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WORKPLACE FOR MEASURING COMPRESSED AIR CONSUMPTION IN LABORATORY CONDITIONS

Compressed air consumption in industry is increasing. It is necessary to be able to determine its value during operation. These data can reveal malfunctions in the compressed air distribution. The article presents the implementation of the measuring station in laboratory conditions, the aim of which was to create a functional solution that allows accurate measurement of compressed air consumption during operation. The Aventics AF2 flow meter operating on the thermal principle with the possibility of communication using OPC UA was used. The system was integrated into the equipment of the pneumatic laboratory and the measured values were processed in the MATLAB. This tool allows you to monitor the change in selected quantities in real time. It allows you to save them as MS Excel files or as graphic outputs. Verification of the system's functionality was carried out by a series of measurements. The results confirmed the suitability of the selected technical solution. The article is an overview and informational.

Keywords: *compressed air; consumption; measuring device; architecture of the measurement chain; the communication protocol.*
Fig.: 6. Table: 1. References: 10.

Relevance of the research. At the time when the issue of energy savings and related environmental pollution with exhalates arising during energy production is becoming more and more relevant, the issue of saving all energy, the production of which is linked to the consumption of fossil fuels in particular, is coming to the fore [1]. These types of energy undoubtedly include electricity, which consumption also significantly burdens the carbon footprint associated with the production of compressed air [1].

Companies using compressed air (practically all automated operations) today monitor compressed air consumption very strictly.

Until recently, compressed air consumption in operations was considered a marginal problem and users paid almost no attention to it. This was not only due to the fact that existing compressed air leaks were overlooked, but also to the absence of existing technical means that provide a picture of the economic use of compressed air energy.

Problem statement. Often, suspected compressed air leaks were detected only by a trivial procedure, where the operator of the compressor stopped the operation of individual workplaces in operation to monitor whether the compressor activity still occurred. Although this procedure confirms the losses, it does not provide information about their size and therefore does not allow a decision on their elimination method.

The aim of the project we implemented was to find a suitable methodology for collecting editable data on the level of compressed air consumption in laboratory conditions using available technical means [2].

Analysis of recent research and publications. Companies producing a range of pneumatic components are coming up with ever newer and more advanced elements that serve to monitor and collect data related to total or current compressed air consumption [3-6]. Using comparative virtual models of operation, it is possible to effectively and accurately eliminate the detected losses. This is done by special audits offered by these companies, which are designed to determine the real value of the required volume of compressed air per unit of time based on the detection of actual information about the customer's operation and, by examining other parameters of operation, to determine areas in which there are reserves [7; 8].

However, in these audits it is imperative that the customer provides the auditor with truthful data, which in many cases is not entirely self-evident.

The problems associated with this lie mainly in inaccurately interpreted documentation of the realized first-run system or the use of components that do not exist in the project. Most often, these are the values of the lengths of the hoses used (sometimes also their cross-sections).

Isolation of previously unexplored parts of the general problem. In the implemented project, we did not deal with the simulation of the evaluated process, despite the fact that the system processes data in an environment that allows it. For our purposes, it was sufficient in this step of the solution to create a functioning system that would allow the collection of editable data, with which, after completing the measurement workplace and only after creating a virtual environment for modeling the course of the measured process, these two systems could be connected. Simulation already represented an issue beyond the scope of the assignment of the diploma thesis project. However, it is not excluded that in the given project this deficiency was eliminated, e.g. by announcing a new diploma thesis assignment focused on this problem.

Research objectives. When solving the task of collecting defined data while monitoring the ongoing operation of a pneumatic system, the goal was to achieve a usable system that would allow for the recording and display of measured data at a certain speed according to the operator's specifications. The output was to be tabulated measured values of selected parameters, with which it would be possible to work and analyze them further.

