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Research Article

PLC and Computer Based Brake Unit Testing Device for Heavy Vehicles

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Abstract – The Since the discovery of vehicle technologies, brake systems have been one of the indispensable parts of these technologies. Air brake systems were invented in 1869 to shorten the braking distance of train locomotives. These systems allow the vehicles to slow down, maintain their stopped state and maintain the movement in a controlled manner by preserving their kinetic energy. Various test methods have been developed to test the produced brake system parts. Some of these tests are tightness test, life test, breakout test, valve test and load sensitivity tests. Heavy vehicles use air pressure to create braking force, and this is achieved with the help of air compressors. The air obtained is stored in an air tank and when the brake is not used, if the tank is full, the compressor is turned off. It is desirable that there is no air leakage in a healthy braking system. Leakage and life tests are carried out to ensure that the produced brake system parts do not leak air. In this study, Delta DVP SE model PLC (Programmable Logic Controller) and Visual Studio GUI application in C# language were used to control the air brake lower and upper central test device. The GUI application is run on the computer, and it communicates with the PLC using the Modbus TCP communication protocol. All the manual indicators on the tester have been transferred to a GUI application and all the values obtained can be displayed in a real-time graphic on the application. Obtained values and real-time graphics are presented to the user with a report. The results of the tests can be compared thanks to the GUI application.

Keywords – Brake Test Device, Delta PLC, Visual Studio, Modbus TCP, C#

I. INTRODUCTION

This Air brake systems are systems that are frequently used in heavy vehicles such as trains, trucks, trailers, and buses. The first air brake systems were designed by an engineer named George Westinghouse in 1869 to shorten the braking distance of train cars, and later, they were also used in other heavy-duty vehicles such as trucks, lorries and buses [1]. Today, new types of braking systems are still being produced and developed. A new type of air disc brake was designed for trailer type vehicles by Büyükköprü [9].

Maintenance of air brake systems is very important. Air can easily leak if there is a leak in the area where it is stored. In case of air leakage, accidents may occur in vehicles using air brakes due to the failure of the brake system due to the discharge of air. When the accidents in Turkey in 2011 are analyzed, 10% of the accidents are composed of accidents involving heavy-duty vehicles such as trucks, lorries and trailers. Looking at the data of the Turkish Statistical Institute in 2012, it is stated that 12,99% of the accidents are due to faults in the brake systems. For this reason, periodic maintenance and control of air brake systems should be carried out with utmost precision

[2]. Toklucu has published a leak test device for brake systems in heavy-duty vehicles as his master's thesis [12].

Brake systems are produced to slow down or stop the vehicle, to protect the potential energy of the vehicle while going downhill and to ensure that a stationary vehicle can remain stationary. In these cases, the brake systems must operate under very strong pressures. These issues are taken into consideration in the production of brake systems. For the brake systems produced to work stably on the vehicle, they must be produced in certain standards and value ranges. The robustness of the brake systems is tested at these intervals determined by the manufacturer before they reach the user. If the test results are not within the specified value range, the product is tested again and again by making appropriate changes and improvements by the control officer. If the test result is deemed appropriate and approved, it is delivered to the user. Testing the product is considered very important to ensure product satisfaction of the user [3, 4, 5]. Surblys et al. performed and analyzed both loaded and unloaded brake tests [8]. A test device was developed by Güntay to analyze brake performance in his master's thesis [10]. Caliskan improved the driving performance by using the regenerative braking method in his study [11]. In the study published by Aksu, a pneumatic ALB test device was designed for heavy vehicle braking systems [13]. In the study conducted by Özçelik, a test device capable of electronically measuring the four-way safety valves in heavy vehicle brake systems was designed [14]. Hydraulic brake systems can be tested in an experiment set at Bursa Technical University [15]. Criteria were developed and developed by Güney et al to evaluate the actual braking performance of the disc/drum and pad duo [17].

Test equipment: It is produced using three different disciplines: mechanical, electrical-electronic and software. These disciplines can be used separately in the production of test equipment, or they can be used in the production of a single product. The most effective production is achieved by using all three disciplines together.

