OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

05289

Distr.
LIMITED

ID/WG.163/27
16 January 1974

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Seminar on the Furniture Industry
Lahti, Finland 6-25 August 1973

LOW-COST AUTOMATION 1/

by

Osmo Moilanen
Lahti Technical Institute
Lahti, Finland

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

I Definition

Manual work is the first stage of production. Various manually operated tools can be used in it.

Machinization means the use of such tools in which the major part of the work is performed by a machine.

Mechanization is the first stage of further development of production, in which the worker's simple motions are replaced by machines.

Automation is a more advanced stage of production, in which a large number of the worker's motions are replaced by special equipment and components.

Low cost automation involves mechanization and automation. One can also of a "degree of automation", in which case mechanization means a low degree of automation.

An impulse means the initial signal, order, control of operation and actual starts the operation.

Feed-back system is used to evaluate the result, and the resulting value corrects the control of the machine if required.

II Significance of Automation

The main consideration is human and economical: a human being should not be used as a machine in simple, heavy or fast work because machines perform more economically in these respects.

Several advantages are obtained because:

- the work becomes lighter
- the precision of the work is improved
- the quality of the work is improved
- the machines last longer
- the tools last longer
- the speed of the work increases
- the monotony of the work decreases
- the work motivation is increased

Many of these advantages are obtained even at a low level of automation. It is particularly important to realise that automation does not only mean advanced, sophisticated and expensive systems, but frequently several advantages are obtained even with very simple means.

A machine is tireless and therefore can operate with great precision beyond the point at which human beings tire.

III Means of Automation

Mechanical devices are some of the oldest means of automation. For example in steam engines the control of speed with centrifugal force has long been used, as have moving levers. Because of their cumbersome and wearing nature, large size and several other reasons, their use is continuously decreasing.

Electric devices have been used ever since electricity was invented and their use is still increasing, particularly where advanced automation is concerned.

Electronics has made the automating of even demanding systems possible.

Pneumatic devices are inexpensive means at the low and central level of automation and are now very popular in industry. This series of lectures will concentrate almost solely on pneumatics.

Hydraulic devices operate on the same principle as pneumatic devices, except that the fluid allows high pressures so that large powers are obtained with small devices. The fact that the fluid cannot become compact results in precise motions. This quality is often of great importance in working and machining.

IV Pneumatics

Why Compressed Air?

Compressed air is frequently used in automation for, among others, the following reasons:

- compressed air is a simple way to obtain both a rotating and a linear movement
- speed control is simple
- use of air involves no danger
- air can stand high temperatures
- air is compatible with all chemicals and humidity
- leaks are neither harmful nor dangerous
- the devices are simple, often inexpensive, and it is possible to make them oneself
- the principle of operation is not difficult to comprehend
- it does not continuously require the use of expensive, specialised and often difficult to find workers
- the power needed in automation is sufficient
- compressed air is elastic and, therefore, does not easily break the devices
- it can be used in both demanding and simple jobs.

V Producing Compressed Air

A. Compressors

A compressor is a device which compresses air to a desired pressure.

In small compressors the compression is performed in one stage. In medium-sized compressors - the type generally used in industry - the air is compressed in two stages with a cooling stage between to obtain greater efficiency.

The most commonly used pressure varies from 6-10 bar.[1/]

The temperature of the air rises up to approximately 200°C. in one-stage compression and up to approximately 100°C. in two-stage compression.

During compression the humidity in the air is also compressed which, when cooled, is condensed to water. This causes a great deal of trouble and, therefore, it is necessary to aim at continuous removal of water from the compressed air network.

In a warm climate with high humidity in the air there is a tendency for excessive water to be developed in compressed air. The water causes operational disturbances, corrosion and wear.

1/ One normal atmosphere = 1.013,250 bars

1. Piston Compressors

The piston draws the air into the cylinder and compresses it to the desired pressure. The inlet and outlet of air is controlled by valves.

A piston compressor is the most common type. Its efficiency is good and high pressures - even up to 1,000 bar - can be obtained with it. Because of the back and forth motion the machine vibrates, and partly for this reason it has lost some of its popularity during the past few years.

2. Vane Compressors

Vane compressors are provided with a rotor with eccentric bearings. The rotor has slots in which the vanes can move freely. The volume of air between the vanes changes, and thus the air can be compressed. Efficiency is satisfactory, but the machine is vibrationless and has become increasingly popular.

A pressure of approximately 10 bar can be obtained with this machine.

3. Screw Compressors

The screw compressor is the newest type of compressor and is still relatively little used. In it the air is compressed between two screws. The machine is vibrationless and produces air without pulsation.

The pressure is approximately 10 bar. It can be used only in medium-sized and large compressors, preferably over $2 m^3/min$.

B. Pneumatic Centre

Location:
- in the centre of consumption
- supply of clean air
- easy maintenance and service
- a sufficiently spacious place

Erection: For piston compressors on the ground, for others no special requirements

Air Intake:
- from a dust-free place
- must be protected from rain and dust particles

Filtering: Intaken air is filtered before its arrival in the compressor

Cooling of Air:
- for water removal
- air or water cooling

Air Receivers:
- pressure resistant steel receiver
- volume approximately 1/5 of the production of the compressor per minute
- location preferably in a shady place outside

Air Drying:
- very dry air if required
- for low pressure automatics
- for instrumentation

Oil Filter: If excessive oils are used in the compressor

Water Trap: To ensure that only the minimum amount of water gets into the pipe system

VI Pipe System

Form

Linear form is suitable only in very small use when the main line is short.

Ring is the most common form and should be used. Large systems can be divided into several rings.

Dimensions

Exact dimensioning is difficult and therefore diagrams based on experience are used.

Manufacturing is done welding to steel pipes and brazing to copper pipes.

Installation should be on an inclined surface, approximately 1 : 100 in the air intake direction so that the water can be removed.

For **water removal** water traps spaced 30-50 m from each other are recommended.

Air Intake from Pipe System

- The air in the device must be dry and clean and it should contain some oil in order to prevent wearing of the devices.
- In the pipe system there is always humidity and dirt particles to cause corrosion.
- Therefore the following instructions must be observed in the air intake:
  - The air is taken from the top, when necessary using a water trap.
  - The air is taken through a so-called maintenance unit.

Maintenance Unit

It usually consists of 4 parts:

1. Filter which is frequently a sintered filter to clean the air.
2. Pressure reducing valve which reduces the higher network pressure to operation pressure.
3. Pressure guage for pressure control.
4. Lubricator which mixes a small amount of oil with the air.

VII Cylinders

Cylinders are the muscles of automatics which perform the work.

