Rethinking engineering education

GUNT DigiSkills 4

Energy efficiency in compressed air systems

Skill Level 1 2 3 4 5

Industry 4.0 | Education 4.0

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Foreword

More than any other group, the industrial metal-working and electrical professions are in the spotlight when it comes to **digitalisation** and **Industry 4.0**. The new profession profile Digitalisation of Work – binding for all German establishments – requires the concrete implementation of the fields of competence and training content relevant to Industry 4.0. Conventional and innovative techniques coexist and must both be mastered. As a **vertical integration of learning content**, the new profession profile: Digitalisation of Work, is taught over the entire training period in the training company and in the vocational school.

The DigiSkills 4 learning project supports the teaching of these professional groups. At the same time, the DigiSkills 4 learning project is also ideally suited to universities and colleges in the fields of environmental engineering, energy engineering, mechanical engineering and mechatronics. Lectures and practical courses on energy management, energy engineering and compressed air technology are supported by the DigiSkills 4 learning project.

GUNT can help you with these complex vocational educational tasks. Our practical, work process-oriented learning projects, which are perfectly suited to developing digital skills, are available to you in the form of the **GUNT DigiSkills product line**.

Develop skills for the world of work 4.0 with the **GUNT DigiSkills 4** learning project

interdisciplinary – digital

Visit the DigiSkills website

The GUNT DigiSkills 4 learning project

Compressed air is the most widely used energy source in industry and trade today, alongside electrical energy. Compressed air is easy to produce, store and distribute. However, compressed air has to be provided at considerable cost and is therefore a valuable and expensive energy source.

There are many initiatives (including government initiatives) to make compressed air applications in companies more energy-efficient. The potential for savings is diverse and high. In addition to reducing operating costs, there is also the aspect of improving the climate situation to consider.

The topic "Energy efficiency in compressed air systems" of the DigiSkills 4 learning project deals with these potential savings. The didactic concept includes familiarisation with the components and learning how they work and interact. Potential savings are identified and analysed in order to achieve energy-saving operation and to create an appropriate design of compressed air systems.

Practical tasks are worked through with the aid of instructions and information.

The **GUNT Media Center** provides a digital learning environment for all steps of the didactic concept. Examples of digital media from the GUNT Media Center are shown throughout this brochure. You will find suggestions for your own tasks and specific ready-made tasks including solutions and examples.

GUNT DigiSkills learning projects

1. Engineering drawing – Technical communication
2. Dimensional metrology
3. Preventive maintenance
4. Energy efficiency in compressed air systems
5. Robotics and automation

1 | Fundamentals
2 | Function
3 | Energy and efficiency

MT141 Assembly exercise: piston compressor

MT142 Energy efficiency in piston compressors

ET500 Two-stage piston compressor

MT175 Energy efficiency in compressed air systems

1 | Compressor fundamentals – Familiarisation with the components

The compressor is the central component of a compressed air system. In it, the mechanical energy supplied is converted into a pressure increase of the air. There are essentially two different methods of generating compressed air: the positive displacement principle and energy transfer via flow forces.

The positive displacement principle describes the air being sucked into a compression chamber and enclosed there. Force is applied, which reduces the volume, thereby compressing the air. Two typical designs are the piston compressor and the screw compressor.

MT 141 Piston compressor

Small compressor

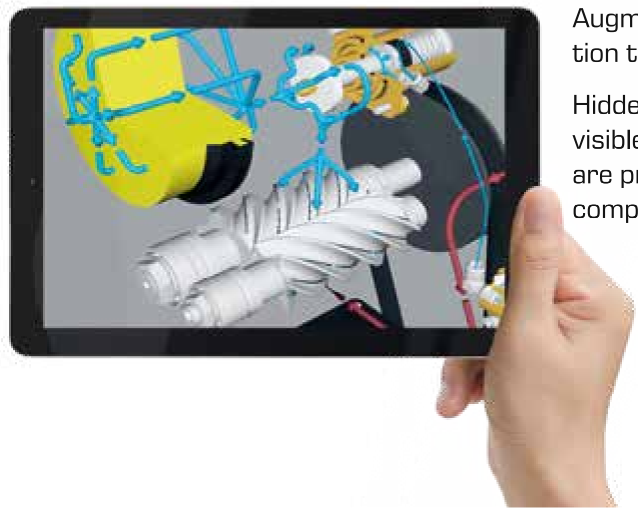
- study components and learn about their interaction
- assembly/disassembly of a small compressor
- recognise functions
- measurement exercises
- familiarisation with materials
- engineering drawing and communication

Experience our example with your smartphone: just scan the QR code and dive right in.

Screw compressor from MT 175

Industrial compressor unit

- familiarisation with areas of application
- examples of typical applications
- familiarisation with the mode of operation



Augmented reality brings the function to life.

Hidden components are made visible, complex functional principles are presented in an appealing and comprehensible manner.

Suggestion for tasks:

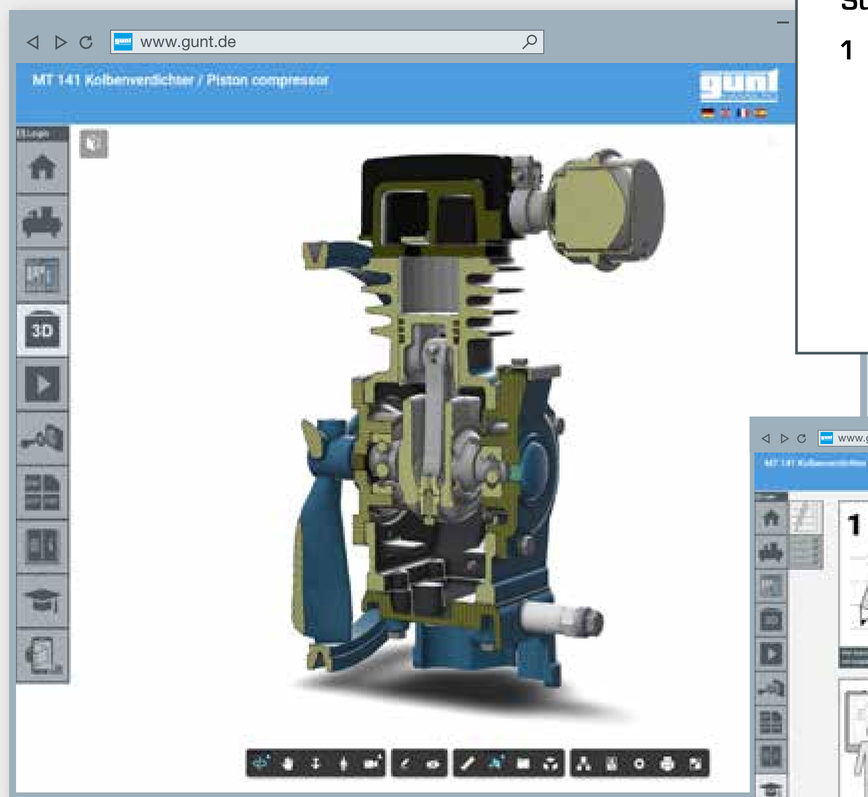
The principles of operation of the two compressors can be analysed with the help of augmented reality.

- compare the two designs: piston compressor – screw compressor
- specify the characteristics of the two different designs and typical applications

Whether assembly or explanatory films, the videos can be played again and again, a repetition that ensures learning success.

Content that is appropriate to needs and context, such as technical data, complete sets of drawings as DXF, STP and PDF files, and parts lists are available in digital form for the MT 141.

Access to all the digital content of your project can be found on GUNT's own web-based platform, the GUNT Media Center.