PLC (Programmable Logic Controller) device is one of the products of electrical-electronics and software disciplines. The status of input elements such as buttons and sensors used in real life is converted into digital data by the PLC device. These numerical data are processed into the PLC device according to the flow written by the software developer. Thus, it is ensured that output elements such as asynchronous motor and relay can be controlled. Since these processors are produced to be resistant to negative factors such as noise, dust and liquid in the industrial environment, they are used extensively in the field of industrial automation [5, 6]. Grass developed a PLC and hmi-controlled mechanical test setup in the test setup [16].

Computer programs that convert the user's physical operations into digital data and send this data to the machine that will process the data are called GUI (Graphical User Interface). These interfaces direct the machine by translating the physical operations given by the user into machine language. One of the most frequently used methods to create an interface is the Visual Studio application running on the Windows platform. The Visual Studio application communicates with the processors using standard communication protocols such as Modbus and Serial port. Communication protocols such as Modbus 232, Modbus 485, Modbus TCP are frequently used when communicating with the PLC processor [5,7].

II. Materials and Method

Considering the needs of the measurement system design, it was thought and designed to be built on PLC and computer. PLC is considered as a bridge between the outside world and the computer with its flexible programming and ease of data entry and exit. The computer, on the other hand, is used to provide ease of use between the human-interface facing the user. The connection between the computer and the PLC is provided via Ethernet

in detail the materials and methods used when conducting the study. The citations you make from different sources must be given and referenced in references.

A. *Programable logical devices*

Previously, electronic control systems were working with analogue methods more than now. Due to the development of technology and the inadequacy of analog systems, digital methods have been used. Automation systems work with the joint control of digital and electronic systems. Microprocessors or microcontrollers, which we can describe as the brain of automation systems, offer a very comfortable way of use because they can be programmed. PLC (Programmable Logic Controller) devices are devices created using microprocessors or microcontrollers. PLC devices are produced to replace relays controlled by remote or manual methods. An example of PLC is given in Fig. 1.

Fig. 1 Delta DVP-12SE brand PLC

The PLC device makes evaluations in line with the user software by numerically synthesizing its physical states such as sensors and buttons. According to the evaluation, control elements such as motor, LED and valve are controlled [18]. Solenoid valve and asynchronous motor are shown in Fig. 2.

Fig. 2 Example of solenoid valve and motor controlled by PLC device

Figure 2. Example of solenoid valve and motor controlled by PLC device

PLC devices can be used in a wide variety of fields such as hydroelectric power plants [19], food [20], IOT technologies [21] and textiles [22].

B. *Microsoft Visual Studio Application*

Figures Microsoft Visual Studio performs coding, testing, debugging, analyzing, and distributing the standards and quality of the code in the process from planning the work to be done to GUI design. In the Visual Studio program, applications are made for many platforms other than the Windows platform. These are various examples such as smartphone applications such as Android and IOS, websites, IOT programs, console games. These applications can be programmed using C#, C, C++, JavaScript, F# and Visual Basic languages [23]. C# programming language, one of the most used languages in this field, is a language that runs on the .Net platform. It works with C# .Net Framework version. The C# language, which emerged with the development of the C++ language, enables the applications to be developed with C and C++ languages to be developed with a long time and effort in a shorter time. Since it is an objective language, it prevents unnecessary code usage by incorporating class logic into applications [24].

C. *Industrial Communication Systems*

Industrial communication systems have been a renewing field for years. The communication of the devices produced for use in industrial fields with each other is thanks to the communication systems. While producing these systems, certain standards are taken into consideration. These standards are called protocols. According to the protocols, control elements such as sensors, valves, relays and motors used in the industry share information about their status among themselves, with PLC devices and computers. Thus, data flow is provided, and desired operations can be performed because of the analysis [25]. In Table 1.1, communication protocols used in the industry, supporters of these protocols, market share and applied areas are given.