A. Construction

Ends - aluminium or brass
- without cushion
- with cushion

Cover - aluminium, copper or brass

Piston - seal, piston rod

Size - ⌀ = 25-300 mm 500 mm
- l = 25-400 mm 4000 mm

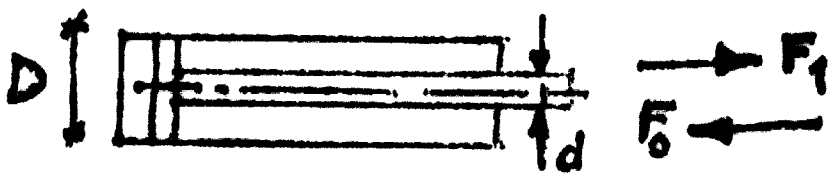
B. Operation

Single-acting - in which the air operates in one direction only Return stroke e.g. by a return spring.

Double-acting - in which the air operates in both directions. The most common cylinder type.

C. Dimensioning

The power obtained with a cylinder can be calculated from the following equations:



$$F_1 \approx 0.8 * 3.14 * D^2 * p/4$$

$$F_0 \approx 0.8 * 3.14 * (D^2 - d^2) * p/4$$

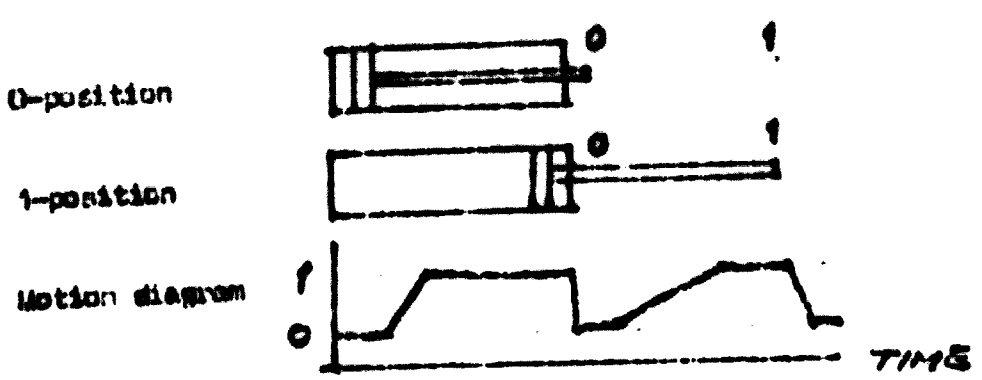
D. Use of Air

The cylinder uses air from the network.

$$V = k * n * A * s * p/p_0$$

k = 1 (single-acting cylinder)
k = 2 (double-acting cylinder)
n = number of strokes per minute
A = cylinder area, $A = 3.14 * D^2/4$
s = length of stroke
p = network pressure
p_0 = pressure of the outside air $\approx$ 1 bar

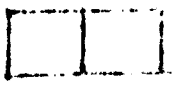
E. Positions

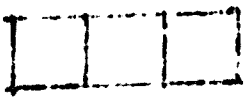


II Valves

The valves guide and control the motion of the air

Directional control valves

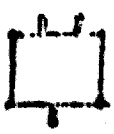
Positions: 2 positions 

3 positions 

Flow paths: open 

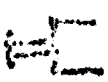
closed 

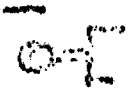
Connections: 2 parts 

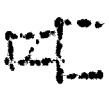
3 parts 

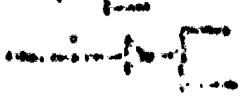
5 parts 

Designations: number of parts/number of positions
e.g. 2/2, 3/2, 5/2, 5/3

Control: Manual control 

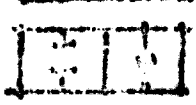
Mechanical control 

Electrical control 

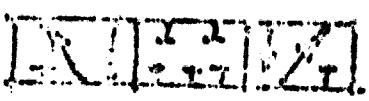
Pneumatic contro 

Types:

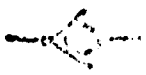
2/2 

3/2 

5/2 

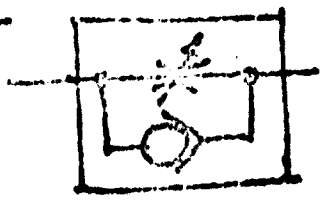
5/3 

Dimensioning according to the instructions of the distributor.