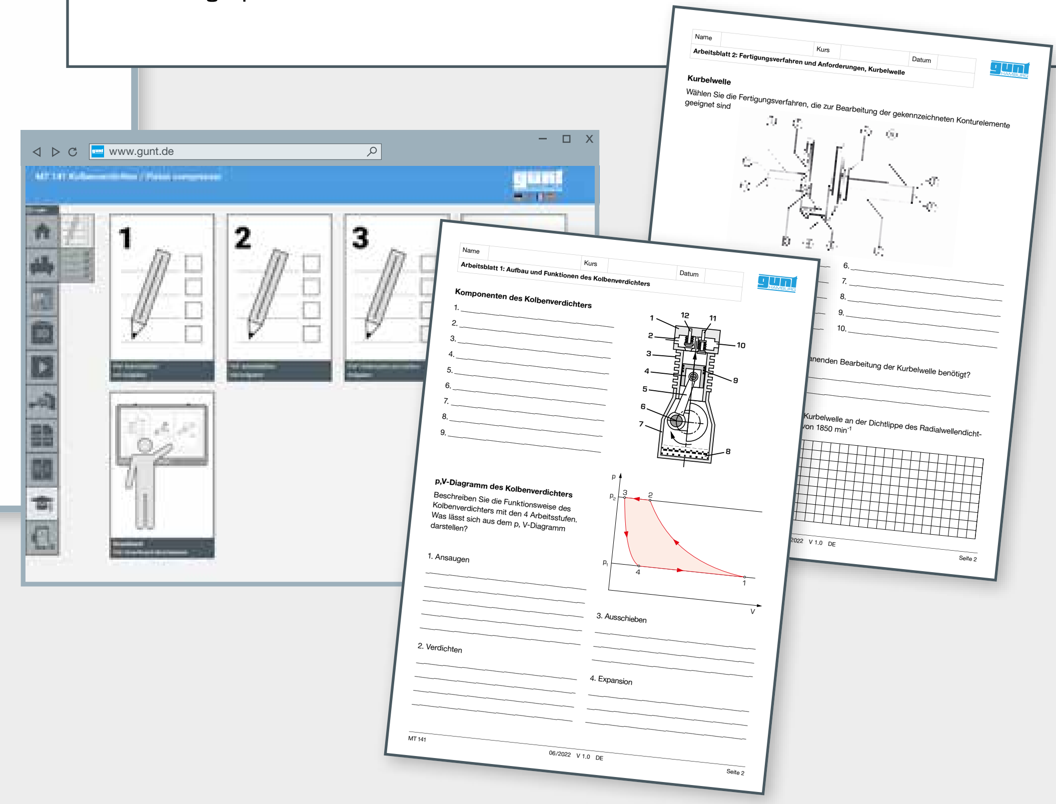
Suggestion for tasks:

1 Use the exploded drawing to create a work plan for disassembling the compressor. Write down the steps and the tools needed in the work plan forms.

What precautions must be taken before disassembling housing halves that hold during operation?

2 Various types of seals are installed in the piston compressor.

Using the parts list and the exploded drawing, write out all the seals present in the piston compressor.



Learning projects with practical relevance for assembly, manufacturing, production, digitally supported with:

- drawings and videos
- assembly instructions
- tasks for practical exercises

The corresponding solutions are available in the GUNT Media Center. Access to the solutions is password-protected, so they are only available to teachers.

GUNT's Media Center turns our basic technology projects into digital projects. Industrial-grade hardware is combined with digital data packages.

- all files directly via an Internet browser: smartphone, tablet or PC
- no other software required
- no licences, full rights of use for your school
- constant updating and expansion of the data, available to you as a customer and absolutely free of charge

Learning projects with practical relevance and digital support

The Media Center is the platform that provides digital data via the Internet for tablets, PCs and smartphones. Customers can access files and product information for selected products at any time and from any place. The data includes:

- Augmented Reality interface
- drawings as CAD, STP or DXF files
- videos with functional principles or assembly
- detailed assembly instructions
- practical exercises

