A Study on the Improvement of Release Application Characteristics of Pneumatic Brakes for Freight Train

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We have performed experimental studies for the improvements of pneumatic brake systems of freight trains. Currently, most of the freight trains operated by the Korean National Railroad have either empty-load or diaphragm type brake systems. In this study, appropriate methods that the air pressure characteristics in both type of brake systems are in accordance with each other have been investigated. We have also performed running tests using a 30 car-train set to design optimum capacity of a quick release valve. The test results show that the quick release valve is considerably effective in shortening the release time of the diaphragm type brake system. In the case of a normal brake application, the diaphragm type brake system with the quick release valve reduces the release time to 34% of that of the system without the quick release valve. This release time is almost equivalent to that of the empty-load type brake system. Accordance of braking performance in different types of brake systems in a train set is expected to prevent wheel flats and to reduce maintenance costs.

Key Words : Pneumatics, Air Brake System, Freight Train, Empty-Load Brake, Diaphragm Valve, Triple Valve, Pressure Loss

1. Introduction

The road traffic has induced some problems, for example, traffic jam and environment pollution due to emission gas and a large number of automobiles. In contrast to the road traffic, the railroad system is reassessed as an alternative means to solve the problems mentioned above. It is well known that the railroad system has many advantages of safety, low-pollution, scheduled operation, and mass transportation. In case of the railroad system, it is very restricted for a rapid train to pass a train started in advance. This restriction results in the low efficiency of total line capacity.

In case of a freight train set consisted of various kinds of cars, there is disharmony of pressure variations in brake cylinders between freight cars in front and the ones in rear. The discord of air pressures in the brake cylinders between front cars and rear cars results in difference of idle running time among freight cars. The troubles related to the brake system, for example, wheel flat or bad release application, cause the delay of train operation as well as unnecessary maintenances.

Because each country around TKR(Trans-Korean Railway), TCR(Trans-China Railway) and TSR(Trans-Siberian Railway) has its own brake systems for freight cars, some country may experience these phenomena when, what is called, the iron silk-road between Europe and Asia is opened to traffic.

Computational studies have been conducted to solve the characteristics of pneumatic brake system for the brake pipe and the simple model (Bharath, 1990 ; Murtaza, 1989 ; Abdol-hamid, 1988). However, there is no study to analyze the

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entire pneumatic brake system with various control valve, brake pipe, and brake cylinder due to the complexity of modelling. The running test using freight cars and a locomotive was conducted to measure the pressure characteristics of brake pipe and brake cylinder (Nam, et al. 1999).

In this study, experimental studies using the running tests with freight cars have been conducted to improve the pneumatic brake systems of freight trains. We also modulate the pneumatic characteristics of brake and release applications using a quick release valve incorporated in diaphragm valve to attain coincident pressure variation of each brake system and to shorten the release time of the gradual release brake system.

2. Pneumatic Brake System of Freight Train

Figure 1 shows the schematic diapram of a pneumatic brake system for freight trains. The brake valve supplies the compressed air in the main reservoir of a locomotive to the auxiliary reservoir of each freight car via brake pipes. To stop the train set, it is necessary to control the brake valve to exhaust the compressed air in the brake pipe. The control valve of each freight car passes the compressed air in the auxiliary reservoir to the brake cylinder. Those movements of compressed air result in the frictional force between a brake shoe and a wheel. To release the brake shoe from the wheel, driver needs to control the brake valve to pass the compressed air to the auxiliary reservoir and the brake pipe. Pressure increase in these parts makes the control valve to exhaust the compressed air in the brake cylinder to the atmosphere. The pneumatic brake systems of freight cars are controlled by the brake valve to increase and decrease the brake pipe pressure that plays the signal of brake-release applications (Kyoyusya, 1993).