Check valves 

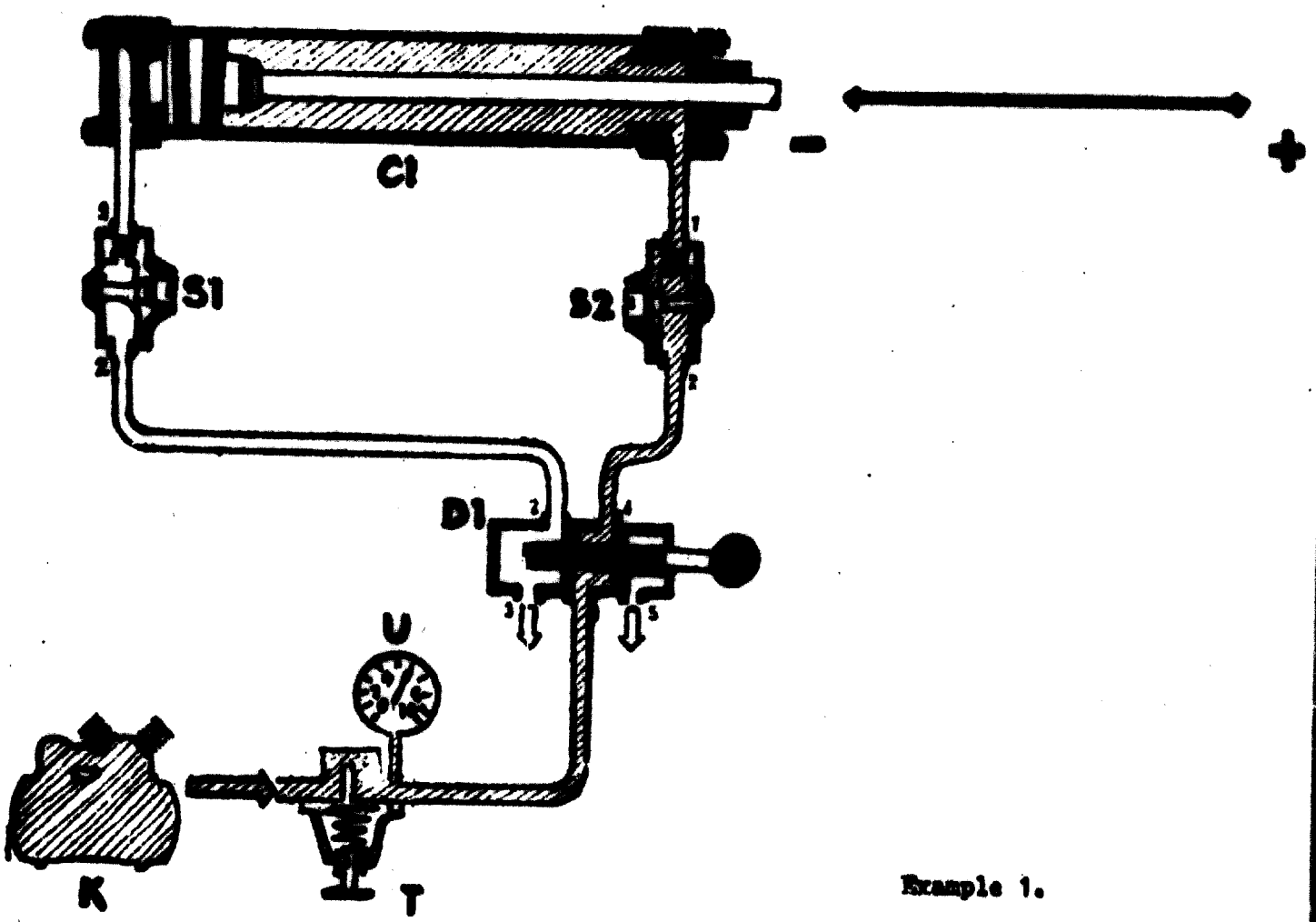
Shuttle valves 

Flow control valves 

One way restrictors 

IX Examples

Seven examples of basic pneumatic circuits are shown in the following pages, along with detailed descriptions of their operations.



Example 1.

Example 1.

Components:

C 1	Double acting cylinder, with cushion at both ends
D 1	5/2-Valve, manual control, bistable function (5/2-Valve = 5 ports/2 position-Valve)
S1, S2	One-way throttle valve
T	Pressure regulator
U	Pressure gauge
K	Compressor

Function:

This example intends to show the three basic methods of controlling a pneumatic cylinder, namely:

1. The direction of the piston movement which is done by the directional control valve D1.
2. The piston speed by means of the flow control one-way throttle valves S1 and S2.
3. The piston force, which is adjusted with the pressure control valve T.

From the compressor K compressed air is obtained, the pressure of which usually oscillates around 7 bar (bar = kgf or kp/cm^2). The pressure regulator T is set on a working pressure suitable for the cylinder, e.g. 6 bar is read on the pressure gauge U.

In the initial position thus the cylinder has a pressure of 6 bar on the piston rod end, i.e. the minus chamber.
When the slide is in the valve D1 is switched over, connexion between inlet and outlet 2, but also between outlet 4 and exhaust 5 is obtained. The plus chamber of the cylinder C1 is thereby pressurised, simultaneously as the compressed air in the minus chamber is evacuated to the atmosphere, with a flow which is determined by the one-way throttle valve S2. The piston and the piston rod in the cylinder C1 moves now in the plus direction with a speed likewise determined by S2. When the slide in the valve D1 is reset to its initial position, connexion between inlet 1 and outlet 4, but also between outlet 2 and exhaust 3 is obtained, whereby the piston in cylinder C1 moves in the minus-direction with a speed that is governed by the one-way throttle valve S1.

The piston speed in a cylinder is actually governed by the following three factors:

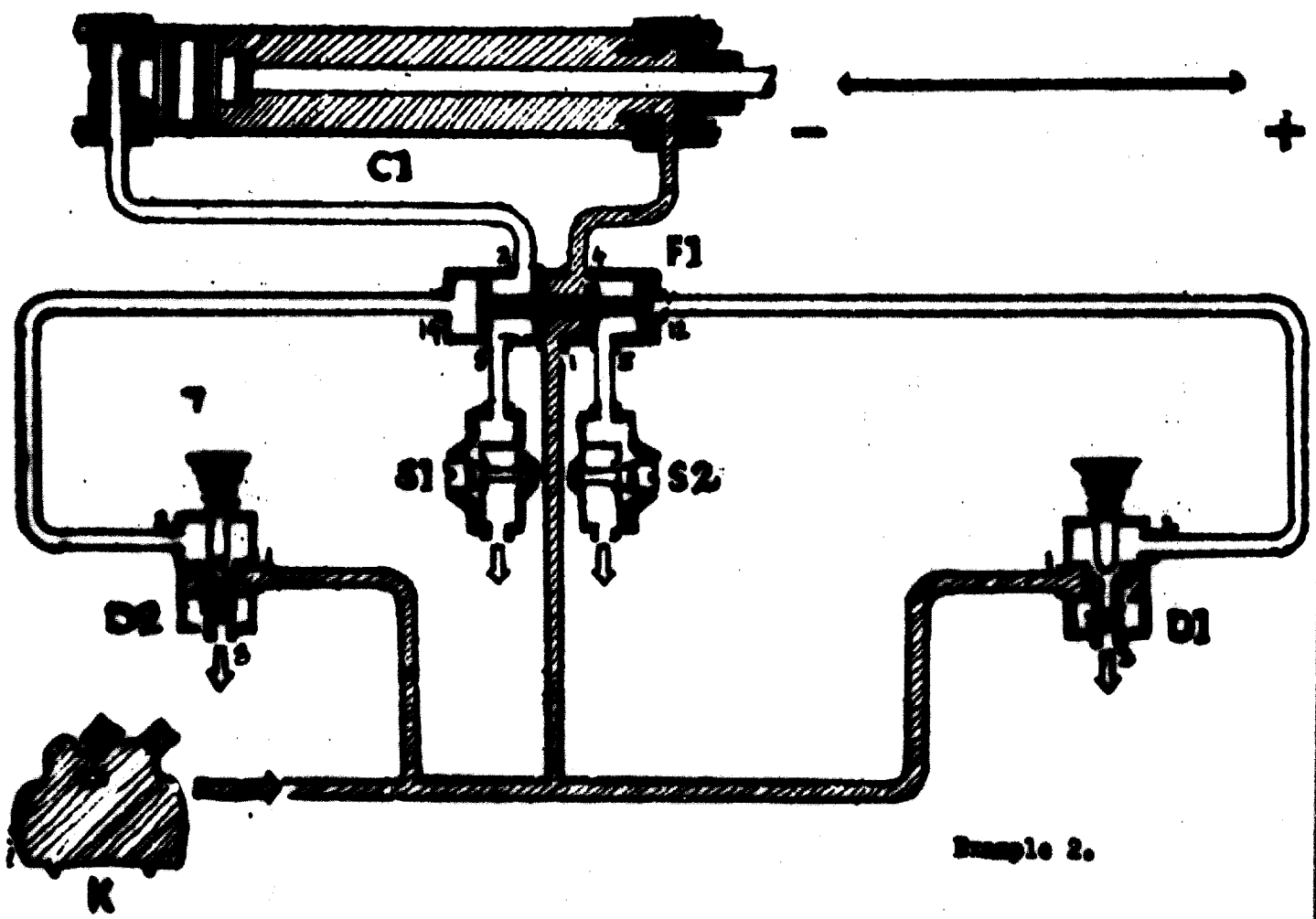
1. The motive pressure, i.e. the pressure which moves the piston forward. The motive pressure is governed partly by the pressure regulator T, and partly by the dimention of the valves and the piping. The motive pressure is always lower that the static pressure which is read on the gauge U when the piston is resting in one end position. This pressure difference is also defined pressure drop and is a condition for fluid power transmission.