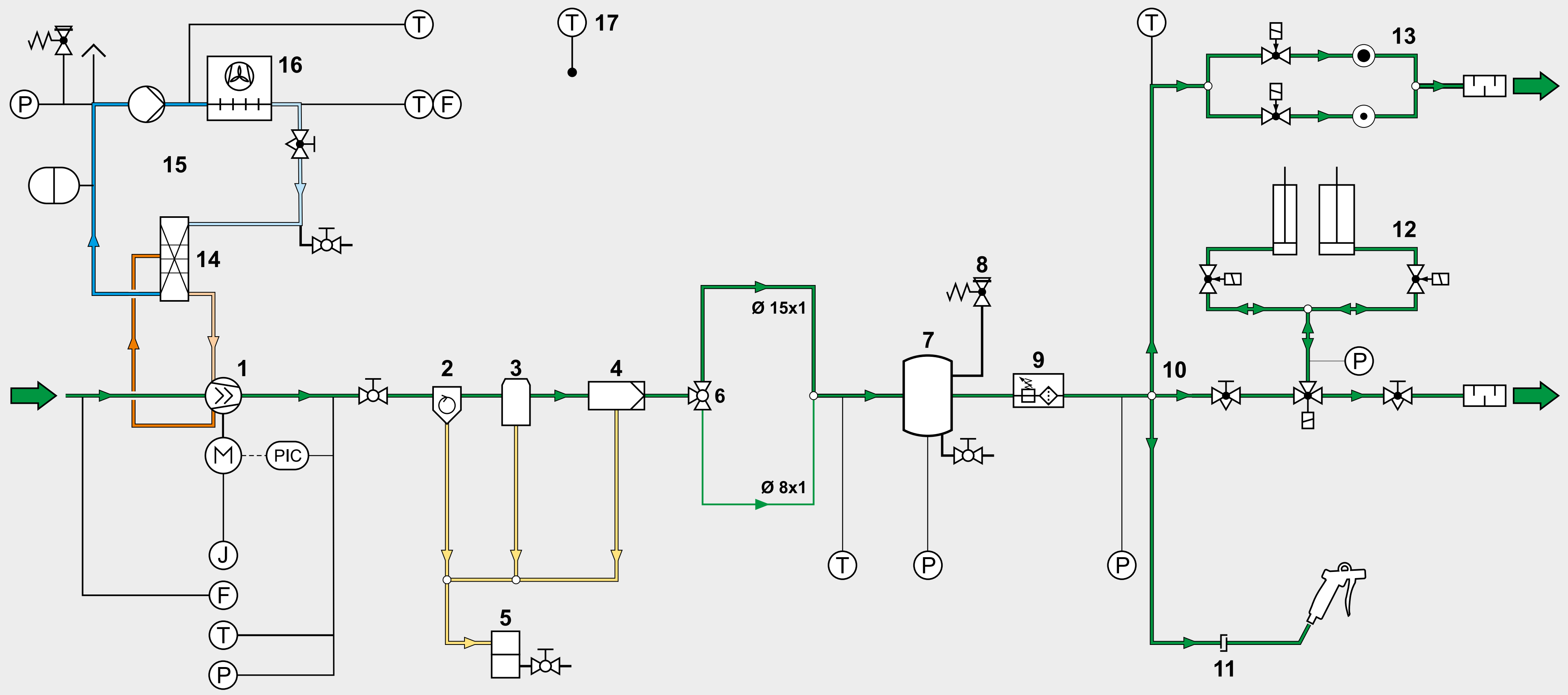
GUNT Media Center

Augmented reality in the classroom

1 | Compressor fundamentals – Familiarisation with the components

1.1 | Familiarisation with the components in the MT 175 compressed air system

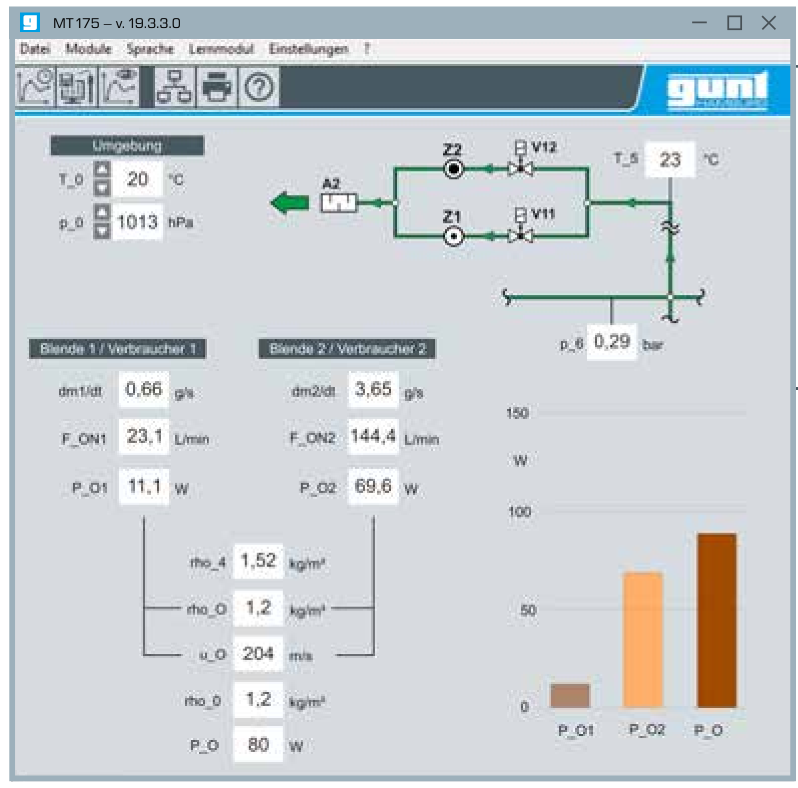
1 compressor unit
2 centrifugal separator
3 refrigerant dryer
4 filter
5 condensate tank
6 selection: large/small pipe
7 compressed air tank
8 safety group
9 maintenance unit
10 compressed air distribution to consumers
11 connection for short-term consumer, e.g. blow-out gun
12 load lifter: two pneumatic cylinders as continuous consumers
13 leakage via orifice plates
14 oil/water heat exchanger
15 water circuit for heat recovery
16 water/air heat exchanger
17 ambient temperature



■ compressed air ■ oil, hot/cold ■ water, hot/cold ■ condensate with oil

P pressure, **T** temperature, **F** volumetric flow rate, **J** electrical power, **PIC** pressure control

Suggestion for tasks



Leaks in the compressed air distribution system

Leaks can be simulated using two different orifice plates.

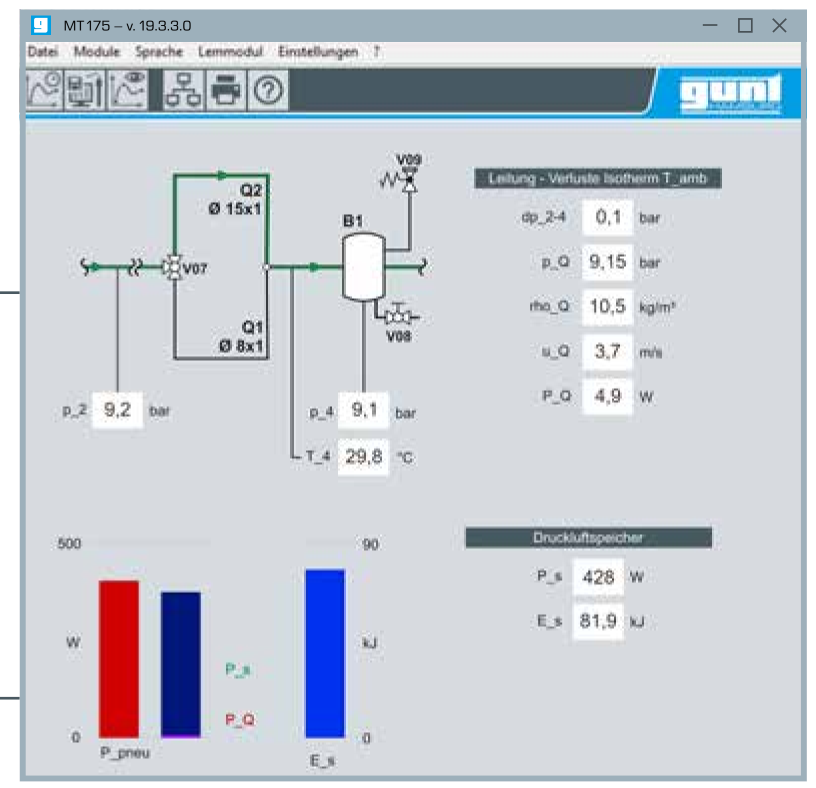
Determine the pressure drop at the consumers. Investigate the power losses. How do the control behaviour and the duty cycle of the compressor affect the power? Measure the time until the final pressure is reached.

Influence of the pipe diameter in the compressed air distribution

The compressed air tank should be filled. Pipes with different diameters are available for compressed air distribution.

Use the pipe with the small diameter and measure the time until the compressed air tank is filled. Carry out the same task, this time using the pipe with the large diameter. Compare the two pipes.

What effect does an undersized pipe have on how the compressed air system works?

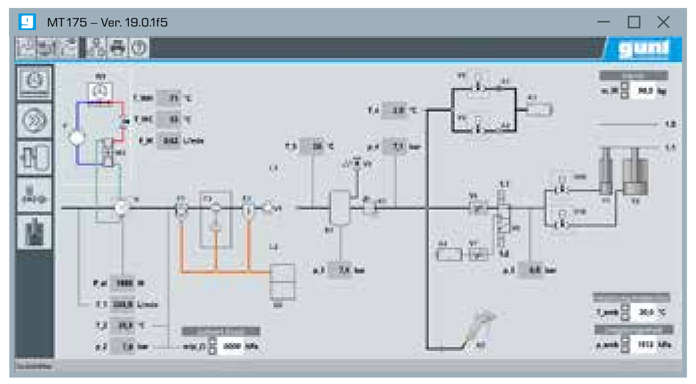


1 | Compressor fundamentals – Familiarisation with the components

1.2 | Functional groups of the MT 175 compressed air system

Students use the MT 175 system to familiarise themselves with all the functional groups of an industrial compressed air generation system: compression, preparation, storage and consumption. Heat generated during compression is efficiently utilised to heat rooms and other spaces. The overall process is analysed from an energy perspective and potential savings are identified.

Pressure, temperature, volumetric flow rate and electrical power are measured at relevant measuring points. The GUNT software uses these to calculate characteristic variables in order to analyse the energy efficiency of the system.



Compressed air distribution

The entire section or the area from the compressor to the consumer:

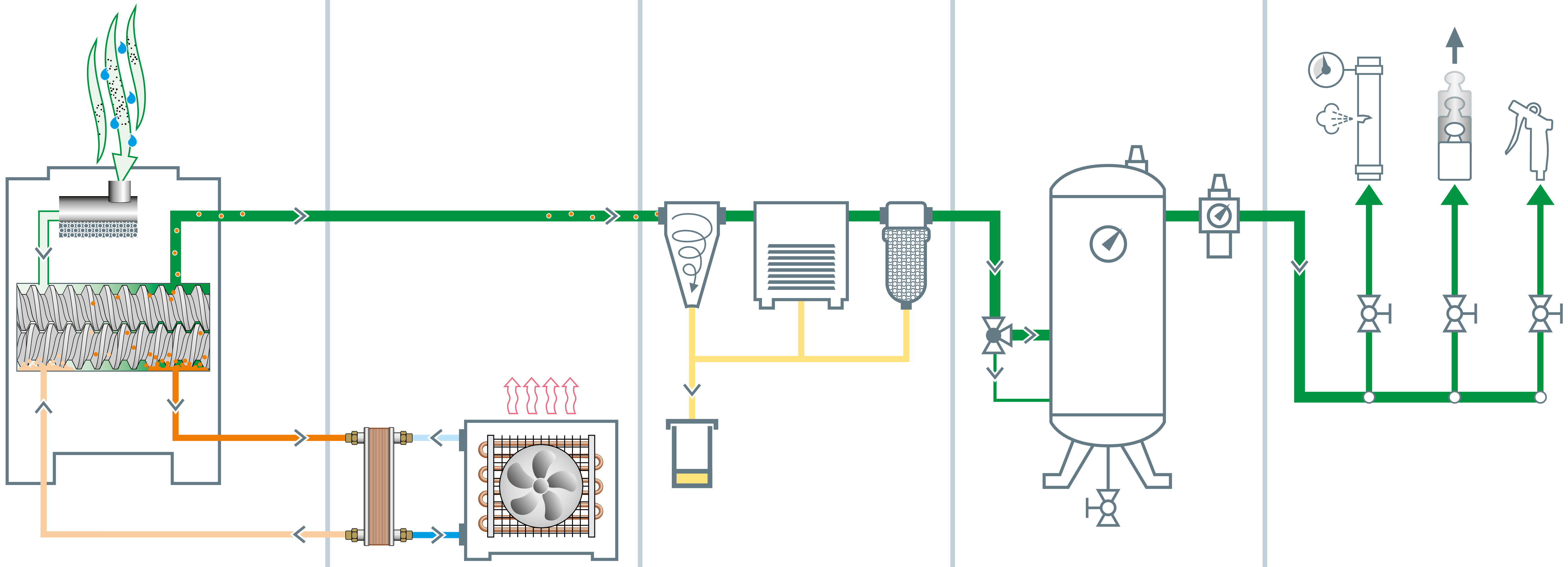
- pipes
- connecting elements
- valves and fittings, etc.

The pressure loss between the compressor and the consumer should be as low as possible.

Learning objectives

- investigate the influence of different pipe diameters
- determine and measure pressure drops
- familiarisation with steps to minimise the pressure drop
- find, learn about and implement potential savings

Compressed air generation | Heat recovery | Compressed air preparation | Compressed air storage | Compressed air consumer



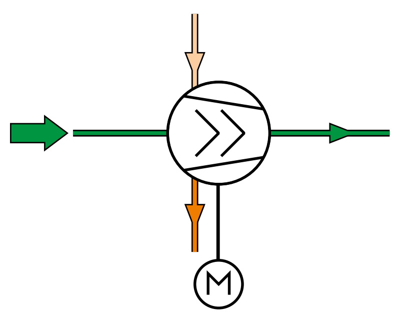
Compressed air generation

The working media considered are air ■, from the intake to the compressor outlet, and oil ■ for cooling the compressor.

- air filter
- screw compressor with oil injection (direct cooling)
- oil separator tank, oil separation, oil cooling, oil filter
- condensate trap

Learning objectives

- determine the suction volume flow
- determine how long it takes to reach the final pressure
- adjust the control behaviour of the compressor
- investigate polytropic compression



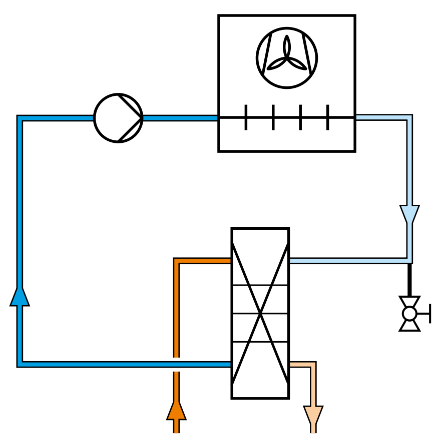
Heat recovery

High temperatures are generated during compression. The heat is dissipated and utilised via oil ■ in the primary cooling circuit and via water ■ in the secondary cooling circuit.

- primary cooling circuit, oil/water
- secondary cooling circuit, water/air
- transport of heated air by means of a fan

Learning objectives

- energy analysis of heat recovery
- calculate usable waste heat
- describe energy flows



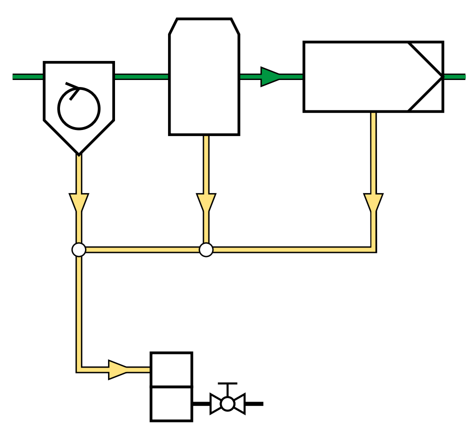
Compressed air preparation

The impurities in the compressed air ■, such as oil, dust and moisture, are removed to the required quality by:

- centrifugal separator, cyclone design
- refrigerant dryer
- compressed air filter
- condensate ■ tank with filter for oil/water separation

Learning objectives

- familiarisation with components: setup, function and effect, compare advantages and disadvantages
- learn to recognise and assess the consequences and damage to pipes and consumers caused by contaminated compressed air
- determine pressure drop via components



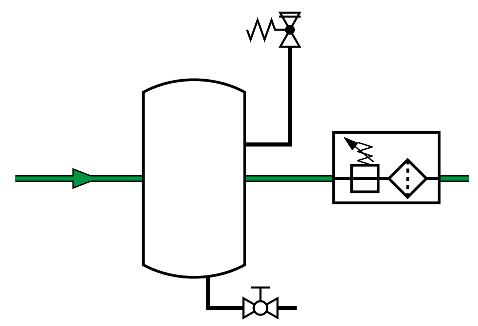
Compressed air storage

Compressed air tanks store the generated compressed air ■ and are also used for pulsation damping and condensate separation.

- compressed air tank with safety valve and manometer
- maintenance unit with pressure controller, manometer and filter

Learning objectives

- theoretical comparison of compressed air consumption with accumulator volume and without accumulator
- familiarisation with the effects when using consumers with high fluctuations
- determine pressure drop via accumulator



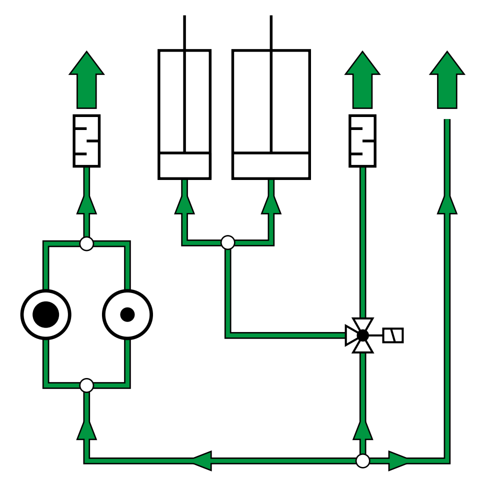
Compressed air consumer

Different consumers can be studied individually or in combination.