Table 1. Example of a table

Comm. Protocol	**Market Share**	**General Application Areas**	**Supporters**
CAN Bus	25%	Automotive, Medical Systems	Cia, Ovda, Honeywell Bosch
Profibus	26%	Electricity, Water, Natural Gas Systems	Siemens, ABB
LON	6%	building automation	Echelon, ABB
Ethernet	50%	Many systems such as production, distribution, control Many companies	Many companies

Fieldbus	7%	Chemical Industry	Fisher-Rosemount, ABB
ASI	9%	Building Automation	Siemens
Modbus	22%	Many systems such as production, distribution, control	Many companies
ControlNet	14%	In-plant bus	Rockwell
InterBus	7%	Production	Phoenix Contact

Modbus communication protocol provides data exchange between a master device and one or more slave devices. Many industrial devices use this protocol. Due to the development of technology and the change of industrial needs, Modbus has been divided into various sub-protocols. The most used Modbus subprotocols today are Modbus TCP, Modbus ASCII and Modbus RTU protocols. Modbus TCP is connected with Ethernet connection method, Modbus ASCII and RTU protocols are mostly used RS232 and RS485 connection methods. The biggest factor in choosing these protocols is that they work independently of the lower layers. Sub-protocols of Modbus protocol are given in Figure 3 [26].

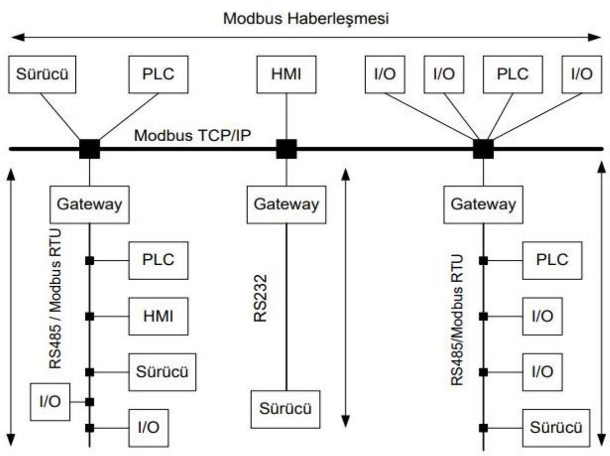

Fig. 3 Modbus network architecture [26].

PLC devices have RS-485 hardware structure to communication to other devices. Mod bus is an software that suitable for RS-485 hardware [27].

III. Realization of PLC and Computer Based Brake Unit Measurement System

In this study, the automation of the brake center test device, which is already in the ARSKAR Automotive company, has been made. A pressure transmitter was applied parallel to the pressures on the test device and the vehicle was transferred to the DVP SE brand PLC, which was received from the transmitters. 0-16 Bar was purchased from this vehicle in PLC. Visual Studio has been imported into the GUI application to be created. It has been applied in the life test and applications test for the data obtained, and the reports of these tests are listed to the user with the report. Comparability of multiple reports.

A. Computer Interface

The pressure data obtained and interpreted are presented to the user with virtual indicators by calculating both bar and PSI values. This data works in real time and is updated every 100 ms. Virtual gauges give more precise results than manual pressure gauges. This situation is given in Fig. 4.

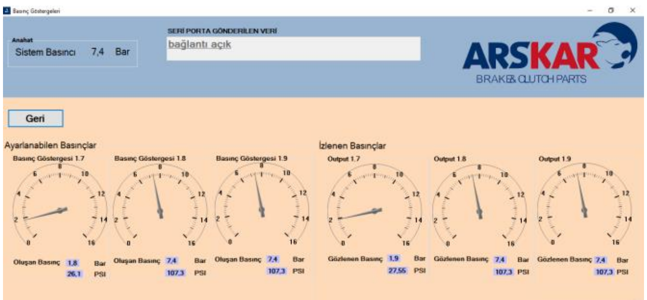

Fig. 4 Virtual pressure gauges

Sections with life test and leak tests are given in Fig. 5. These sections are explained in detail.

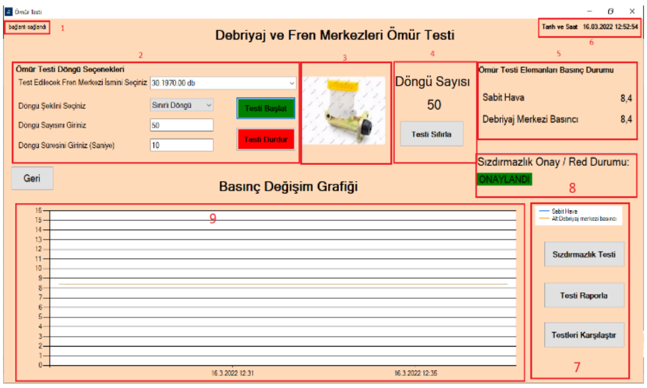

Fig. 5 Test Screen

1. Connection check
2. Test settings
3. Picture of the unit to be tested
4. Number of cycles of the test performed
5. Pressure situations

6. Date and time
7. Leakage test and test reports
8. Tightness test result
9. Pressure change graph devices can be used

In part 1, it is checked whether the computer, which is a part of the system, and the PLC device, which is another part of the system, provide Modbus TCP connection. When the connection is established, it says "connection established". If the connection fails, “check your connections.” warning is displayed.