2. The back pressure, i.e. the pressure in front of the piston and which is governed by the throttling of the exhaust air, in this case by means of one-way throttle valves S1 and S2. The built-in non-return valve in these valves, are to give free flow in the opposite direction. The motive pressure can thus flow into the cylinder unrestricted.

3. The load, i.e. the actual work the cylinder has to do, plus friction losses in the guidings and seals.

Most double-acting cylinders are provided with built-in cushioning in their end positions, which means that the piston speed is effectively damped immediately before its end position and thus decreasing its impact to the end cover of the cylinder. The cushioning effect is usally adjustable from the outside.

The directional control valve D1 can alternately be provided with spring return and has in such case a monostable function. Besides the valve can have various control devices, manual or mechanical, such as handle, foot pedal, plunger, roller lever etc.



Example 2.

Example 2:

Components:

C1	Double acting cylinder
D1, D2	3/2-valve, push button control, monostable
F1	5/2-valve, pneumatic control, bistable
S1, S2	Throttle valves

Function:

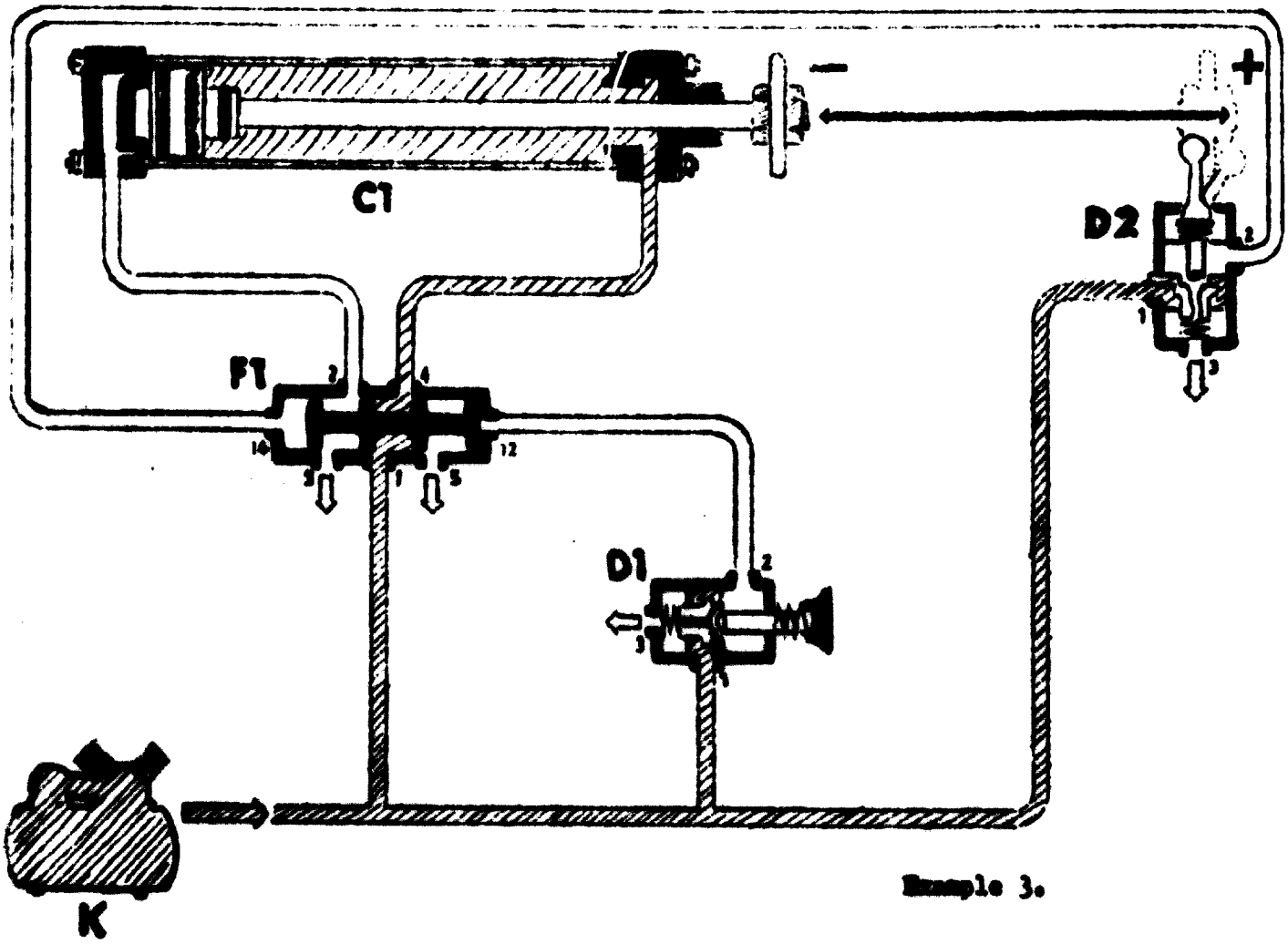
In the initial position the valves D1, D2 and F1 have air supply to their inlet ports. As there is a connexion between inlet 1 and outlet 4 through the valve F1, the cylinder C1 has its minus-chamber pressurised.

If the valve D1 is actuated, a connexion between port 1 and 2 is obtained and the control port 12 of F1 is pressurised and the valve slide is switched over. Thereby connexion between inlet 1 and outlet 2, as well as between outlet 4 and exhaust 5 is obtained. The piston in the cylinder C1 moves in plus-direction with a speed which is controlled by the throttle valve S2.

As soon as the slide in F1 has changed over, the valve D1 can be released and the control air between F1 and D1 is evacuated through exhaust port 3 at valve D1. As the valve F1 is bistable, the slide maintains in its new position and the piston in C1 carries on to its plus position and stops there. When the valve D2 is actuated, the slide in the valve F1 is reset and the piston in the cylinder C1 returns to its minus position with a speed controlled by the throttle valve S1.

In order to be able to reset the slide in the valve F1 with a control signal from D2, the valve D1 has to be unactuated simultaneously, otherwise the signal from D1 will be blocking the switching of the slide. The same is of course valid reverse when the slide in F1 is to be changed over by a signal from D1, the valve D2 has to be unactuated.

The piston speed is here controlled by means of throttle valves fitted into the exhaust ports of the main valve F1. To be able to adjust the piston speed individually in both motion directions, the main valve has to be equipped with two exhaust ports.



Example 3.

