

# Four Way Safety Valve Tester Design for Heavy Vehicle Brake Systems

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## Abstract

Although vehicles use various types of brake systems and different technologies, the main purpose is to ensure safe navigation of vehicles in traffic, slow down and stop them. Air brake systems are used in heavy vehicle vehicles carrying loads and passengers. In case of any air leakage that may occur in the braking system during the course of the cruise, a part called The Four-Way safety valve is used to prevent the air tanks from emptying completely. The task of the four-way safety valve is to ensure that compressed air to be used for the handbrake, front axle and rear axle is stored in separate air tanks. In the event of a possible air leak, the damaged tank should not affect the tanks that are intact. During periodic controls of vehicles, air brake system is tested for four-way safety valve. In the current case, the four-way safety valve test is conducted manually. In this study, the four-way safety valve test was intended to be performed automatically. For this purpose a tester was developed using microcontroller card, solenoid valve, pressure transmitter and PC software. Thanks to the developed Tester and software, the test is automated and the non-ergonomic movements made by the technician are eliminated. The reliability of the test has been improved and the polluting elements have been eliminated during the test.

*Keywords:* Four-way safety valve, Air brake system, Test device, Traffic safety

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## 1. Introduction

Brake safety of vehicles is the crucial performance for automobile safety and is one of the central issues in the research field of active safety [1]. Air brake systems are used in order to ensure road safety of heavy vehicles carrying cargo and passengers. The most important system that helps to slow or stop a moving vehicle and to keep a stationary vehicle in place is called the braking system [2]. In fatal and injured accidents involving heavy vehicles, there are factors such as driver defect, vehicle defect, pedestrian and passenger defect [3]. In case of an air leak on the system for any reason, it will be inevitable that the air stored in the air tanks on the vehicle will be completely exhausted after a while. In such a situation, if the vehicle is completely unbraked, it will endanger the safety of life and property in traffic. In heavy vehicle air brake systems, specially designed and manufactured parts called Four-Way safety valve are used in order to eliminate the aforementioned risks. The task of the four-way safety valve is to ensure that the vehicle's front, rear and handbrake tubes operate independently. In case of an air leak in any air

tank or line, the robust tanks help the leaking tank, if the leak is excessive, the line is deactivated and the brake system works with the robust tanks. For example, if there is an air claw on the front air tank, it is to prevent the line from acting on the rear and hand brake tanks and to ensure that the rear and hand brake remain intact during braking.



Fig. 1. Four-way safety valve [4]

The illustration shows a four-way safety valve. It has to be used in vehicle braking systems where four-way safety valves are manufactured by vehicle manufacturers. It is of great importance in terms of traffic and vehicle safety to test whether the Four-Way safety valves on the vehicle are working in authorized and private inspection institutions.

In our country, it is a legal obligation to carry out periodic examinations of vehicles travelling on highways in certain periods. Tractor Group vehicles 3 years, Motorcycle and Automobile Group vehicles 2 years, light and heavy commercial vehicles must have periodic examination every year. The authority to carry out periodic inspection, modification inspection, compulsory inspection and roadworthiness examinations of vehicles used in road transport in our country has been given to TUVTURK, which operates under the Ministry of Transport and infrastructure. Table 1. January - November 2019 in the first 11 months of the total number of inspection of Heavy Vehicle Group was 947.747 in TUVTURK vehicle inspection stations in Turkey.

Table 1. TUVTURK Vehicle Inspection Stations (January - November 2019) Number of heavy vehicle vehicles under examination

Number of Heavy Vehicle Vehicles Under Examination	GM	TM	ZM	Total
Tow Car	172.375	193	12	172.580
Fire Truck	4.937	114	1	5.052
Truck	256.136	12.601	22	268.759
Minibus	312.421	14.642	40	327.103
Caravan	321	128		449
Bus	127.390	4.088	9	131.487
Special Purpose Tow Car	22	1		23
Special Purpose Truck	24.912	891	2	25.805
Special Purpose Bus	544	4		548
Tank Truck	15.144	796	1	15.941
<b>The Overall Total</b>				<b>947.747</b>