In section 2, there are settings that need to be adjusted before starting the test. These arrangements must be made before starting the test, otherwise the system will not start the test. First, the code of the product to be tested must be selected. Afterwards, if the system is required to perform and complete a specified number of tests, the "Limited Loop" option should be selected, and if the limit is not clear and it is desired to be stopped by outside intervention, the "Infinite Loop" option should be selected. If there is no outside intervention, the system will continue without stopping. If desired, a security limit can be set.

The criteria to be tested for the products to be tested may be different. For this reason, the operator who will perform the test should know how many seconds a test cycle should last for the product and how many cycles will be sufficient for the product. In the light of this information, “Number of Cycles” and “Cycle Time” information should be entered. In part number 3, there is a picture showing which product the selected code corresponds to.

Section 4 contains the number of tests that have been made. This number is protected against errors caused by any power cut or accidental shutdown of the program and will not be reset unless the reset test button is used.

In section 5, the bar value of the constant air pressure supplied to the system and the bar value of the pressure inside the tested product are given. Thus, the pressure coming from the system and the pressure inside the product can be observed by the operator as well as the machine. Section 6 contains instantaneous date and time data. These values are taken from the operating system.

In the marked area numbered 7, there are “Leak Test”, “Report Test” and “Compare Tests” buttons. With the tightness test button, it is tested whether the trapped air in the tested product is leaking or not. The trapped air pressure for 2 minutes is controlled by a real-time graph. If the air pressure of the tested product falls below the specified approval limit, the difference screen turns red and the result "Rejected" is given. This test screen is given in Fig. 6.

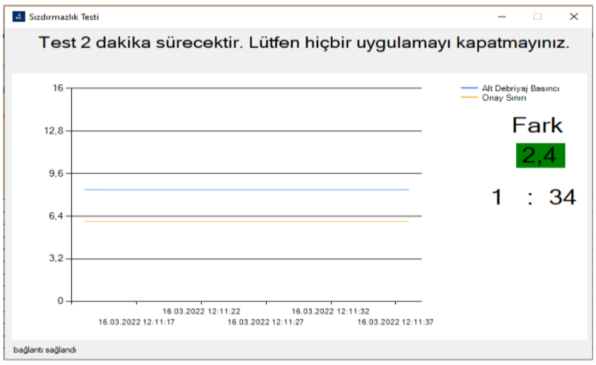

Fig. 6 Sealing Test system

With the report test button, this test is reported after the test is completed. This test, which is reported with the Compare Tests button, can be compared with another previously performed and recorded test. In Figure 7, the selection screen is given for the comparison of the tests.

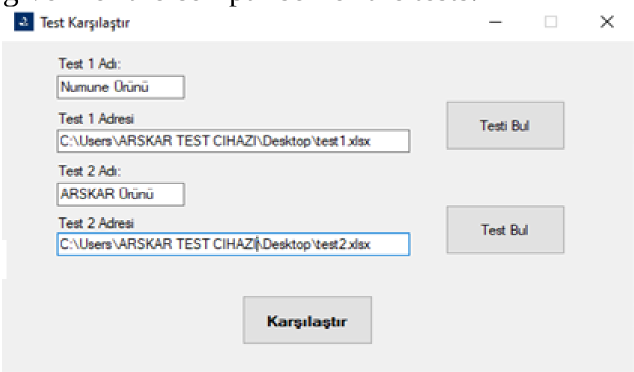

Fig. 7 Test comparison screen

In section 8, the result of the leak test can be seen. If the air pressure inside the product is below the determined values, it is written "REJECTED", if it is above or equal to the determined values, "APPROVED" is written.

In the last part number 9, after each test cycle, the air pressure supplied to the product under test and the air pressure formed inside the product are listed in bar. This list is refreshed during the test cycle time specified on the test screen.