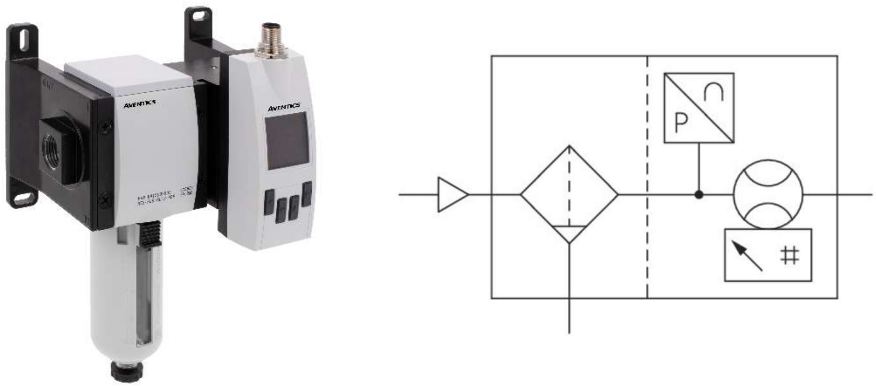
Based on the successfully implemented data transfer architecture, it was necessary to perform verification measurements. For these purposes, laboratory-used circuits with compressed air were used [2].

In the future, it is expected to use this system in the design of new drive units for the International EMERSON Aventics Pneumobile Competition project [9].

Measuring system for determining compressed air consumption. The project was created based on the need to verify some parameters related to the real consumption of compressed air for the needs of the educational process at the department as well as for the needs of finding relevant data for the aforementioned project of constructing an economical pop-up unit for the EMERSON Aventics Pneumobile Competition project [9].

In the form of a diploma project, a methodological procedure was proposed for determining the actual value of the volume of flowing compressed air as either an instantaneous value, an average value or its graphic course by using a suitable flow meter.

An industrial compressed air flow meter AF2 from EMERSON (Aventics) [3] was used for the project, Fig. 1, *a*).



a *b*

Fig. 1. Flow rate sensor AVENTICS AF2 (R412026837)

Source: [3].

This device provides the ability to measure the value of the normal flow rate Qn in the range from 5 l/min to 1590 l/min.

It is installed at one of the workplaces in the Laboratory of Pneumatic Systems, which serves to train our students in the compressed air use. On the pneumatic diagram of the part of the workplace with the internal designation ST01, Fig. 2, it is marked as 02.

As can be seen from its schematic symbol, Fig. 1b), it is a combination of a measuring device and an air treatment unit consisting of a filter and a condensate separator.

The most important parameters are listed in Table 1.

Table 1 – Parameters of flow rate sensor AVENTICS AF2 (R412026837)

Flow measuring principle	calorimetric
Minimal flow	5 l/min
Nominal flow	1060 l/min
Maximal flow	1590 l/min
Min. working pressure	0 MPa
Max. working pressure	1.6 MPa
Min. ambient temperature	-20 °C
Max. ambient temperature	60 °C
Min. medium temperature	-20 °C
Max. medium temperature	60 °C
Medium	Compressed air Argon Nitrogen Carbon dioxide
Output signal	OPC UA MQTT Integrated WEB server

Source [3].