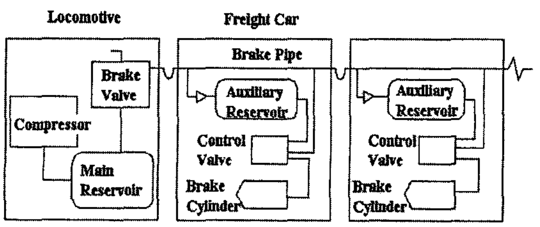
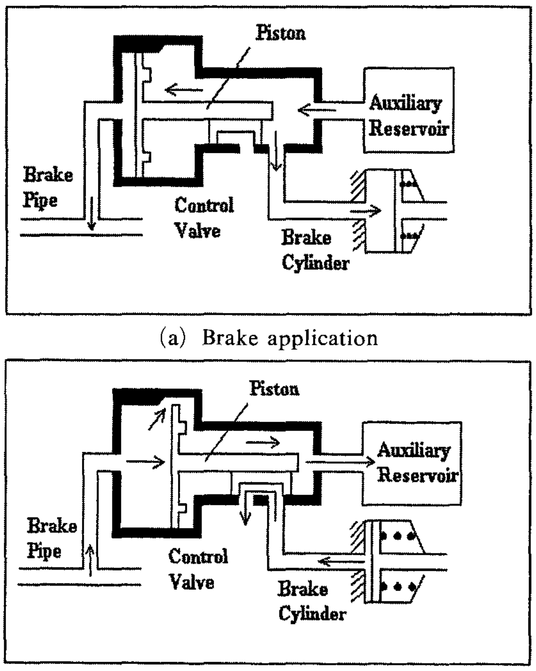


Fig. 1 Schematic diagram of brake system for freight train

The brake and release functions of a triple valve for freight cars are shown in Fig. 2. The name of triple valve is derived from three functions (brake, release and lap functions). It has been used in the empty-load brake system as a control valve. In case of the brake application, the piston in the control valve is moved to the left side in Fig. 2(a). Because the passage between the auxiliary reservoir and the brake cylinder is opened, high pressure air in the auxiliary reservoir flows into the brake cylinder. The lever connected to the piston of the brake cylinder forces the brake shoe to stick to the wheel tread. These mechanism produces the frictional force to stop the train. In case of the release application, the piston in the control valve is moved to the right side in Fig. 2(b). The compressed air in the main reservoir of a locomotive flows into the auxiliary reservoir of a freight car. At the same time, the compressed air in the brake cylinder is



(a) Brake application

(b) Release application

Fig. 2 The function of triple valve

exhausted to the atmosphere and the piston of the brake cylinder is returned to its former position by a release spring. Consequently, if the brake pipe is broken at any point and pressure is completely lost, the brake is automatically applied without driver's control.

While the triple valve is easy to maintain valve because of its simple structure, it is difficult to regulate precisely.

The schematic sketch of a diaphragm valve is shown in Fig. 3. The valve contains a main diaphragm and a smaller upper diaphragm. In the release position, the brake cylinder is connected to exhaust through the limiting valve and the inlet-exhaust valve. This action makes the brake released. If the brake pipe is charged, high pressure air enters not only the chamber above the main diaphragm but also the control chamber and the auxiliary reservoir through non-return valve A, B. When all of these parts are charged to the normal brake pipe pressure of 500kPa, no movement occurs because the pressure across the main diaphragm are almost same. In case of the brake application, the pressure in the chamber above the main diaphragm is reduced. The non-return valves A and B shut out any back flow from the control chamber and the auxiliary reservoir, respectively. The pressure difference between above and below the main diaphragm causes the diaphragm to move up and open the inlet-exhaust valve. It allows air to flow from the auxiliary reservoir to the chamber above the upper diaphragm and to the brake cylinder.