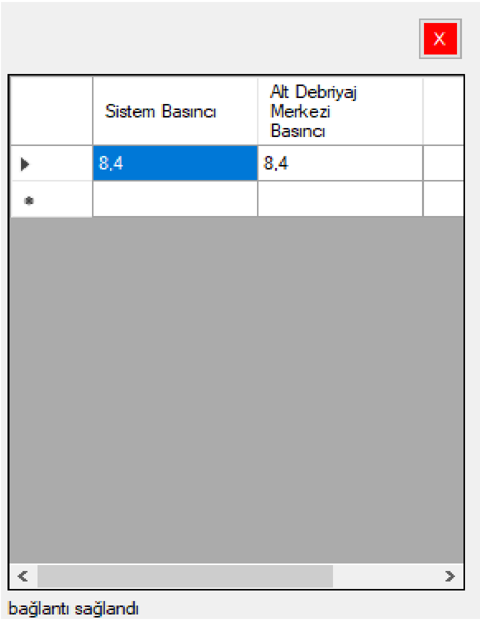

Fig. 8 Pressure monitoring screen

Pressure values after each cycle can be written on the pressure change graph, but when this method is used, very dense number data is seen on the graph, and this can cause ambiguity. Instead, double-clicking on the chart opens a screen and displays the values listed. This screen is given in Fig. 8.

B. PLC and Control Elements

The pressure transmitters that measure the air pressure from the control elements and the 2-position 5-way valve used for the life test are controlled by the PLC device. Pressure transmitters can make precise measurements in the range of 0-16 bar, and these measurement values are converted into amps and transferred with the help of an analog-digital converter module that can be integrated into the PLC device. Trafag 8252 Nat brand pressure transmitter, which is also used in the test device, is given in Fig. 9.

Fig. 9 Pressure Transmitter

Values in the range of 4-20 amps coming from the pressure transmitter were transferred to the PLC device thanks to the Delta Dvp04ad-Sl analog-digital converter. This converter converts the amperage or voltage values coming from the sensor into numerical values and provides meaningful expressions in the PLC device. The Delta Dvp04ad-Sl analog-to-digital converter used in this study is shown in Fig.10. PLC is considered as a bridge between the outside

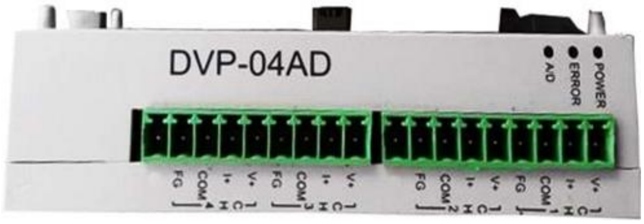

Fig. 10 Dvp04ad-Sl analog-to-digital converter

Analog-digital converter is added from the right side of Delta DVP12SE11T brand PLC and maximum 4 voltage or amp output sensors can be connected to this converter. 2-position, 5-way solenoid valve was controlled with the help of a relay to carry out the life test. In case of current is given to the electronics of the 2-position solenoid valve, the first air channel is activated, and air flow is provided. After the given current is cut off, the second channel is opened, and the air thus provides flow from the second channel. The 2-position 5-way solenoid valve used in the study is given in Fig. 11.

Fig. 11 2-way 5-position solenoid valve

In order for the PLC device to communicate with the computer interface, the COMMGR program, a product of Delta company, was used. This program includes communication protocols such as Modbus RTU, Modbus TCP and Modbus ASCII that can be communicated with PLC device. While communicating, an IP address is given to the PLC device. After an address adjacent to this address directory is defined on the computer, data can be received from the PLC device. This communication is provided by the COMMGR program. The visual of the COMMGR program is given in Fig. 12.