Table 1. January-November 2019 in the first 11 months of the 947.747 heavy vehicle inspection stations in Turkey in TUVTURK 458.089 Heavy Vehicle Inspection of the group is up to 48.3% when compared to the total number of vehicles entered. On average 50% of the approximately 1 million heavy vehicles operating in our country are evaluated as seriously defective due to their deficiencies in the first inspection. This rate reaches 70% as the age of the vehicle progresses. The inspection data shows that one of the two commercial vehicles (carrying cargo and passengers except vans) in our country in traffic has such defects as to prevent the completion of the inspection and to require the repair of the vehicle.

Wear and damage caused by usage and material life-span over time in parts affecting the traffic safety of vehicles constitute a risk in traffic. Some of the wear and damage in these parts, although not directly causing the accident increases the severity of the accident at the time of the accident, some of the wear and damage can cause the accident directly.

Wear and damage caused by both usage and material life in vehicles do not occur suddenly before inspection. These

wear and damage occur gradually, between two periodic examinations, over a certain period of time. Periodic inspection of vehicles, brake tester, mobile brake tester, load simulator, headlight adjustment control device etc. Test devices are used. The brake tester [1], [5], has done several studies on the brake tester related to the test stages used in vehicle inspections.

Table 2. TUVTURK Vehicle Inspection Stations (January - November 2019) Number of vehicles entering the Inspection and remaining for Inspection for any reason

Number of vehicles entering the Inspection and remaining for Inspection for any reason	GM-MT	TM-MT	ZM-MT	Total
Tow Car	67.520	102	4	67626
Fire Truck	1.607	21	1	1.629
Truck	162.521	6.296	16	168.833
Minibus	133.679	5.194	18	138.891
Caravan	156	77		233
Bus	55.397	1.557	1	56.955
Special Purpose Tow Car	11			11
Special Purpose Truck	13.925	311	2	14.238
Special Purpose Bus	135	2		137
Tank Truck	9.120	416		9.536
<b>The Overall Total</b>				<b>458.089</b>

Considering that the percentage of heavy vehicles left from inspection in our country (with heavy and unsafe defects in inspection) is above 50% on average, this situation shows that heavy vehicles watch a large part of the one-year period between the two periodic examinations in traffic with heavy and unsafe defects. In other words, a serious or unsafe defect that occurs long before a vehicle's inspection period one year later (e.g. 6 months after inspection) can potentially lead to a direct accident or increase the severity of the accident if it is not detected within a reasonable period.

However, as the age of the vehicles increases, their economic life decreases as well as the number of defects detected in the inspection increases in direct proportion to the age of the vehicle. As the vehicle ages, components with heavy and unsafe defects are re-formed in a short time, even if they are repaired. In other words, heavy and unsafe defects repaired prior to the inspection, the next inspection date before you re-formed and the duration of heavy traffic between two periodic vehicle inspection with defects or unsafe for a long time remains.

In our country, heavy vehicles and light vehicles over a certain age are far above an acceptable level of examination rates at the end of the periodical inspection periods prescribed in our legislation [6]. Early detection of severe and unsafe defects occurring before the next periodical inspection of the vehicles and efforts should be made to prevent the vehicle's course in traffic with these defects[7][8].

(January – November 2019) of 458.089 heavy duty vehicle groups in all of Turkey (January-November 2019) and remaining to repeat inspection Table 3. as can be seen in the ‘Four-Way safety valve: not working ’ defect took 11.014. This number was 2.4% when compared to the number of vehicles left to repeat the inspection.