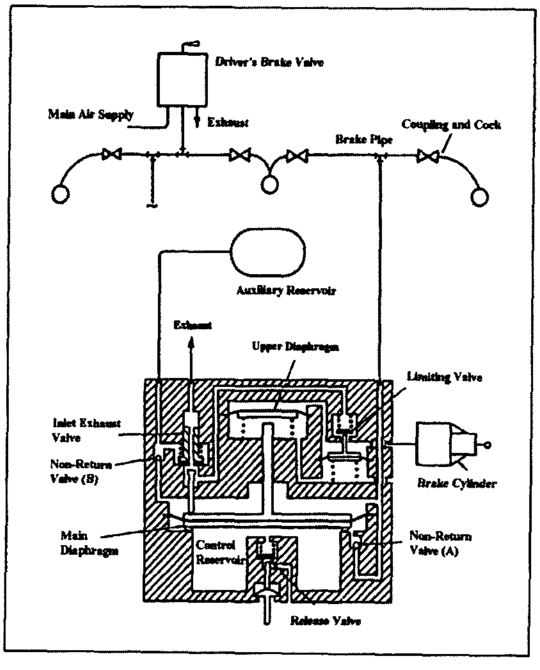


Fig. 3 Diaphragm control valve

As shown in Fig. 3, the main stem moves up or down due to the differences between pressures applied to the main diaphragm and the upper diaphragm in the diaphragm type brake system. Since the forces applied to these diaphragms are calculated by multiplying pressures by areas, the effective cross-section area of the diaphragm is related to the opening and closing of the valve. In other words, the amount of air flows into the auxiliary reservoir of a freight train depends upon the level of valve opening. Since the release time is proportional to the amount of air flows into the auxiliary reservoir, the effective area of the diaphragm affects the release time.

When the brake cylinder and the chamber are filled with the air from the auxiliary reservoir, the upper diaphragm moves down and contacts with the main diaphragm. As the brake cylinder pressure has risen sufficiently, the main diaphragm moves down and the inlet-exhaust valve returns to its former position. Due to the relationship of effective areas between the upper diaphragm and the main one, the pressure in the brake cylinder is approximately 2.5 times the reduction of brake pipe pressure. If the brake pipe pressure is steadily maintained at any intermediate level, the control valve holds the brake cylinder pressure at the corresponding level. When the brake pipe pressure is increased, the pressure difference across the main diaphragm is reduced and the main diaphragm moves down (Robert, 1982).

This action allows air to flow from the brake cylinder to exhaust. Since the brake cylinder pressure acting on the upper diaphragm is decreased, the main diaphragm moves up and closes the inlet-exhaust valve. Therefore, the control valve holds the brake cylinder pressure at the new intermediate level. With the diaphragm control valve, it is possible to control the brake cylinder pressure according to the brake pipe pressure. The valve also has some merits sach as low-maintenance efforts and low leakage. Recently, KNR adopts the diaphragm valve as the control valve of a pneumatic brake system for a freight car.

3. The Details of Experiment

An experimental freight train set in Fig. 4 is composed of a diesel locomotive, twenty-nine freight cars, and a test car equipped with various measuring instruments. Through the experiment using freight cars installed with the empty-load brake systems and the diaphragm ones, the pressure variation and release characteristics of the brake cylinder have been investigated. In order to attain the similar braking behavior between the systems, the quick release valve was additionally incorporated in the diaphragm brake system.

When the locomotive is located in the left side in Fig. 4, the test freight cars, A (#24), B (#27) and C (#29) are in the rear condition. Reversely in the right side, A (#7), B (#4) and C (#2) are in the front condition. Therefore, various conditions can be conducted by changing the locomotive position. The brake pipe pressure and brake cylinder pressure are simultaneously measured in the case of minimum, normal, emergency, and repeat brake applications. If the overall length of each freight car is taken as 15 meters and the locomotive as 20 meters, the length of the train of 30 cars becomes 470 meters. Pressure sensors are installed in the brake cylinder of each car, and the nominal capacity and nominal output of the pressure sensor are 1 MPa and 1.0mV, respectively. The 16 bit data acquisition and analysis

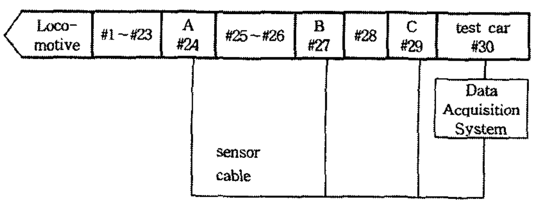


Fig. 4 Experimental freight train

instrument having a performance of 100kHz sampling rate is used.

Figure 5 shows the schematic sketch of the quick release valve incorporated in the diaphragm valve to reduce release time. As explained above, because the diaphragm valve is controlled by the pressure balance between the upper diaphragm and the main diaphragm, release time is longer than the direct release valve. In the case of a long train set composed of various brake systems, high friction force will be applied in the freight car installed with the diaphragm valve and may result in wheel flat or the breakdown of shoes. Therefore, it is necessary that the release time of the diaphragm valve should be shortened for using together with the triple valve. To shorten the release time in case of the release application, a few methods can be considered as follows: to supply much more air to the freight car installed with the diaphragm valve and to decrease the pressure of the control chamber. The former method is impractical because supplying much higher pressure air to the relevant car is very difficult. The latter one is chosen in this study. In the release application, the diaphragm of the quick release valve moves up and open the chamber A because the brake pipe pressure is increased.