- pneumatic cylinders for lifting weights as continuous consumers
- blow-out gun or own compressed air consumers, e.g. pneumatic tools, as short-term consumers
- leaks in pipes as continuous consumers

Learning objectives

- determine compressed air drop for different consumers
- effect of compressor settings on consumption: pressure head, pulsation, etc.
- theoretical comparison of closed circular pipeline/tap line



2 | Functional testing of compressors and compressed air systems

The functional test provides initial indications of potential savings and interactions within the system. The scope of the functional test includes work such as:

- determining pressure losses
- leak test
- measurement of volumetric flow rate, pressures, temperatures
- checking pipes
- testing the pressure switches, pressure reducers and safety valves
- checking for correct installation and adjusting the alignment

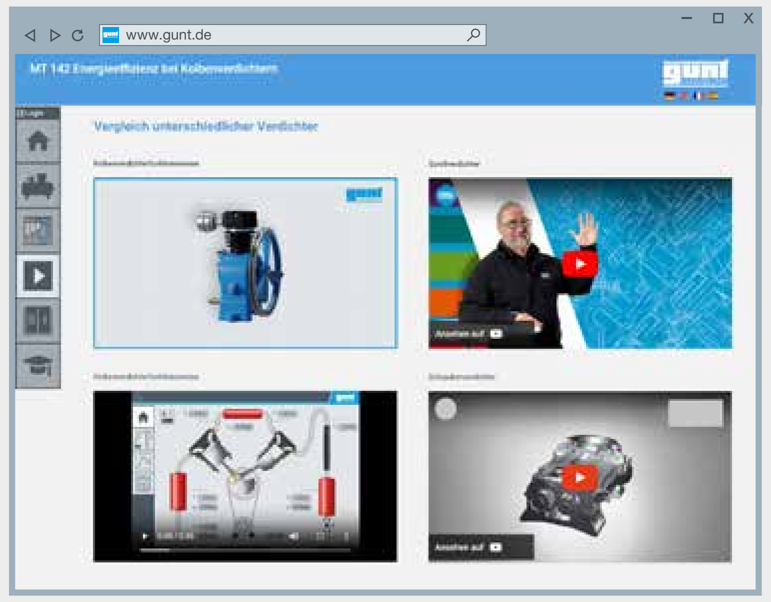
View data sheet

Functional test of a single-stage piston compressor with MT 142

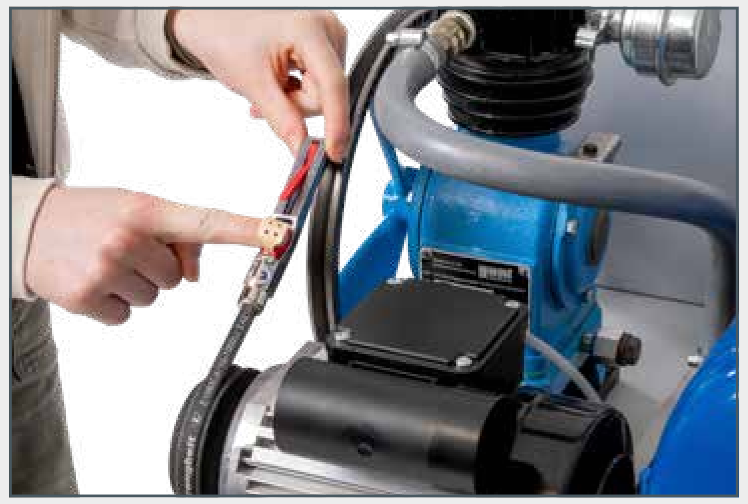
Learning objectives

- familiarisation with the function and testing process
- professional installation of the piston compressor including adjustment and alignment procedures
- function and operation of safety elements: pressure switch, non-return valve, safety valve
- testing and adjusting the belt tension

The MT 142 test stand is operated together with the MT 141 piston compressor



Videos with functional principles and engaging animations on GUNT's own web-based platform, the GUNT Media Center

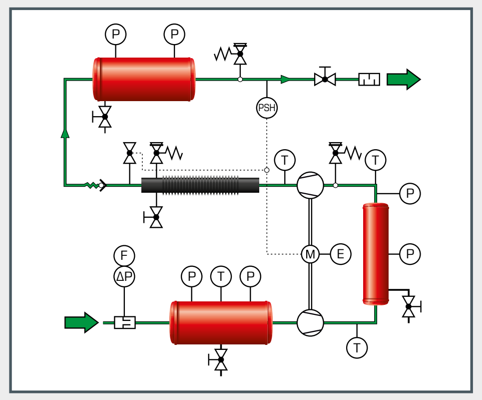


Checking the belt tension

Functional test of a two-stage piston compressor with ET 500

Learning objectives

- setup and function of a two-stage compressor
- measurement of relevant pressures and temperatures
- determine the intake volumetric air flow rate
- compression process on a p-V diagram

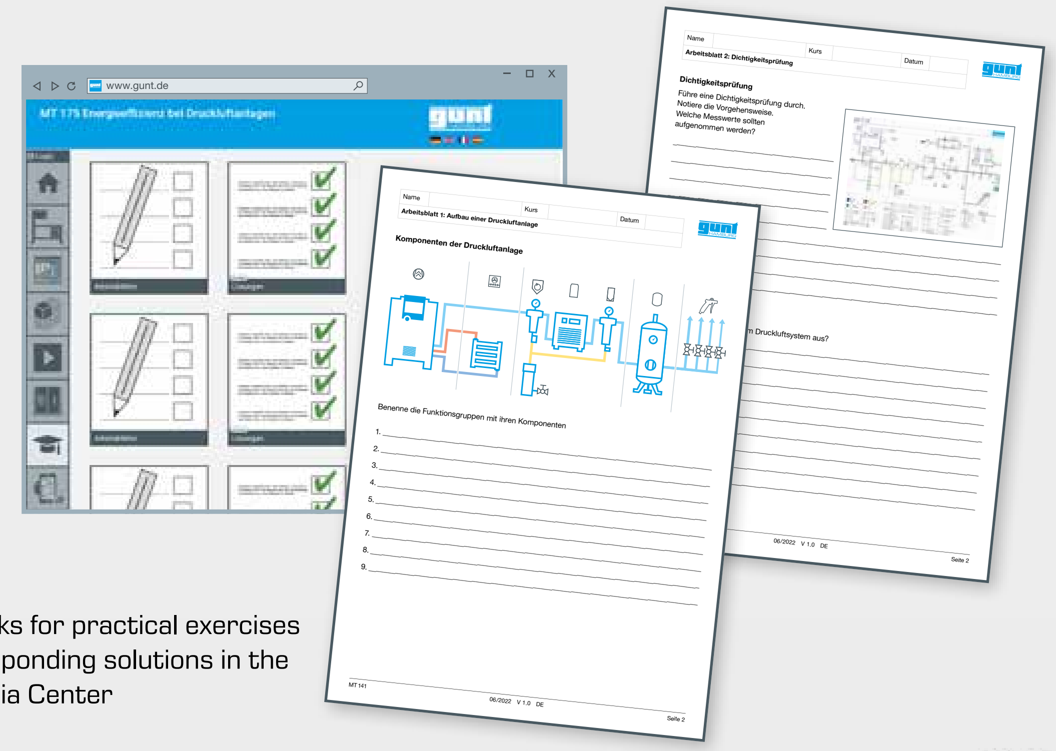


View data sheet

Functional test of a screw compressor in a complete compressed air system in MT 175

Learning objectives

- adjustment options on the screw compressor
- determine how long it takes to reach the final pressure
- adjust the control behaviour of the compressor
- leak test
- measurement of relevant pressures and temperatures
- determine the intake volumetric air flow rate
- oil check using a sight glass
- study continuous and short-term consumers, individually or in combination
- familiarisation with remote monitoring of the compressor unit