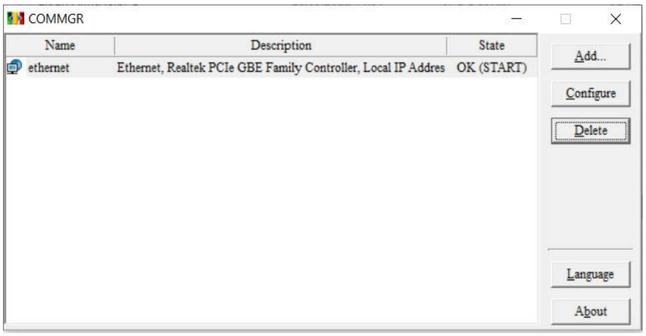

Fig. 12 COMMGR Software

The WPLSoft program is the software platform where the software necessary for the PLC device to control the sensors and the valve is developed. This program is a computer software developed by Delta company for PLC devices. An example of a program in the WPLSoft program is shown in Fig. 13.

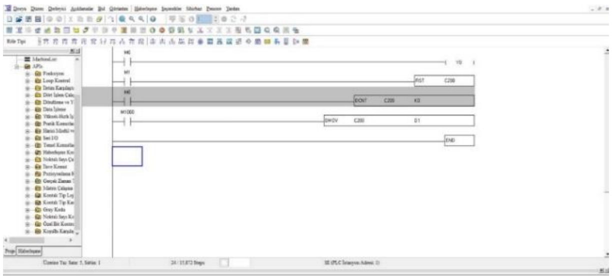

Fig. 13 An example of a program made in WPLSoft

The PLC program written on the WPLSoft platform was written using the Ladder diagram method.

C. *Mechanical Assembly*

A mobile test device panel has been produced so that the user can use the test device easily and comfortably. The test device panel enables the operator performing the test to direct the panel with the help of hinge and handle. The test device panel created is shown in Fig. 14.

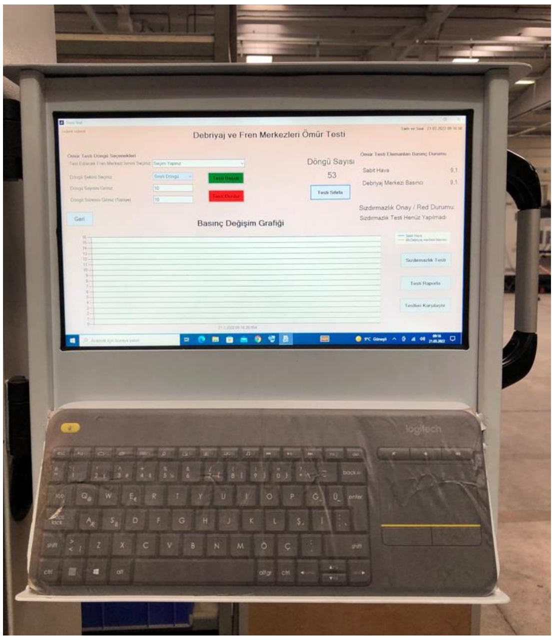

Fig. 14 Created touch test panel

The This panel is mounted on a manual tester using a torque hinge. Thus, wobbles that may occur due to vibration or impacts are prevented. The image of this link is shown in Fig. 15.

Fig. 15 Connection of the test panel

The test panel was made with the comfort of the user in mind. The user will be less tired during a long test process and the workload will be reduced. The assembled state of the test panel and manual test device is given in Fig. 16.

Fig. 16 Test unit after installation

As can be seen in Fig. 16, the panel is mounted on the right side where the indicators and buttons that are widely used in the manual tester are located. This provides ease of use for the operator.

IV. CONCLUSION

This study proposes a system design based on computer and PLC for real-time testing of parts produced for heavy-duty vehicles and examining product behaviour. The manufactured product has been tested by attaching an apparatus that simulates the vehicle surface with an apparatus. The apparatus is equipped with sensors that will provide data to the system.

With the measurements made, it was possible to monitor and record the predictions about the safety of the manufactured part and the changes during its operation in real time. While the previous manual tests gave partial information about the product, the instantaneous behaviour of the tested product became possible to examine, since the data collection rate could be done in 100-ths of a second in the test setup. Thus, the comments about the trust in the product and the behaviour of the product have become more realistic.

In manual tests, if the product is only defective or if there is a visible error, the product leaves the healthy ones, and since more data is collected with these tests, more comments can be made about the quality of the product.

In particular, the fact that the pressure loss can be continuously monitored from the product tests contributes to the modelling and future development of the product. In the tests, especially the pressure loss was examined with a sensitivity of 0.01bar, which increased the confidence in the product. Thus, it was possible to compare it with other commercial products.

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