The air in the control reservoir flows into the additional air reservoir of the quick release valve via chamber A. Therefore, the pressure of the control reservoir decreases and the main

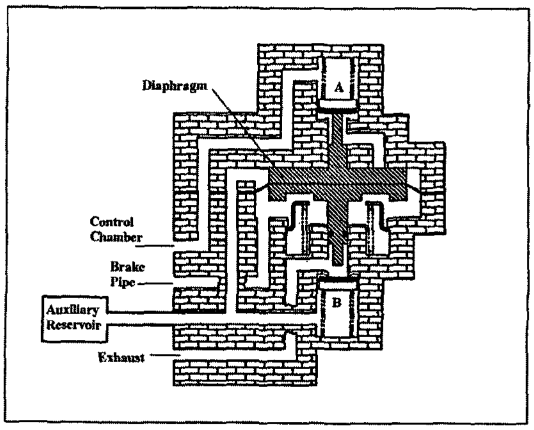


Fig. 5 Quick release valve

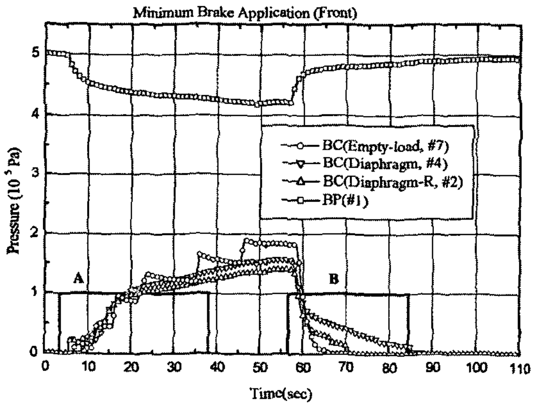
diaphragm moves down. These movements help to exhaust the air in brake cylinder.

4. Results and Discussion

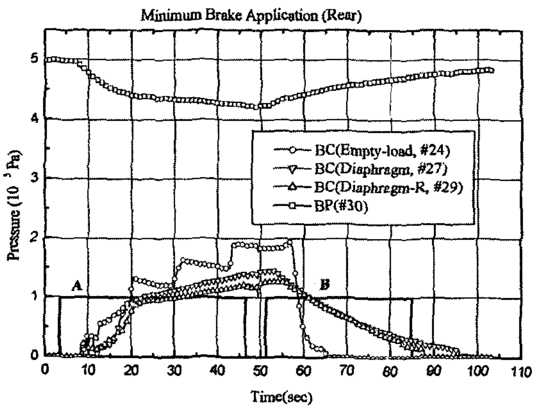
Figure 6 shows the pressure variation of the brake cylinder and pipe in case of minimum brake application. In the minimum brake application, the brake pipe pressure is varied from 500kPa to 430kPa. The sections A and B correspond to brake command and release one, respectively.

In graph, lines with ○, ▽ and △ symbols represent the pressure variances in the brake cylinder of the empty-load type brake, diaphragm type brake without and with the quick release valve, respectively.

After the brake application, the brake pipe pressure which is represented by line with square symbols are decreased. The brake cylinder pressures which are represented by the lines with delta, circle and inverse triangle symbols, is increased. The difference of the brake cylinder pressure of each car is due to the weight difference of cargos because a variable load valve controls the pressure according to the weight. Compared with the brake cylinder pressure of the triple valve which varies intermittently, the pressure of the diaphragm valve varies continuously. From the structure of the triple valve, the balance piston in the control valve moves when the pressure difference overcomes the friction force between the housing and piston. In the front condition like Fig. 6(a), there is no difference of the brake cylinder pressure of each car because of rapid pressure variation of the brake pipe. In the rear condition, the release time of the diaphragm valve is longer than that of the triple valve. There are about 20 and 30 seconds of release time delay between equipments in the case of front and rear condition, respectively.