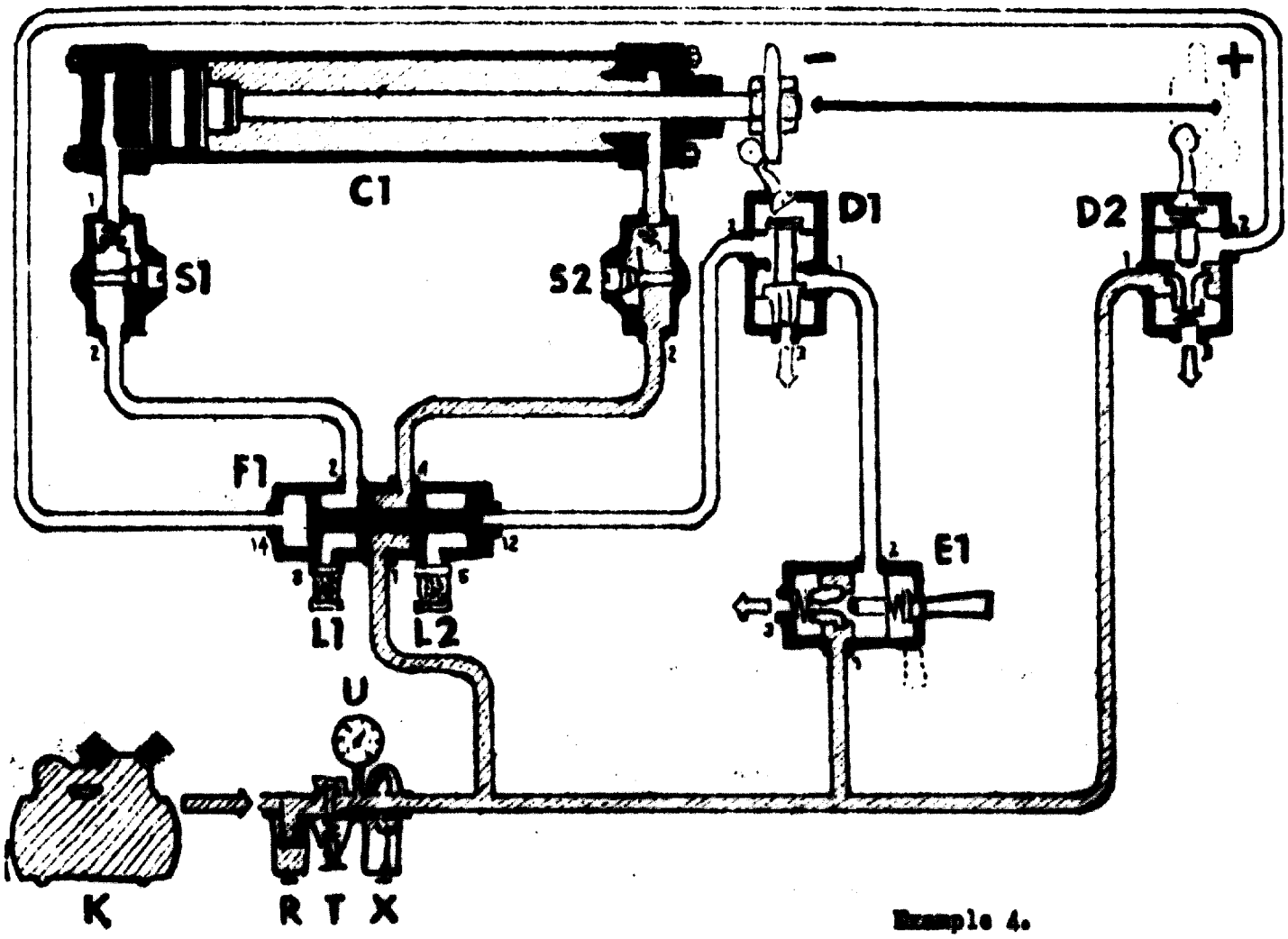
Example 3:

Components:

C1	Double acting cylinder
D1	3/2-valve, push button control, monostable
D2	3/2-valve, roller control, monostable
F1	5/2-valve, pneumatic control, bistable

Function:

When the valve D1 is actuated, F1 changes over (i.e. the slide in the valve) and the piston in the cylinder C1 moves in the plus direction. When the piston rod end reaches the valve D2 and actuates it, F1 is reset and C1 retracts (i.e. the piston in the cylinder C1 moves in the minus-direction). To make it possible for valve D2 to reset F1, the valve D1 has to be unactuated earlier. Usually the valve D2 is located so that it is actuated only when the piston in the cylinder has completed the total length of stroke, but if required the stroke length can be shortened by locating the valve D2 closer to the cylinder.



Example 4.

Example 4:

Components:

C1	Double acting cylinder
D1, D2	3/2-valve, roller control, monostable
E1	3/2-valve, handle control, bistable
F1	5/2-valve, pneumatic control, bistable
L1, L2	Silincer
S1, S2	One-way throttle valve
R	Air Filter
T	Pressure regulator
U	Pressure gauge
X	Lubricator

Functions:

In the starting position the valves D2, E1 and F1 have air supply from the compressor, and thus the minus chamber of cylinder C1 is pressurised. When the valve E1 is changed over, air passes to D1 and as D1 is actuated F1 changes over and the cylinder C1 goes in the plus-direction with a speed controlled by the one-way throttle valve S2.

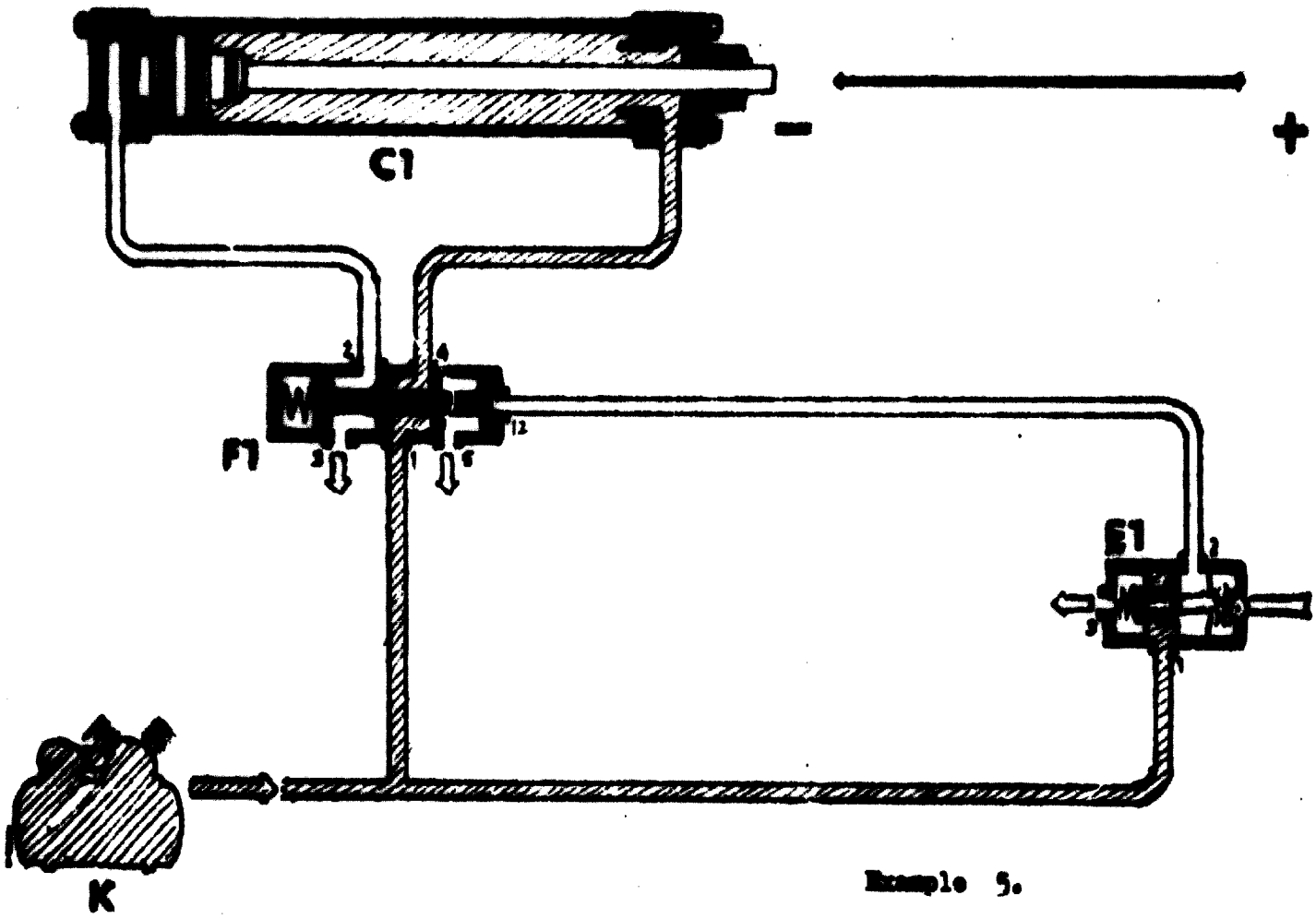
When the piston rod actuates the valve D2, F1 is reset and the cylinder moves in the minus-direction with a speed controlled by S1. In the minus-position D1 is actuated again, which causes the cylinder C1 to move positively, then D2 once again causes a negative motion and so on.