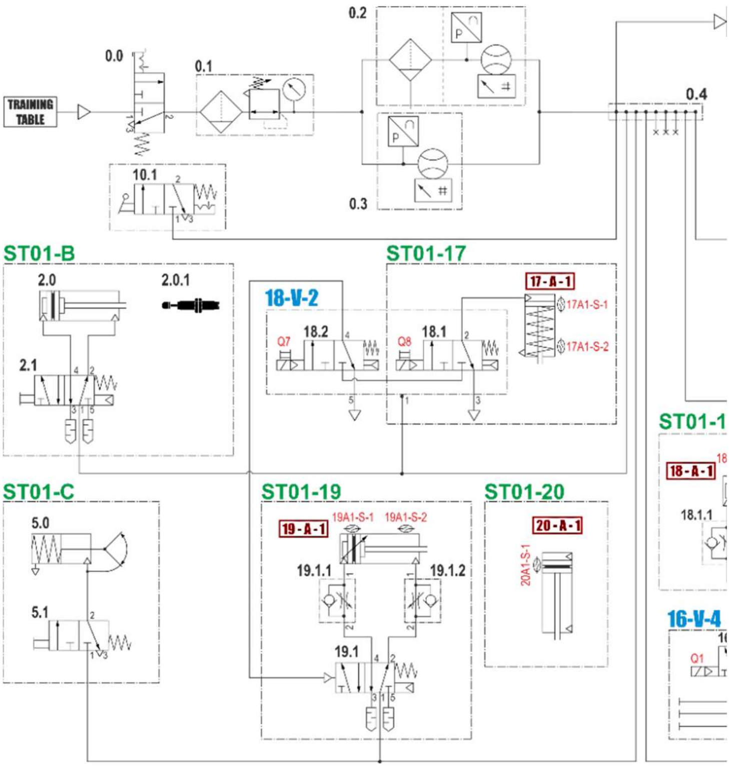


Fig. 2. Part of a pneumatic circuit with an integrated flow meter
Source: compiled by the author.

Since this is a device that can communicate via the RJ-45 interface within the Ethernet network connection of the workplaces in the laboratory, it was necessary to solve the value of the voltage level that the device requires.

While the high-frequency signal does not exceed 3V during Ethernet transmission, our device needs a supply voltage of 36 V DC transmitted via the RJ-45 interface. Therefore, it was necessary to include a PoE Injector in the network, which mediates the required voltage.

The architecture of the arrangement is shown in Fig. 3.

The implementation of the connection according to Fig. 3 already allows data transfer via the WEB server application, Fig. 4, however, the data provided by this application are not sufficiently interperable (they can only be preserved by the PrtScr - printscreen service of the computer operating system), and the data transfer has a significant delay.