(a) Front side



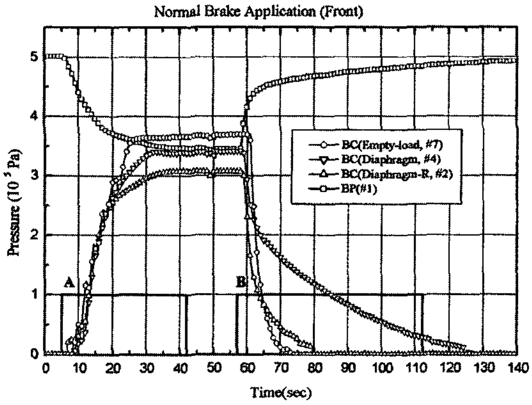
(b) Rear side

Fig. 6 Pressure variation of brake pipe and cylinder in case of minimum brake

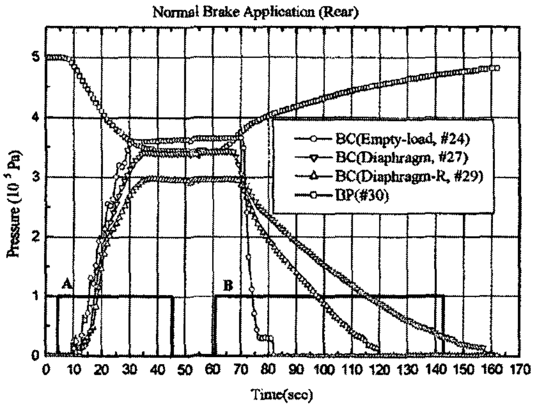
Figure 7 illustrates the pressure variation of the brake pipe and the cylinder in the case of a normal brake application. Brake pipe pressure varies from 500kPa to 350kPa. The normal brake application would be frequently used in operation to stop a train. Because the pressure variation of the brake pipe is larger than that of the minimum brake application, the friction force does not play a role to stop the piston of the triple valve. Therefore, the brake cylinder pressure instantly comes to be constant level. The release time of revised diaphragm brake system incorporated with the quick release valve is shortened by 45 seconds. in the case of front condition and 37 seconds. in rear condition. The discord of the brake cylinder pressure between freight cars results in various troubles such as wheel flat, poor release action.

In the pneumatic brake systems of freight trains, braking or releasing applications can be controlled by compressed air supply or exhaust through brake pipes from a main reservoir of a locomotive. While the cars which are located near the locomotive reply quickly to compressed air pressure variation from the locomotive, the brake systems of the cars in rear react slowly due to the delay of signal transmission from the locomotive and air pressure loss during transmission. Therefore, the release time of the brake system in rear cars is relatively longer than that of the brake system in front cars.

Since pressure difference becomes severe in proportion to the length of a freight train, it is necessary to remove the pressure loss elements in the brake pipe line. These improvements may result in the equalization of brake performance in the train set. According to the kind of brake control valves, it is recommended to arrange for the freight cars installed with diaphragm brake valves at front side of the freight train, and for the cars with empty-load brake valves at rear side in order to reduce pressure difference and wear. When the accidents occur or urgent stop is needed during train operation, emergency brake application is operated. In the emergency brake application, brake pipe pressure is decreased from 500kPa to 0kPa and a cut-off valve in a locomotive prevents air flow from main reservoir. In addition, emergency parts help the control valve to flow quickly from the auxiliary reservoir to brake cylinder. The pressure variations of the brake pipe and cylinder in the case of emergency are shown in Fig. 8. Due to the expansion wave induced by sudden pressure decrease, there is a discontinuous part on the line of the variation of the brake pipe pressure. These phenomena cannot be found in the freight cars in rear side. It is considered that the brake pipe pressure of the freight car in rear side varies relatively slowly due to the various pressure loss elements such as tee,

