAC truck mounted brake car set. Two cylinders have been replaced by slack adjusters and a lever arrangement to maintain proper piston travel and the correct braking force. This upsets the volume ratios between the reservoirs and the cylinder displacement volumes, and consequently, the equalization pressures. Additional volume is added to the brake cylinder piping to maintain correct equalization, not unlike the additional volume added to the 8 ½" body mounted brake cylinders. On other equipment, this may be done by changing the diameter of the brake cylinder piping or by adding volume reservoirs into the brake cylinder line.



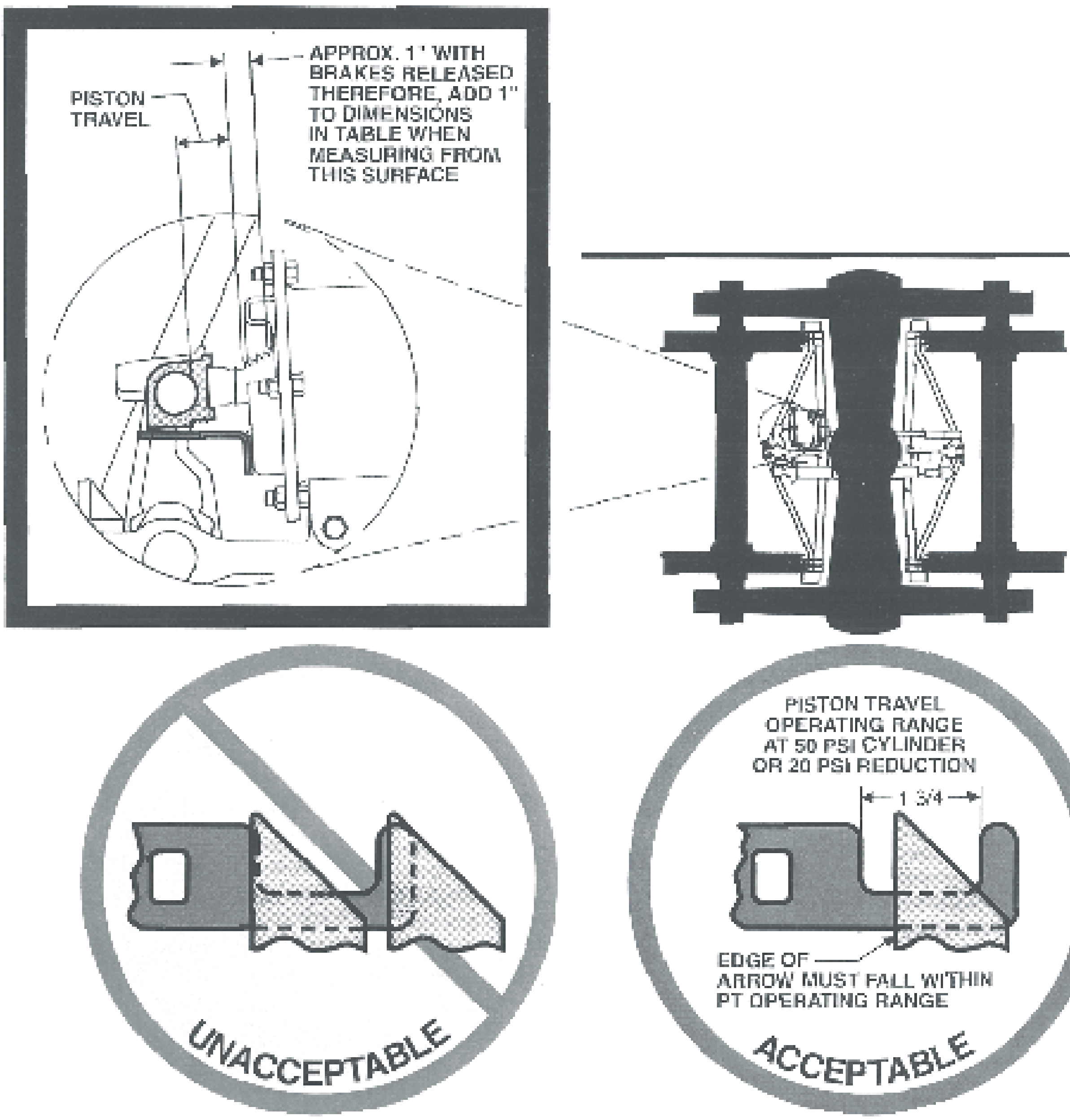
WABCOPAC II

2. TMX Truck Mounted Brake

The TMX brake assembly uses a design similar to the WABCOPAC II. It has one brake cylinder per truck with a slack adjuster to compensate for the wear of the brake shoes. The TMX brake is, however, lighter than the WABCOPAC designs because it use a standard weight No. 24 sliding type brake beam and a simpler design brake cylinder. The TMX Brake arrangement also permits the use of 2" thick composition brake shoes.



In the previous diagram you will note the TMX design is slightly different than the WABCOPAC in other ways. Brake cylinder piston travel may be measured as indicated in the diagram shown on page 18. The TMX Brake Arrangement may also be equipped with a travel indicator shown in the diagram below. This enables a quick determination of the piston travel by visually checking the indicator.



C. Other Brake Cylinder Arrangements

Brake cylinders from other manufacturers may require similar adjustments to maintain the proper equalization with the brake pipe. Generally, the cylinder volumes are smaller, requiring the use of additional volume added in the brake cylinder line.

D. Multi-Unit Articulated Cars

Some multi-unit cars (5-packs or similar) may have extended runs of brake cylinder piping to allow one control valve and reservoir to serve two trucks. These longer runs add significantly to the volume of air that must be provided on a brake application. In some cases, the standard AB reservoir may not be able to provide enough air to give the correct equalization pressures.

E. Brake Cylinder Piping