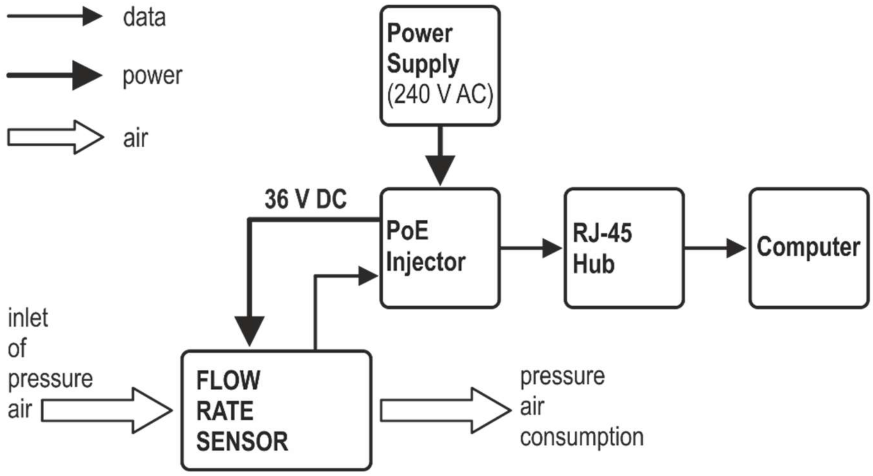


Fig. 3. Flowmeter connection architecture

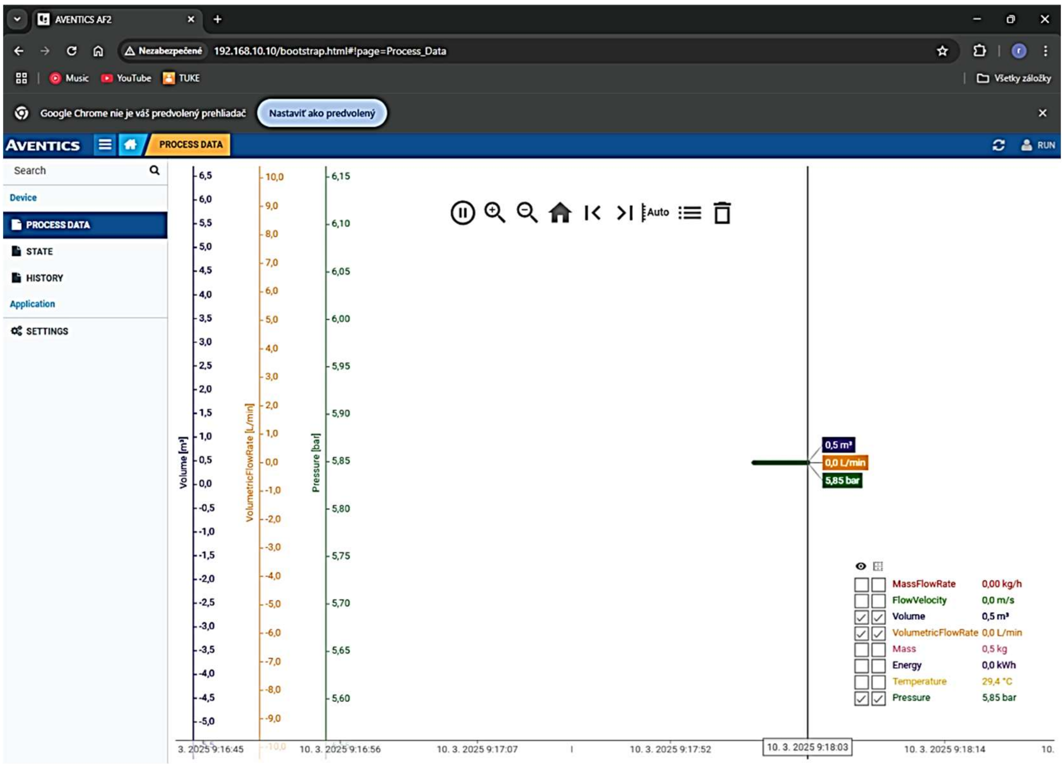


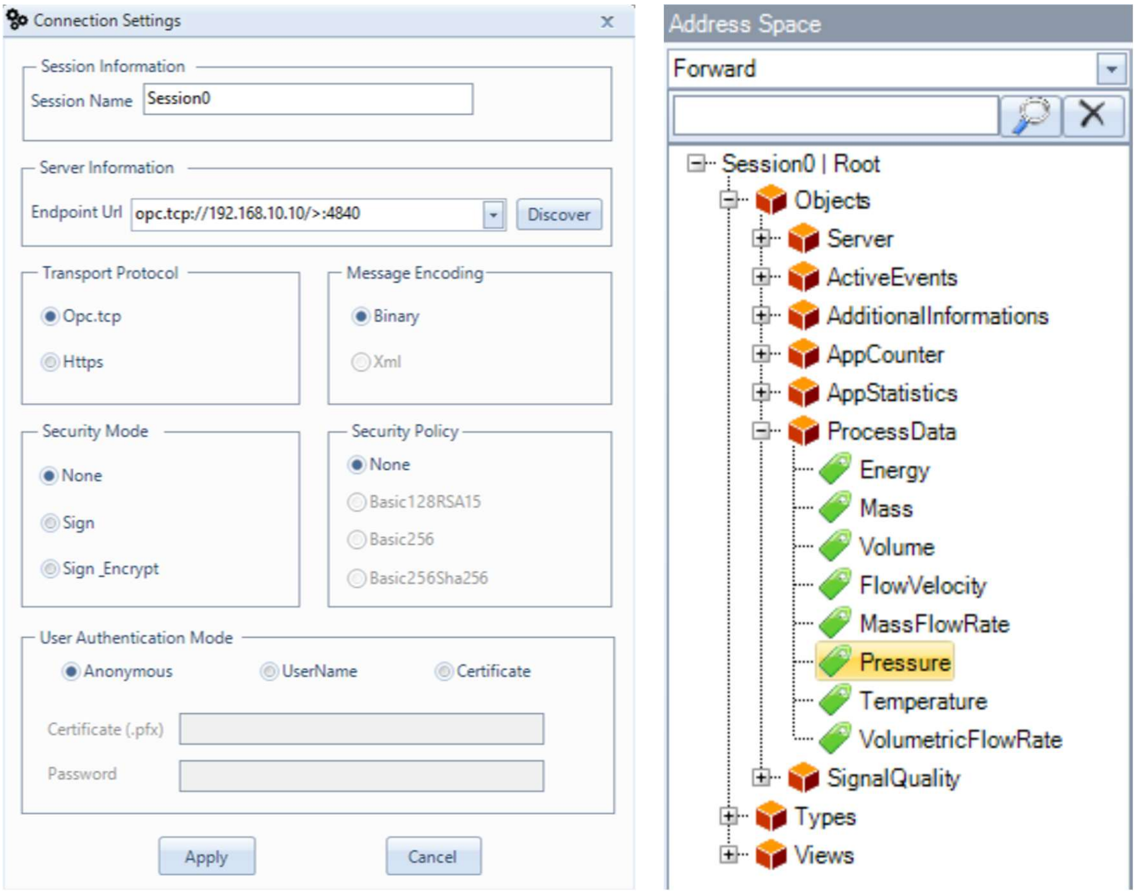
Fig. 4. Environment provided by WEB server service [2]