Table 3. TUVTURK Vehicle Inspection Stations (January - November 2019) Number of vehicles receiving " Four Way Safety Valve: Not Working " fault for the inspection

Vehicle Groups	Defect	Number of Defective Examinations
Tow Car	Four Way Safety Valve: Does Not Work.	4.272
Fire Truck	Four Way Safety Valve: Does Not Work.	58
Truck	Four Way Safety Valve: Does Not Work.	4.532
Minibus	Four Way Safety Valve: Does Not Work.	7
Caravan	Four Way Safety Valve: Does Not Work.	2
Bus	Four Way Safety Valve: Does Not Work.	1.433
Special Purpose Tow Car	Four Way Safety Valve: Does Not Work.	1
Special Purpose Truck	Four Way Safety Valve: Does Not Work.	394
Special Purpose Bus	Four Way Safety Valve: Does Not Work.	3
Trailer	Four Way Safety Valve: Does Not Work.	1
Tank Truck	Four Way Safety Valve: Does Not Work.	311
<b>The Overall Total</b>		<b>11.014</b>

When the data of the first nine months of 2019 are examined, the compressor is pumping oil and we see the number of defects given in the vehicle group with a very long compressor filling time.

Table 4. TUVTURK Vehicle Inspection Stations (January - October 2019) Number of vehicles receiving " Compressor Oil is pumping and Compressor filling time is too long " inspection

Defect	Compressor: pumping oil.					
Vehicle Groups	2015	2016	2017	2018	2019	The Overall Total
Off-Road Truck	1					1
Tow Car	186	151	226	195	142	900
Fire Truck	18	17	11	6	4	56
Truck	1.611	1.434	1.496	1.170	876	6.587
Minibus	22	10	20	17	8	77
Bus	179	212	314	249	215	1.169
Special Purpose Truck	74	84	123	90	73	444
Special Purpose Van			1			1
Tank Truck	126	131	111	81	59	508
<b>The Overall Total</b>	<b>2.217</b>	<b>2.039</b>	<b>2.302</b>	<b>1.808</b>	<b>1.377</b>	<b>9.743</b>

## 2. Method

The task of the four-way safety valve is to ensure that the front axle brake, rear axle brake and hand brake operate independently of each other. If the brake system is operating with compressed air at any point in the event of air leakage, the vehicle is completely brake-free to prevent. Fig. 2. as can be seen in four-way valve control, the goal is to test the independence between all circuits. The vehicle is operated and stopped until the system pressure (pressure regulator evacuates).

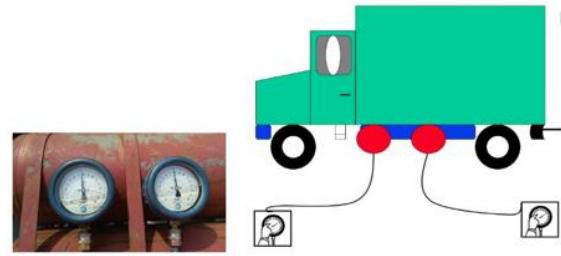


Fig. 2. Four-way safety valve test view

In Fig. 3. manometer is connected to the test ends of the heavy vehicle air tanks.

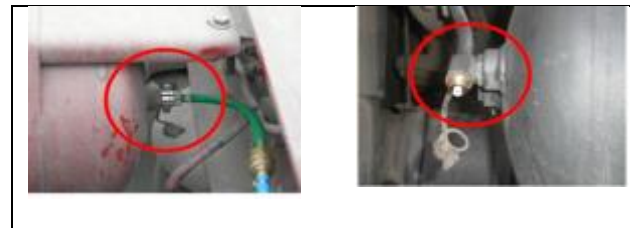


Fig. 3. Air tanks test leads

In Fig. 4. it is seen that the air tanks are emptied from the air discharge valves and the pressure control is done.



Fig. 4. Emptying of air tanks and pressure control



Fig. 5. Pressure change control in other tanks after emptying tank

During the process shown in Fig. 5. the air pressures in the manometers connected to other air tanks should not fall below 4 bars.

When the engine is started, it is observed that the system first safely fills the other air tanks which are not defective (which have not fallen below 4 bars), then fills the air tank which is drained to the level of the other tanks, and finally all tanks are filled together at the same time until the system pressure.

First, it will safely refill other air tanks that are not defective (which have not fallen below 4 bars). It will then be observed that it fills the air tank that has been drained to the level of the other tanks.

Finally, all the tanks will be filled together at the same time up to system pressure.

By performing the same test in other air tanks, it is checked whether the four-way safety valve works for all circuits.