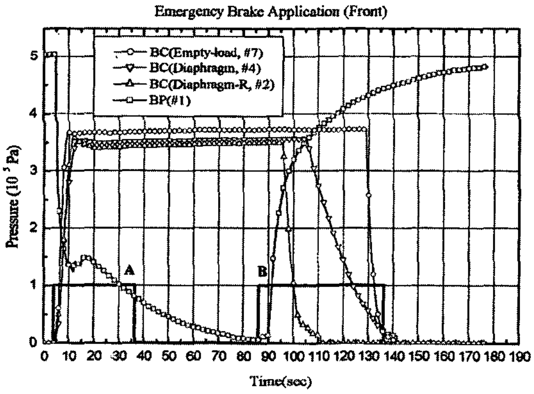


(a) Front side

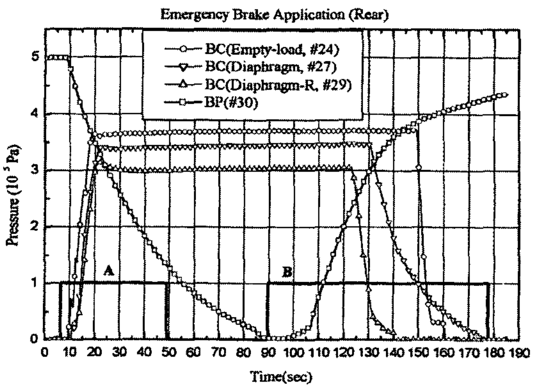


(b) Rear side

Fig. 7 Pressure variation of brake pipe and cylinder in case of normal brake



(a) Front side



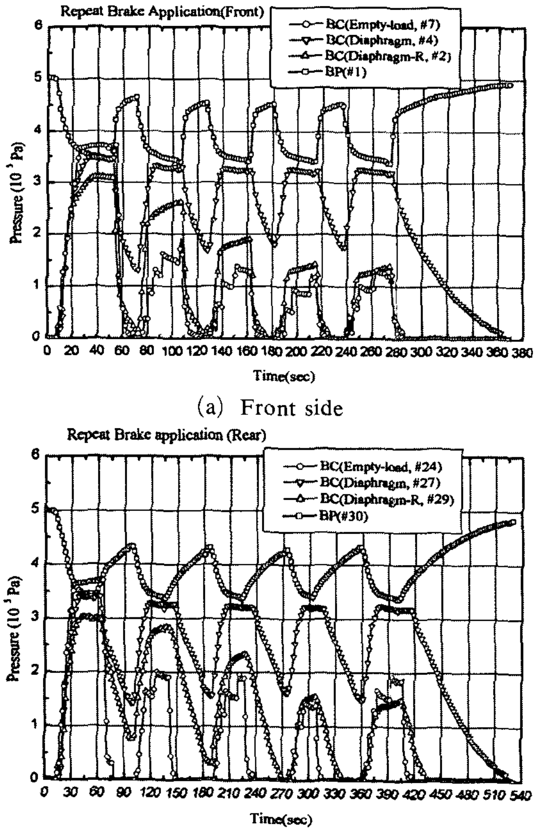
(b) Rear side

Fig. 8 Pressure variation of brake pipe and cylinder in case of emergency brake valve, coupling and bend in the brake pipe line. Because the exhaust air velocity is proportioned to the pressure reduction for the brake application, the pressure variations among cars also differ greatly.

In general, the minor losses in pipe flow are proportional to the square of velocity, it is considered that flow loss is increased with the exhaust velocity of the brake pipe.

Figure 9 shows the pressure variation in case of a repeat brake application. The repeat brake is used for decelerating railroad vehicles when they are being operated in sharply inclined mountainous areas. This needs quick release of brake with the supply of constant air pressure to the brake cylinder under the condition of repeat brake and release applications.

As seen in the figure, the main difference between empty-load brakes and diaphragm brake valves is the amount of compressed air exhaust. As the brake is released, the pressure in the brake cylinder of the empty-load system drops to 0 Pa. However, the pressure in the brake cylinder of the original diaphragm system under the same condition applied to the empty-load system maintains 180kPa. Therefore, in the case of a train set using both brake systems, excessive frictional forces are applied to the contact areas of wheels and brake shoes of the vehicles with diaphragm systems. Consequently, this causes some kinds of hindrances such as wheel flats and brake shoe fractures. For the case of the repeat brake application with the empty-load system, the pressures generated from 2nd to 5th braking decrease compared with that generated from the first braking.



(a) Front side

(b) Rear side

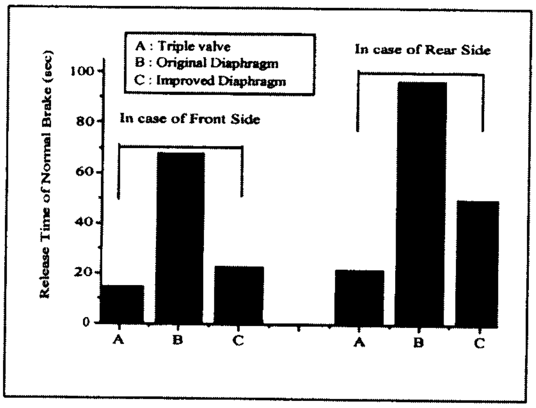
Fig. 9 Pressure variation of brake pipe and cylinder in case of repeat brake