View data sheet

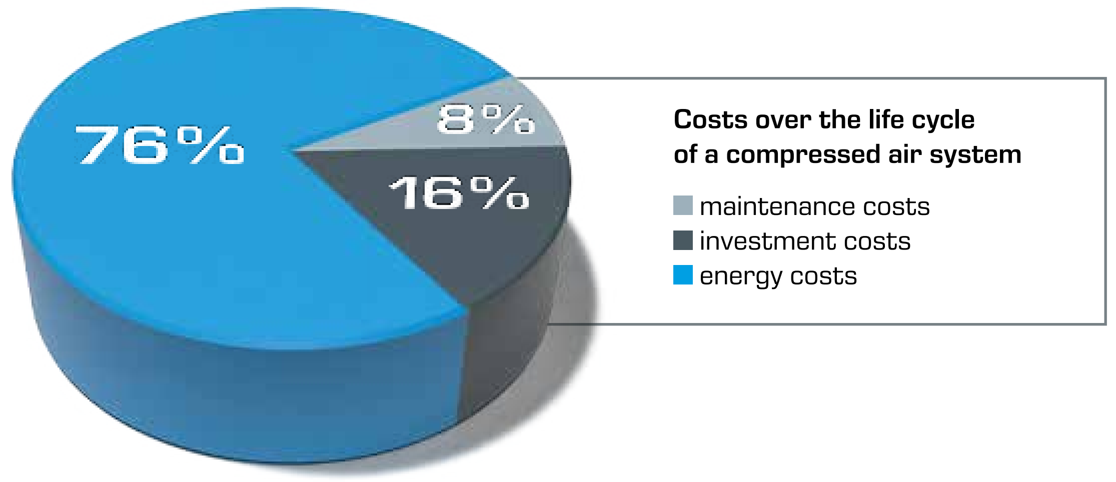
Lots of tasks for practical exercises and corresponding solutions in the GUNT Media Center

3 | Energy analysis

Compressed air is used in a wide range of applications as a clean, safe and versatile source of energy:

- working air: pneumatic applications such as pneumatic cylinders or pneumatic tools
- active air: as a carrier medium and for cleaning
- process air: for drying and cooling
- test air: for inspecting sorting and positioning mechanisms

Easily realizable and usually extremely economical measures can often reduce energy costs by a third.



	Examples with respective savings potential		Devices from GUNT
1	Selection and dimensioning of components	20–50%	MT141, MT142, MT175, ET500
2	Heat recovery	20–50%	MT175
3	Compressed air demand of consumers and applications	20–40%	MT175
4	Pressure head and pressure losses in the network	15%	MT175, ET500
5	Control	20–30%	MT175
6	Leaks	20–30%	MT141, MT142, MT175, ET500
7	Compressed air preparation	2–3%	MT175
8	Maintenance and service: condition monitoring, preventive maintenance	2–5%	
9	Conditions on site: quality of the intake air, installation of the compressor	2–5%	

3.1 | Implementation of energy optimisation

1 Selection and dimensioning of components

Compressed air generation

The design, functionality and features are essential considerations when selecting a compressor. In addition, certain characteristic variables, e.g. delivery quantity or volumetric flow rate and operating pressure, are necessary for dimensioning.

Compressed air distribution

Compressed air is distributed via the pipe network, consisting of pipes, valves and fittings. The selection and dimensioning must take into account:

- diameter
- length
- components with little turbulence in the flow course
- type of distribution: closed circular pipeline/tap line

Compressed air preparation

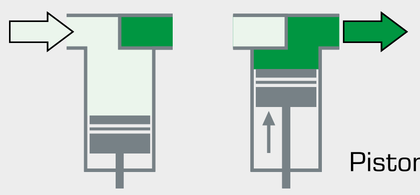
Suitable maintenance units must be selected for the compressed air application, e.g. filters, separators, pressure reducers, etc.

Compressed air storage

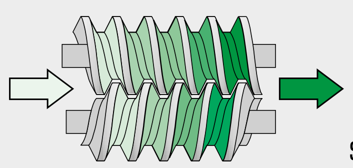
Compressed air tanks are used for compressed air storage, pulsation damping and condensate separation. Their size depends on the delivery volume of the compressor and the consumption.

MT141, MT142, MT175, ET500

With GUNT devices, students are familiarised with the components and learn to assess errors in selection and dimensioning. Two types of compressor can be considered:



Piston compressor



Screw compressor

2 Achieving heat recovery

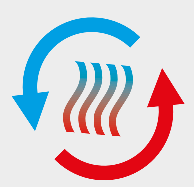
Depending on the design of the compressor, the type of cooling and the operating conditions, there are three options for heat recovery:

Space heating through the use of hot air

Heating water

Domestic water heating

MT 175 is used to investigate the use of hot air for heating rooms.



3 Compressed air demand of consumers and applications

The compressed air consumers are divided into two groups:

- continuous consumers: pneumatic cylinders, continuously running machines and long-lasting work processes
- short-term consumers: paint spray gun and blow-out gun, tools

For a representative determination of demand, the compressed air consumption of the individual devices is added together and the average duty cycle is also determined.

The **MT175** experimental plant is used to analyse and compare the energy consumption of different consumers. A combination of different consumers can be studied.

MT142 and **ET500** can be used to create your tasks on own compressed air consumption.

Blow-out gun as short-term consumer

Pneumatic cylinder as a continuous consumer

4 Pressure head and pressure losses in the network

The switch-off pressure of the compressor is composed of the required pressure of the applications, the pressure losses in preparation and in the pipes, as well as the differential gap. Energy efficiency measures include:

- determine the necessary pressure level and do not exceed it
- install a larger compressed air tank as a buffer if demand fluctuates heavily
- minimise pressure losses

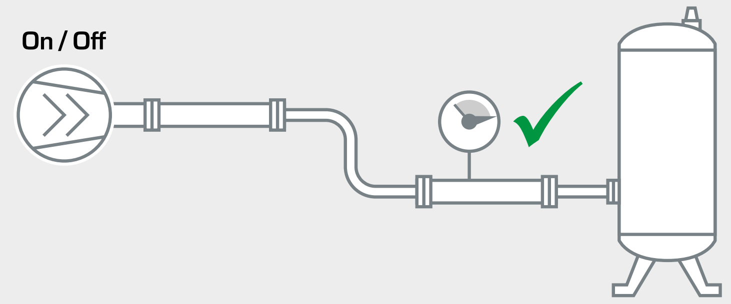
With **MT175**, the pressure level required for the respective consumer can be investigated and optimised. The maximum switch-off pressure of the compressor can be adjusted. The cycle times can be specified and the effect on energy consumption and benefits can be analysed.

With **ET500** and **MT142**, the switch-on pressure can be set on the high-pressure switch; the switch-on times are determined by the control system.

5 Control

Controlling compressors allows compressed air production to be adapted to current consumption. The following must be taken into account in order to limit the cycle times and to be able to set the stopping times optimally:

- determine and optimise the size of the compressed air tank
- adjust the size of the cycle difference
- only switch on the compressor when compressed air is being used, check the necessity of a pressurisation system



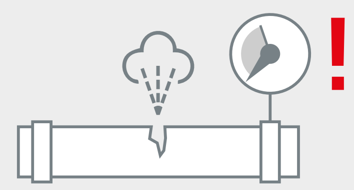
6 Leaks

The cause of leaks is often:

- incorrectly tightened or defective pipe components, pressure controllers or maintenance units
- loose screw and flange connections, hoses, fittings
- corroded pipes due to excessive residual moisture in the system
- internal leaks in the compressor
- inefficient couplings that pass on the compressed air

MT175 can be used to analyse the effect of leaks on consumers from an energy perspective.

With **ET500** and **MT142**, the effects of leaks are measured directly as pressure loss and thus in energy consumption.

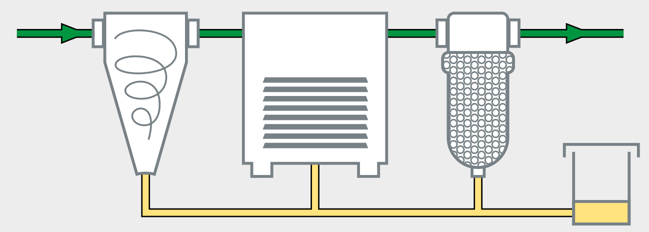


7 Compressed air preparation

Compressed air always contains impurities. However, preparation should only be carried out to the required quality in order to remain efficient.