Since our intention was to obtain a set of editable data with which it is possible to work further and perform the necessary analyses, we decided to use the OPC UA (Open Platform Communications – Unified Architecture) service provided by the device, i.e. an open, independent communication standard for industrial automation. It enables secure and reliable data exchange between machines, systems and the cloud within Industry 4.0.

This protocol is platform-independent and service-oriented. At the same time, it has robust security features. The protocol serves as a "universal translator" for various devices, thus ensuring interoperability and effective communication.

The OPC UA implementation provides access to the operational data of the device – the flow meter. In this case, the server is the data source and manages the data model, while the client connects to this server to read or write live data, browse the data structure.

By setting the IP address and port on the PC, Fig. 5, *a*, the client has access to all necessary data, arranged in a clear tree structure, Fig. 5, *b*.



a *b*

Fig. 5. Setting the IP address and port (a) and displaying the flowmeter variables (b)
Source [2].

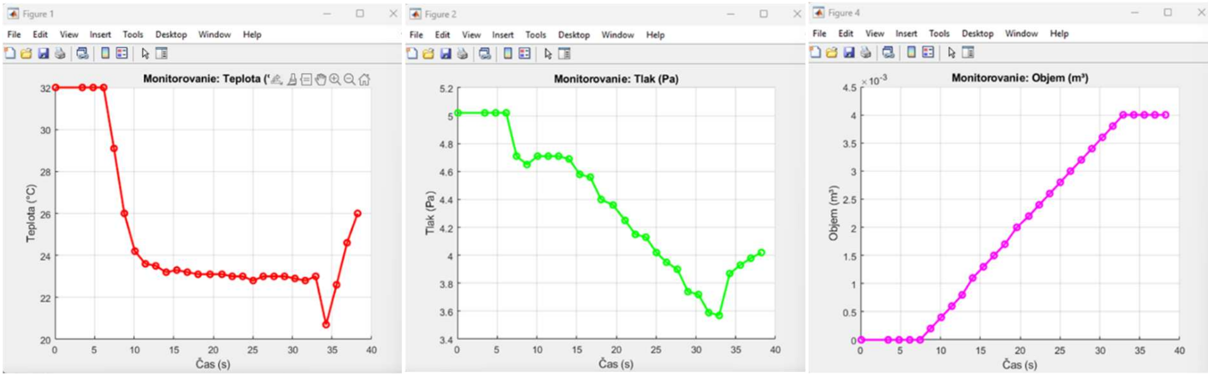
For data flow processing, a monitoring system was developed using the MATLAB computing environment.