The cylinder C1 is thus working continuously forward and reverse as long as the valve E1 remains in "starting position" and the air supply is sufficient.

If the valve E1 is reset to "stop position", the cylinder C1 will just complete a started cycle and then stop in the minus-position. The plus position of the cylinder can of course also be chosen as the initial position, which is obtained if the valve E1 is located on the supply line to D2 instead of D1.
The two silencers L1 and L2 are to decrease the noise from the exhaust air.

The pressure regulator T keeps a constant air pressure, which can be read at the pressure gauge U.

The lubricator X finally injects a lubricant in the form of a micro oil fog into the compressed air and thus to the moving parts of the components too.



Example 5.

Example 5.

Components:

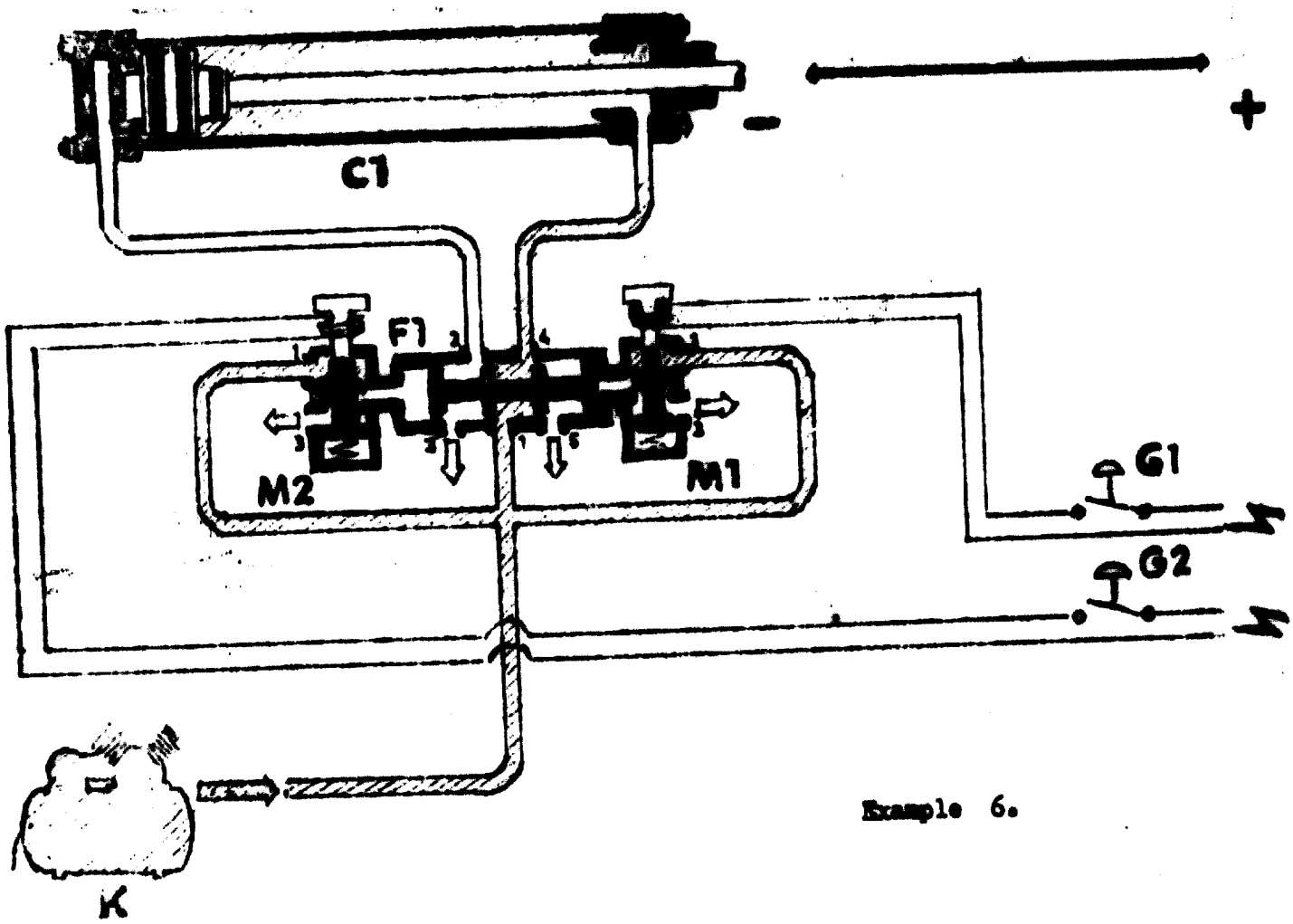
C1	Double acting cylinder
E1	3/2-valve, handle control, monostable
P1	5/2-valve, pneumatic control, monostable

Function:

When the valve E1 is actuated, the valve F1 receives control air and changes over and the cylinder C1 goes in the plus direction. As soon as E1 is released, the control chamber of the valve F1 is evacuated, the valve slide is reset by a spring and C1 goes in the minus-direction. In this case the valve E1 has to be actuated as long as the plus position is to be kept.