However, under the same conditions, the pressure of the diaphragm system remains constant. The compressed air of 500kPa in a control chamber shifts main diaphragm to open the passage from the auxiliary air reservoir to the brake cylinder. Therefore, constant braking pressure can be obtained if the auxiliary air reservoir contains compressed air. On the contrary, in the empty-load braking system which is the direct releasing type, most of the compressed air in the brake cylinder is exhausted to the air in short time, which results in shorter releasing time. In order to compensate relatively longer releasing time of diaphragm brake system, the quick release valve is additionally adopted to the diaphragm system.

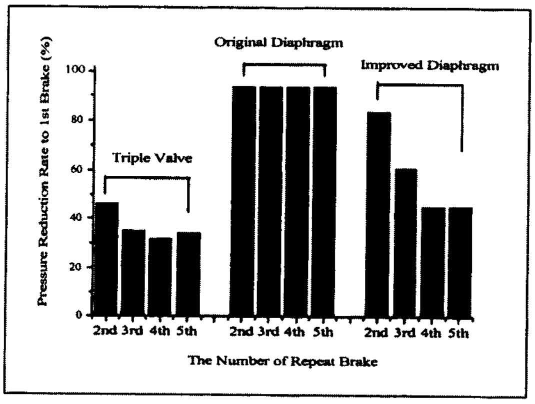
The quick release valve exhausts the air in the brake cylinder to the air at relatively low brake pipe pressure by delivering compressed air in the control chamber to the auxiliary reservoir, and consequently by reducing the air pressure in the control chamber. Once we have improved the diaphragm brake system like the one mentioned above, the releasing time of the brake system has been reduced significantly.

Releasing time is only 34% and 60% of those for the system with no improvement for the cases of vehicles in the front and in the rear of a train set, respectively.

Figure 10 shows the effects of the quick release



(a) Comparison of release time



(b) Comparison of pressure reduction rate

Fig. 10 The effects of quick release valve

valve incorporated with the diaphragm valve. In case of front side, the release time of the normal brake application of the improved diaphragm valve is almost the same as that of the triple valve. In contrast to the original diaphragm valve that has constant brake cylinder pressure in the repeat brake application, the patterns of pressure reduction rate are similar to that of the triple valve.

Table 1 lists the types of breaking, releasing time and ratio of pressure reduction when repeat brake is applied. The percentages in the table indicate the ratios of pressure reductions for the 2nd to 5th braking compare with the pressure for the first braking. For the improved diaphragm brake system, the measured values of releasing time in the case of minimum, normal and emergency breaking have been shortened up to 48%, 34% and 46% for a car positioned in front and

Table 1 Release time & reduction rate

(unit : sec)

Brake application, Loco position		Triple valve	Original diaphragm	Improved diaphragm
Minimum brake	front	8	29	14
	rear	18	49	41
Normal brake	front	15	68	23
	rear	22	97	58
Emergency brake	front	54	54	25
	rear	70	84	50
Repeat brake	front	46% 35% 32% 34%	94% 94% 94% 94%	84% 61% 45% 45%
	rear	51% 51% 38% 51%	94% 94% 94% 94%	93% 77% 53% 50%

83%, 60% and 59% for a car positioned in rear. Pressure reduction after the first braking in the repeat brake test has been observed, and great reduction of releasing time has been obtained for a car placed in front.

5. Conclusions

Experimental study has been conducted to clarify pressure characteristics of various pneumatic brake systems for freight cars. Thirty freight cars installed with the empty-load brake system and diaphragm one are used to assess the pressure variations in the cases of minimum, normal, emergency and repeat brake applications. In order to adjust release time, the quick release valve is incorporated with the diaphragm valve. The pressure characteristics of the brake pipe and cylinder are clarified, and the summarized results are as follows:

(1) With the quick release valve, the release time of the diaphragm valve is shortened to the level of the empty-load valve.

(2) In normal brake application, the release time of the revised diaphragm system is reduced to 34% in front case and 60% in rear case.

(3) The pressure difference between freight

cars becomes small when the freight car incorporated with the diaphragm valve is located in the front side.

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