- determine the required compressed air quality: residual oil content, residual moisture, residual dust, sterility
- select components with the appropriate performance

In **MT175**, the compressed air is preparated with a centrifugal separator, a dryer and compressed air filters. A maintenance unit is located behind the compressed air tank.



3 | Energy analysis

3.2 | Energy optimisation and efficiencies

MT 142 Energy efficiency with a single-stage piston compressor, max. pressure 10 bar

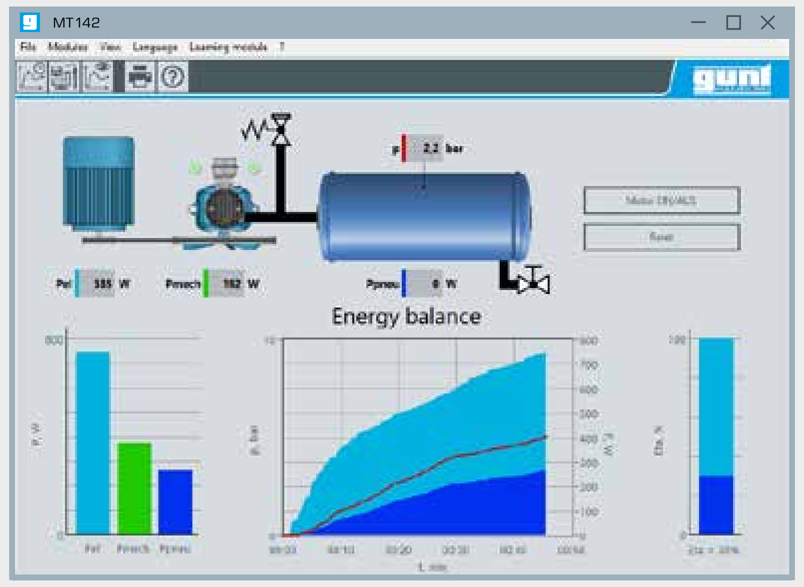
The GUNT software allows you to create an energy balance. The electrical power, mechanical power and pneumatic power are recorded over time while the device is running. The efficiency is then calculated from the energy absorbed.

Suggestion for tasks:

Assume that the compressed air tank has a volume of 10 litres and a positive pressure of 8 bar.

- How much energy is in the compressed air tank?
- What units is this specified in?

First note the basic equation before calculating with values.

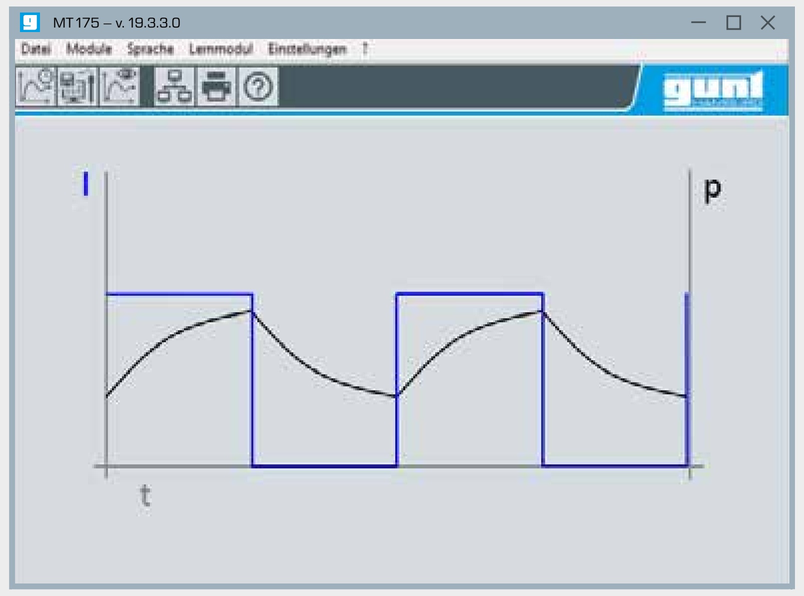


Energy balance

MT 175 Energy efficiency in a compressed air system with screw compressor, max. pressure 10 bar

Pressure, temperature, volumetric flow rate and electrical power are measured. The GUNT software provided uses these to calculate characteristic variables in order to analyse the energy efficiency of the system.

The energy flows within the compressed air system are analysed. The efficiency of the compressed air system is studied.



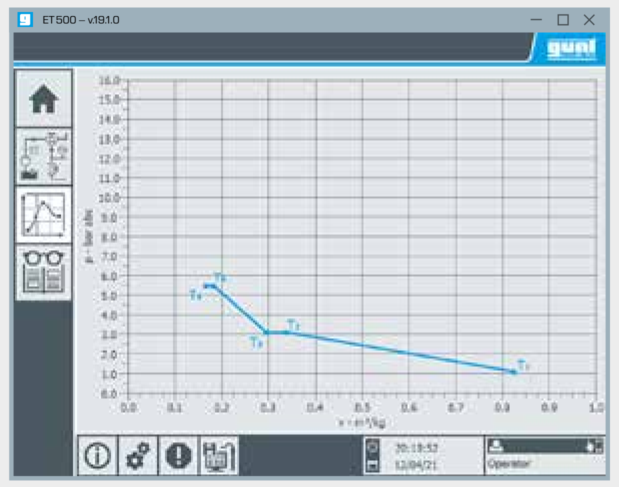
An example of the time curve for pressure and current at the compressor

ET 500 Determination of efficiency with two-stage piston compressor, pressure 12 bar

The ET 500 trainer operates as a two-stage compressed air system with oil-lubricated piston compressors. The operating pressure is 12 bar.

Sensors record the pressures and temperatures in both stages as well as the electrical power consumption. The intake volume flow is determined by a nozzle on the intake vessel.

The efficiency can be calculated from the measured values and the known performance data.



Compression process in the p-V diagram

Isothermal efficiency

The **isothermal power P_{isoth}** of the compressor (where p_{LP} = 1 bar) is:

$$P_{isoth} = p_{LP} \cdot \dot{V} \cdot ln\left(\frac{p_{HP}}{p_{LP}}\right)$$

P_{isoth} isothermal power of the compressor
p_{LP} intake pressure (absolute pressure)
p_{HP} delivery pressure (absolute pressure)
$\dot{V}$ volumetric flow rate

If the **electrical power consumption P_{el}** and P_{isoth} are known, the **isothermal efficiency η_{isoth}** of the compressor can be calculated

$$\eta_{isoth} = \frac{P_{isoth}}{P_{el}}$$

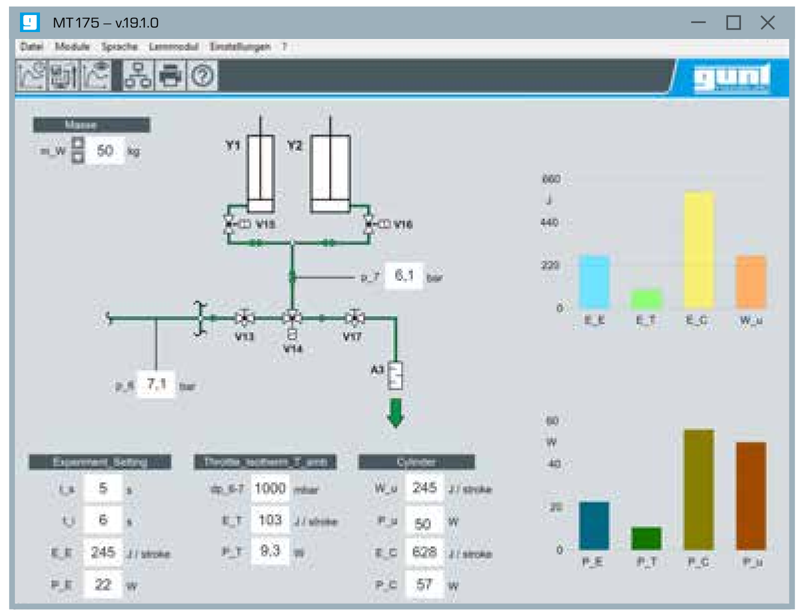
Suggestion for tasks to energy efficiency with the MT 175 compressed air system

The compressed air is drawn by different consumers. The first consumer represents leaks and contains two different orifice plates, through which the compressed air is blown out. A blow-out gun or a separate pneumatic tool of your choice is used as a second compressed air consumer. In the third consumer – the load lifter – weights are raised and lowered by means of two pneumatic cylinders.