If instead the plus position is to be required as the initial position, the piping between the cylinder and the main valve F1 is switched over. The valve F1 can alternatively be controlled by a bistable 3/2-valve.

If the cylinder C1 should operate as single acting, this is obtained either by operating the cylinder direct by a 3/2-valve, or by plugging one of the outlet ports on the 5/2-valve.



Example 6.

Example 6.

Components:

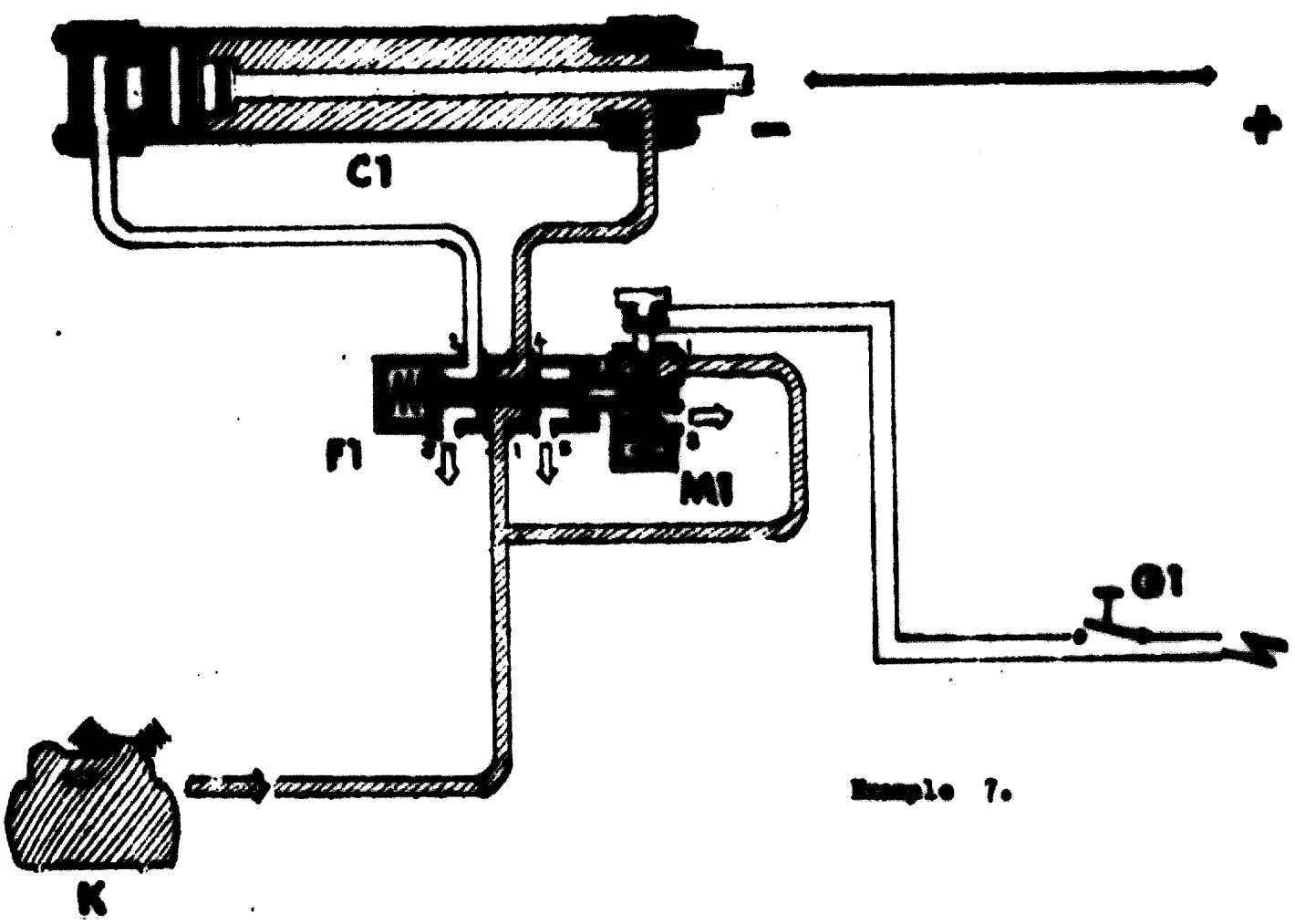
C1	Double acting cylinder
F1	5/2-valve, pneumatic control, bistable
M1, M2	3/2-valve, solenoid control, monostable
G1, G2	Electric push button switches

Function:

When the switch G1 is actuated the solenoid valve M1 changes over, which in its turn means compressed air changes over the main valve F1 and the cylinder C1 makes a plus movement. As soon as G1 is released, the valve M1 is reset.

When instead G2 then is actuated, M2 changed over, the valve F1 is reset and the cylinder C1 goes in the minus-direction. M2 is reset when G2 is released.

The valves F1, M1 and M2 often form a unit with a common inlet on the main valve, which at the solenoid valves are supplied with air through channels in the main valve.



Example 7.

Example 7.

Components:

C1	Double acting cylinder
F1	5/2-valve, pneumatic control, monostable
M1	3/2-valve, solenoid control, monostable
G1	Electric push button switch

Function:

When the switch G1 is changed over, the solenoid valve M1 will open and pass control air to the main valve F1. This will cause the valve F1 to change over and the cylinder C1 to make a positive stroke.