Various uses of pneumatic are available in automotive industry. Air Brake Systems, Air brakes, air suspension systems, pneumatic doors, refrigeration systems, air bags, metal removal machines, drilling machines, lifting equipment, dismantling, crimping tools, tire air inflating, police and sanding machines, spray gun washing machines [9].

Tests of valves used in industry can be done with various devices. Circuit calibration tools are used to determine whether the electronically controlled proportional valves are working properly [10].

There is no similar study on four-way safety valve tests in the literature. The patent application for the Four-Way safety valve Tester in our study was submitted to the Turkish Patent and Trademark institution.

With this study, a tester and test software will be developed. Test equipment and software development and testing, independent of the Test person to convert to a standard Systematics, to perform the test technician/operator by providing ease to achieve error-free results, anthropometry and working environment (employee leaning, crouching, kneeling due to work posture to prevent overload), to ensure the measurement of the test done in a shorter time, ergonomics and ISG to contribute significantly, in addition, with the developed device, the control of other parts in the air brake system will be more effective and can be done within the framework of a certain standard.

### 2.1. Test Equipment Design

The work consists of two parts as Tester and test software. The pressure transmitter will be used to determine the handbrake, front axle and rear axle air tank pressures on the tester. For monitoring the pressure values from the pressure transmitters used, the LCD screen and the solenoid valves will be used to discharge the air tanks. There may be accumulation of water, oil, etc.liquids in the tanks belonging to the transport over time. During the discharge of air through the solenoid valves, the liquid holder will be used in order not to harm the environment of the polluting liquids. The test software will also have handbrake, front axle and rear axle pressure display screens to read tank pressures. The control of the solenoid valves and the discharge of the tanks will also be controlled via the software screen.

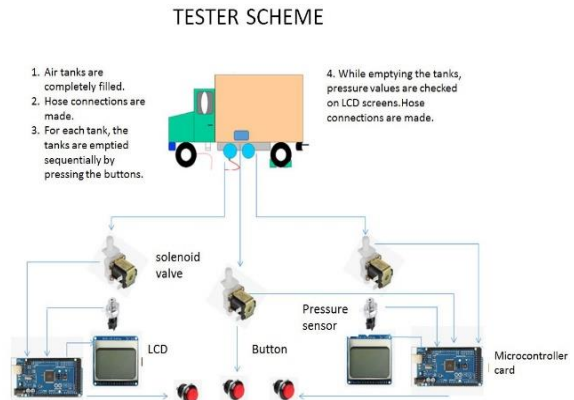


Fig. 6. Tester connection diagram

As seen in Fig. 6, the solenoid valve transmitter connection is made mechanically. In the arrangement, the solenoid valve is always closed. The compressed air pressure value from the vehicle air tank is read by the transmitter. The analog values obtained from the transmitter are converted to digital data with the help of the microcontroller card and are programmed on the microcontroller card to be read in the bar. Pressure readings are also displayed on the 1.6-inch LCD monitor placed on the device. A total of 3 sets were prepared for the handbrake air tank, front axle air tank and rear axle air tank.

### 2.2. Tester Design

The test device consists of two parts, "device hardware" and "software".

As shown in Fig. 7, the solenoid valve transmitter connection was made mechanically. In the Assembly, the solenoid valve is always closed. The pressure value of the compressed

air from the vehicle's air tank is read by the transmitter. Analog values obtained from transmitter are converted to digital data with the help of microcontroller card and read in bars by programming on microcontroller card. The Read pressure values are also displayed on the 1.6-inch LCD monitor positioned on the device. A total of 3 sets were prepared for the handbrake air tank, front axle air tank and rear axle air tank.



Fig. 7. Device hardware connection

In order not to leave the water, oil etc. contaminants that may accumulate in the air tanks of the vehicle directly to the outside environment during the discharge of the tanks, the air outlet part is combined and the liquid holder is placed on the end part. During the discharge of any tank, the air passing through the solenoid valve will also be passed through the liquid holder, preventing the collection of pollutants in a container and transfer to the external environment.