Tasks for consumers

1 The continuously running pneumatic cylinders simulate continuous consumers. The pneumatic cylinders can be used individually or in parallel.

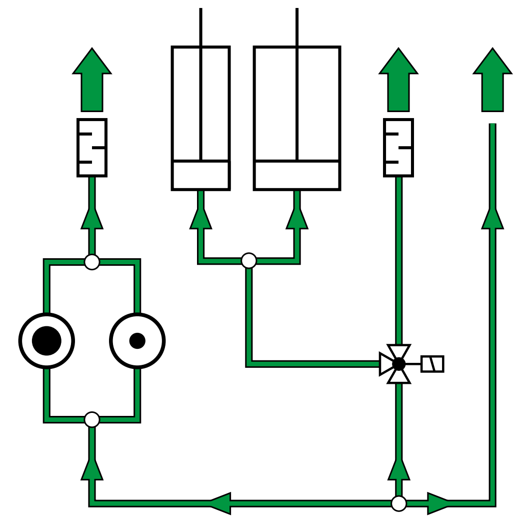
Investigate the power loss during operation with one pneumatic cylinder and then operation with both pneumatic cylinders.



2 All the different consumers can be combined and compared with each other.

Combination of pneumatic cylinder – leakage – blow-out gun

- implementation of a large continuous consumer
- investigation of leaks
- loss of pipe pressure when the blow-out gun is actuated and the effects
- control behaviour of the compressor



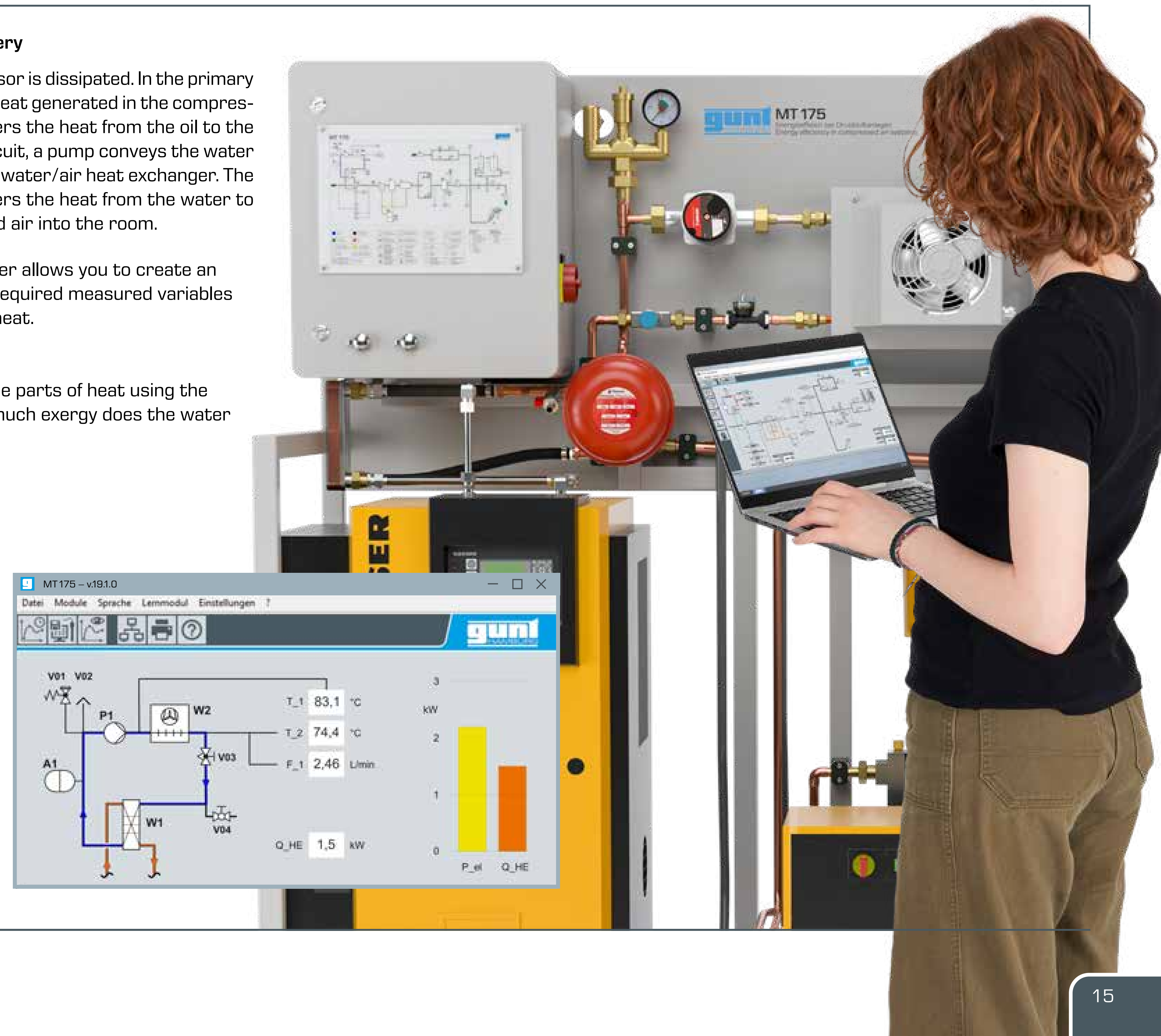
Task for investigating heat recovery

The heat generated in the compressor is dissipated. In the primary cooling circuit, the oil absorbs the heat generated in the compressor. A plate heat exchanger transfers the heat from the oil to the water. In the secondary cooling circuit, a pump conveys the water from the plate heat exchanger to a water/air heat exchanger. The finned tube heat exchanger transfers the heat from the water to the air. A fan transports the heated air into the room.

1 This arrangement of heat transfer allows you to create an energy balance. Determine the required measured variables and calculate the usable waste heat.

2 Describe the energy flow.

3 Describe the usable and unusable parts of heat using the terms exergy and energy. How much exergy does the water transport in the flow pipe?



Summary of further DigiSkills learning projects

DigiSkills learning project no.	Subject area	Learning objective areas/ Features		Focus
1	**Engineering drawing – Technical communication**		■ fundamentals of engineering drawing ■ geometric models, functional models ■ Geometrical Product Specifications (GPS) ■ constructive thinking, machine elements, materials	**Metalworking professions**
2	**Dimensional metrology**		■ fundamentals of inspection technology: testing, measuring, gauging ■ familiarisation with measuring instruments ■ Geometrical Product Specifications (GPS) ■ surface marking, fit systems	**Metalworking professions**
3	**Preventive maintenance**		■ design and function of a sorting plant ■ predictive maintenance, condition monitoring ■ assembly and disassembly, functional testing, commissioning ■ machine elements, materials	**Mechatronics, Metalworking and electrical professions**
4	**Energy efficiency in compressed air systems**		■ design and function of a compressed air system ■ assembly and functional testing of compressed air generators ■ systematic optimisation of modern compressed air systems ■ representation of energy flows	**Mechatronics, Metalworking and electrical professions**
5	**Robotics and automation**		■ robot programming, process automation ■ mechanics, hydraulics, pneumatics, electrics ■ control system, PLC ■ sensors and actuators ■ system integration ■ process integration	**Mechatronics, Metalworking and electrical professions**

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