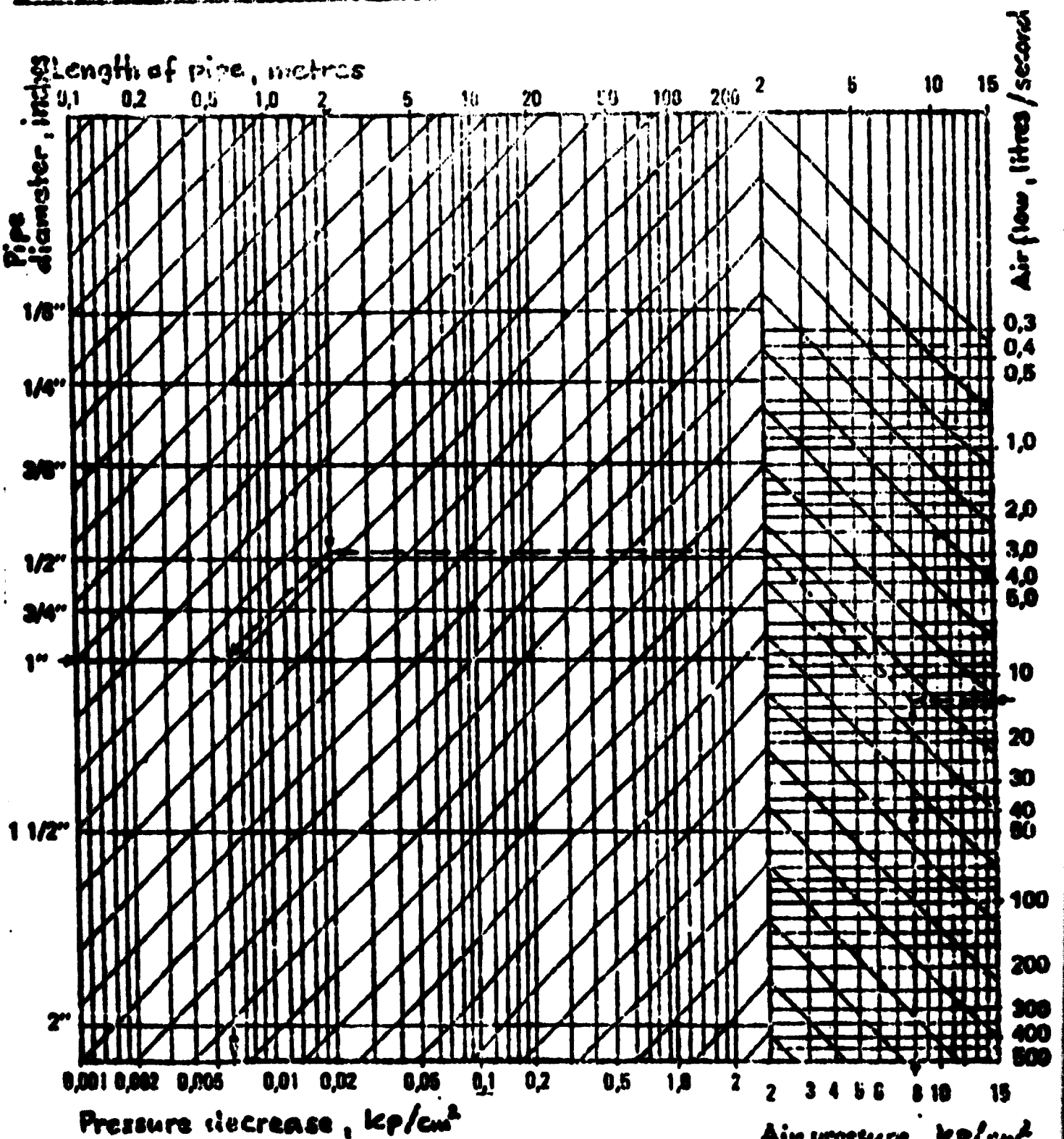
When then G1 is reset, M1 is de-energized and reset, the control air to F1 is evacuated and F1 is also reset, after which the cylinder returns to its initial minus position.

The valves F1 and M1 are often built together to form one unit with common inlet situated on the main valve.

Figure 1 shows pressure decreases in pipeline.

Figure 1.

Pressure decrease in pipeline



Air flow scale is valid in atmospheric pressure and in temperature of 20 °C

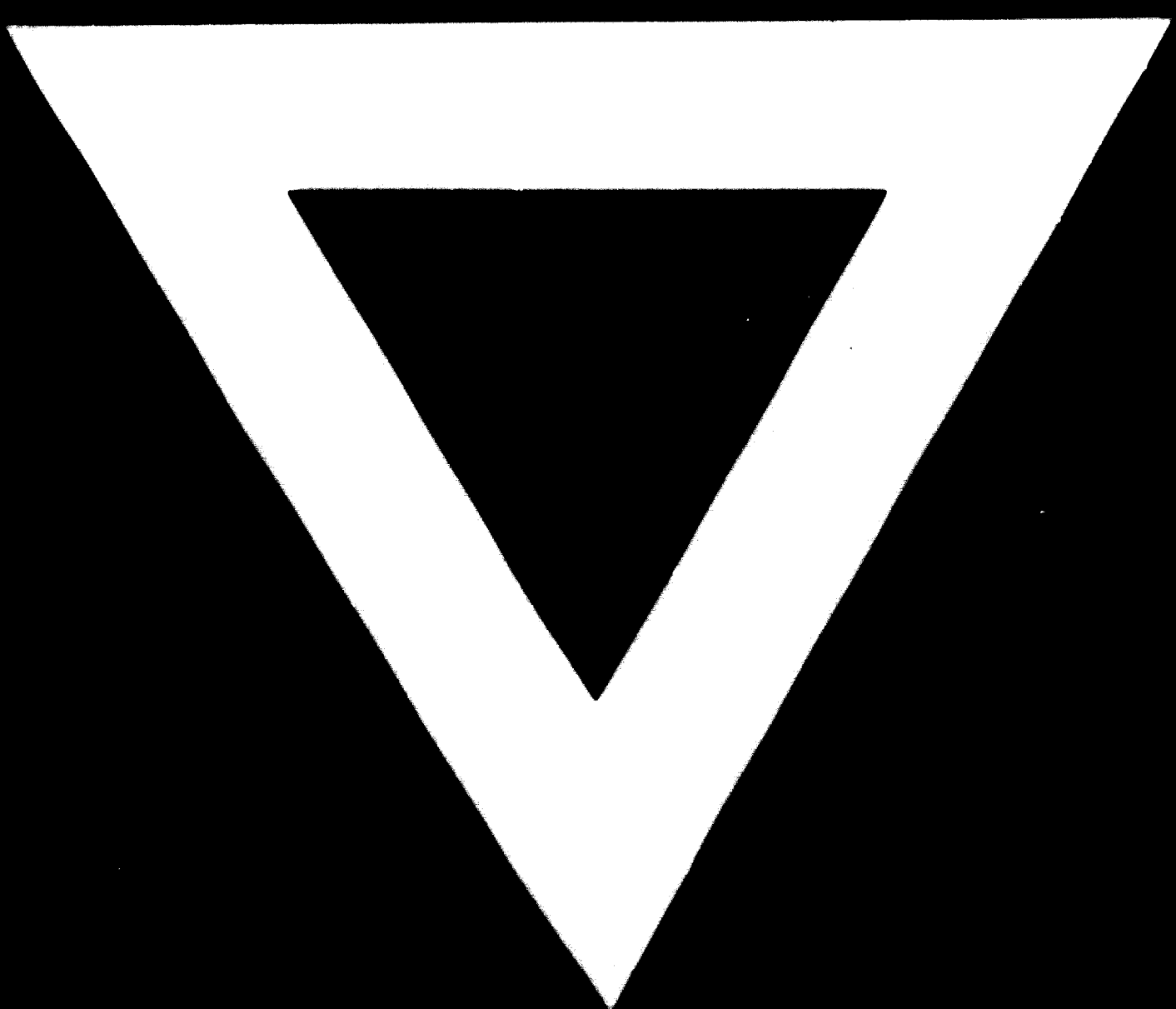
Total pressure decrease in pipeline may not exceed value 0,1 kp/cm²

Example (dot-line in graph)

Values given : Air pressure 8 kp/cm²
Air flow 13 l/s
Length of pipe 2 m

Question : Pressure decrease in 1 inch pipe

Answer : Graph gives 0,006 kp/cm²



3. 9. 74