The installation will be made to the case seen in Fig. 8. There is a handbrake on the chassis, an air input jack for the front axle and rear axle air tanks, and an LCD screen with pressure values. During the discharge of the air in the air tanks there is one outlet channel through which the air free of polluting liquids is evacuated.

Monitoring the pressure values of the designed test equipment and emptying the tanks are provided with the developed software. There are 3 pressure gauges and 3 buttons on the software screen. As shown in Fig. 9, the pressure values of the handbrake, rear axle and front axle air tanks are monitored from the indicators and the buttons for emptying the tanks are also found in the software screen. For its ergonomic and portability, the software is intended to be used on a tablet and the software is prepared in accordance with tablet use.

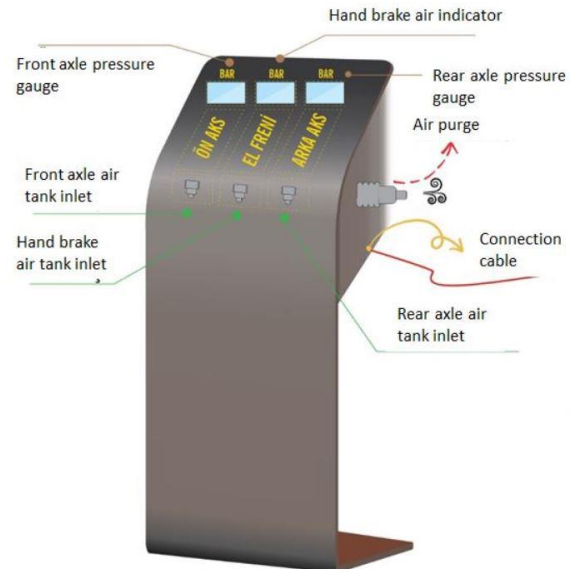


Fig. 8. Test case

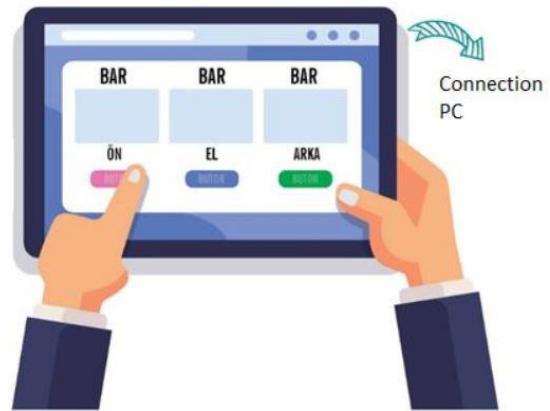


Fig. 9. Tester control screen

### 2.3. Using the Tester

The handbrake, front axle and rear axle air tanks located on the Test vehicle are connected to the hoses and the corresponding jacks located on the tester. The technician gets into the vehicle and starts the vehicle until the compressor is disabled, that is, until the air tanks are fully filled. Once the tanks are full, the vehicle stops. The technician can start the test by emptying any tank for a four-way safety valve test. For example, suppose you empty the front axle, handbrake, and rear axle tanks respectively.

The technician presses the “front axle” button on the software screen installed on the tablet to empty the front axle air tank and opens the solenoid valve on the line connected to the front axle. Thus the front axle air tank begins to empty. Although the front axle air tank is completely empty, the

pressure in the handbrake and rear axle air tanks should not fall below 4 bars. This is also followed by the indicators on the software screen. After the front axle air tank is completely empty, the technician starts the vehicle and starts filling the empty tank. During the filling, it is observed that the front axle air tank is filled up to 4 bars and all the tanks are increased together until the pressure of the compressor is deactivated.

In the second stage, the “handbrake” button is pressed on the software screen to empty the handbrake tank. Thus, the solenoid valve connected to the handbrake line is opened and the handbrake tank is emptied. It is observed that the front and rear axle air tanks do not fall below 4 bars. The vehicle is operated and the tanks are filled.

In the third stage the rear axle air tank is drained. By pressing the “rear axle” button on the software screen, the solenoid valve on the line is opened and the rear axle tank is emptied. At this time it is observed that other air tank pressures do not fall below 4 bars. The vehicle is operated and the tanks are filled.