Since the volume of air in the brake cylinder piping must also be considered when calculating the volumes that effect the equalization pressures, the AAR allows the use of pipe of different diameters. The previous requirement allowed piping of only ¾" in diameter. Brake cylinder piping may now be ½", ¾" 1" or 1 ¼" to obtain and maintain the correct equalization pressures. It should be noted that in order to minimize the effect on emergency brake cylinder pressure build-up time, the use of ½" piping is limited. The brake cylinder displacement volume and the piping volume are interdependent and the AAR has published a formula that allows the calculation of the maximum length of ½" pipe that may be used.

PRESSURE EQUALIZATION EXERCISE

1. For a full service brake application from 90 psi, how much pressure should be in the emergency reservoir? ________________________

2. On a car equipped with longer piston travel, the brake cylinder pressure will be higher/lower than a similar car with the proper piston travel.

3. The braking force required to apply the brakes on a car equipped with high friction shoes would be higher/lower than a car equipped with cast iron shoes.

4. Cars equipped with multiple large brake cylinders may require the use of a __________________________ to ensure proper equalization.

5. The volume of the air line to the brake cylinder must/must not be used when calculating the volumes that effect equalization.

6. TMX and WABCOPAC II brake arrangements use ________ brake cylinder(s) per truck assembly.

NOTES

ANSWER SHEET

PRESSURE EQUALIZATION EXERCISE

1. For a full service brake application from 90 psi, how much pressure should be in the emergency reservoir? **90 PSI**

2. On a car equipped with longer piston travel, the brake cylinder pressure will be **lower** than a similar car with the proper piston travel.

3. The braking force required to apply the brakes on a car equippped with high fricition shoes would be **lower** than a car equipped with cast iron shoes.

4. Cars equipped with multiple large brake cylinders may require the use of a **J-RELAY VALVE** to ensure proper equalization.

5. The volume of the air line to the brake cylinder **must** be used when calculating the volumes that effect equalization.

6. TMX and WABCOPAC II brake arrangements use **ONE** brake cylinder(s) per truck assembly.