This created a real tool for real-time data visualization. This created a prerequisite for the possibility of implementing a real model of expected consumption (theoretical consumption) and comparing it with data measured in real time.

The model and the entire system were tested in conjunction with existing workplace equipment, while monitoring the plausibility of measured data with mathematically calculated values.

The pneumatic cylinder DSNU-25-160-PPV-A (manufacturer FESTO) operating in a cycle, on the pneumatic diagram, Fig. 2, marked as 19-A-1, controlled by an air-operated valve marked 19.1 (monostable air-operated 5/2 valve), for which the control air signal is generated from the PLC via a 3/2 N.C. valve marked 18.2 (part of a double valve 2x3/2 N. C., manufacturer AVENTICS/EMERSON).

The values of the measured selected parameters as displayed by the system are shown in Fig. 6.



Temperature *Pressure* *Volume*

Fig. 6. Graphical outputs provided by the measurement system

Source [2].

The data shown in the graphs is also stored as numerical data in MS Excel.

The model is primarily intended for educational purposes, such as demonstrating the importance of measuring compressed air consumption data when operating automated devices powered by compressed air. However, it can also be used to take measurements at the customer's premises.

Conclusions. Teaching our students to properly connect a pneumatic circuit or draw a wiring diagram is certainly a necessary thing, since the use of compressed air in automated operations is not slowing down, but the added value should be information about the behavior of a particular pneumatic component with regard to its financial burden (acquisition costs) but also the burden associated with its use (operating costs). And, this is exactly the area where it is very easy to save. Someone wise said that you can only save on what you do not have to produce. This is doubly true when it comes to compressed air consumption.

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РОБОЧА СТАНЦІЯ ДЛЯ ВИМІРЮВАННЯ ВИТРАТИ СТИСНЕНОГО ПОВІТРЯ В ЛАБОРАТОРНИХ УМОВАХ

Споживання стисненого повітря в промисловості, особливо в автоматизованих операціях, має постійно зростаючу тенденцію. Пов'язані з цим експлуатаційні витрати погіршують конкурентоспроможність виробника. Тому для користувача стисненого повітря важливо мати можливість визначати значення кількості повітря, споживаного під час роботи, або його пікові значення. У багатьох випадках це може свідчити про несправність у системі розподілу стисненого повітря (розрив трубопроводу розподілу стисненого повітря).

У статті представлено успішну реалізацію вимірювальної станції, призначеної для визначення кількості спожитого повітря у лабораторних умовах. Метою роботи було створення функціонального рішення, яке дозволило б точно вимірювати споживання стисненого повітря під час роботи пневматичних контурів із можливістю зберігання виміряних показників витрати повітря. Лабораторне обладнання також дозволяє цій системі моделювати несправності пневматичних компонентів, спричинені зносом або пошкодженням.

У рішенні використовувався витратомір Aventics AF2, що працює на тепловому принципі та забезпечує зв'язок за стандартом OPC UA. Це, у поєднанні з мережею Ethernet, створеною в лабораторії, є дуже потужним інструментом для навчальної діяльності в лабораторії.

Вимірювальна система інтегрована в існуючий пневматичний стенд, який служить для навчальних цілей у лабораторії. Перевірка її функціональності була проведена шляхом серії вимірювань конкретних пневматичних пристроїв. Деякі графічні результати також представлені в цій статті.

Результати підтвердили придатність обраного технічного рішення. Вихідні дані вимірюваних значень згодом були оброблені в середовищі MATLAB. Програмний інструмент, побудований таким чином, дозволяє відстежувати зміну вибраних вимірюваних величин у режимі реального часу. Потім він дозволяє зберігати їх у вигляді файлів електронних таблиць MS Excel, з яких також можна створювати графічні результати.

Стаття є оглядовою та містить інформаційний матеріал.

Ключові слова: *стиснене повітря; споживання; вимірювальний пристрій; архітектура вимірювального ланцюга; протокол зв'язку.*

Рис.: 6. Табл.: 1. Бібл.: 10.

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