During these controls, which are performed in three air tanks respectively, the technician / operator can ensure that the air tanks are emptied and filled at the same time without ever getting out of the vehicle. It is able to observe and interpret the pressure values of the tanks in a shorter period of time



without assistance from anyone.

Fig. 10. Tester view

### 3. Discussion

Vehicles with air brake system are named as heavy vehicles because of the load and passenger capacity they carry. It is possible to safely stop arcs weighing tons with both strong and reliable braking systems. Air leakage in any connection in the system can cause the vehicle to be completely brake-free. In such cases, the front axle, rear axle and hand brakes to be independent of each other is the most important safety element. A tester has been developed in this study for the robustness of this vitally important part. The developed Tester has the potential to be used in specialized maintenance and repair services as well as authorized inspection agencies. The

gains achieved by the tester will contribute directly and indirectly to the economy of our country.

### 4. Conclusion

With the test device developed as a result of this study;

It is ensured that the error rate caused by the technician/operator performing the test will be minimized and that the decision maker will be the device.

Working environment design; creating a more ergonomic area for the test taker, bending, crouching and kneeling during the test, such as the overloading caused by work postures and movements that will adversely affect human health were prevented.

The measurement was done in a shorter time as a test.

Environmental sensitivity has increased. In the current test the oil found in the air tanks during the discharge of the air tanks, dirt etc. the spread of chemicals and the subsequent contact with the technician threatens the environment and human health. With the tester, it is ensured that the oil and dirt accumulated in this tank are deposited in a container without spreading around during the test phase.

The developed test device, thanks to some air in the brake system other parts (such as compressor and air pressure gauge) is more efficient and also a certain standard to be held within the framework of controls; by running the car after draining the air tanks the air tanks to fill the vacant with the help of the compressor is provided. The air tanks of the compressor on the vehicle must be filled in the required time in the regulation. In this way, it will be provided by the device to determine whether the compressor has filled in the required time for the filling time.

Our test device that we will design is not available in the market. It will make positive contributions to industry and technology.

The safety valves used in pressure vessels are usually used to prevent the risk of explosion by increasing the pressure inside the vessel. The duty of the four-way safety valve used in the air brake system is to enable the tanks to operate with compound vessel logic in case of any air leakage in the system. However, if the amount of leakage is too much, the leak line (air tank) is disabled to ensure normal operation of the non-leak tanks. For the moment, the four-way safety valve test is based on the discharge of the tanks in sequence and observation that they work with the logic of a container up to a certain pressure, and the determination that the air tank is deactivated in case of excessive leakage.

With the tester developed in this study, it was ensured that the quadrature safety valve test was carried out with PC control. During the discharge of the air tanks and filling of the air tanks by the operator by operating the vehicle, the necessity of getting in and out of the vehicle has been eliminated. Therefore, non-ergonomic operator movements have been eliminated and time and Labor gained. During the discharge

of the tanks, the air discharged in the tanks is passed through the water retention filter. Thus, the water, oil, etc. pollutants accumulated in the tanks are prevented from damaging the environment.

In technical services, there is no information on how to do this Test, control and use of the tester to provide more effective control of a part that causes an accident. January-November 2019) as seen in the TUVTURK vehicle inspection data, 11.014 vehicles received 'four-way safety valve: not working' defect and were left to repeat the inspection. The time it takes for these vehicles to leave the inspection stations, to go to the Authorized Service for the inspection and repair of the relevant part, and to change the vehicle's fuel consumption is seen to be a serious burden on the economy of the country.

Most importantly, it is vital to contribute to traffic and Road Safety. Every year in our country and in the world, our people lose their lives due to this part of the brake system. Besides that the national wealth caused by the accident consists of vehicle damage.

### Acknowledgment

This study was carried out using the Master's Thesis titled "Design of Four Way Safety Valve Tester for Heavy Vehicle Brake Systems" at Selcuk University, Institute of Science.

### Nomenclature

ALB : Load sensitive automatic valve [11]

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