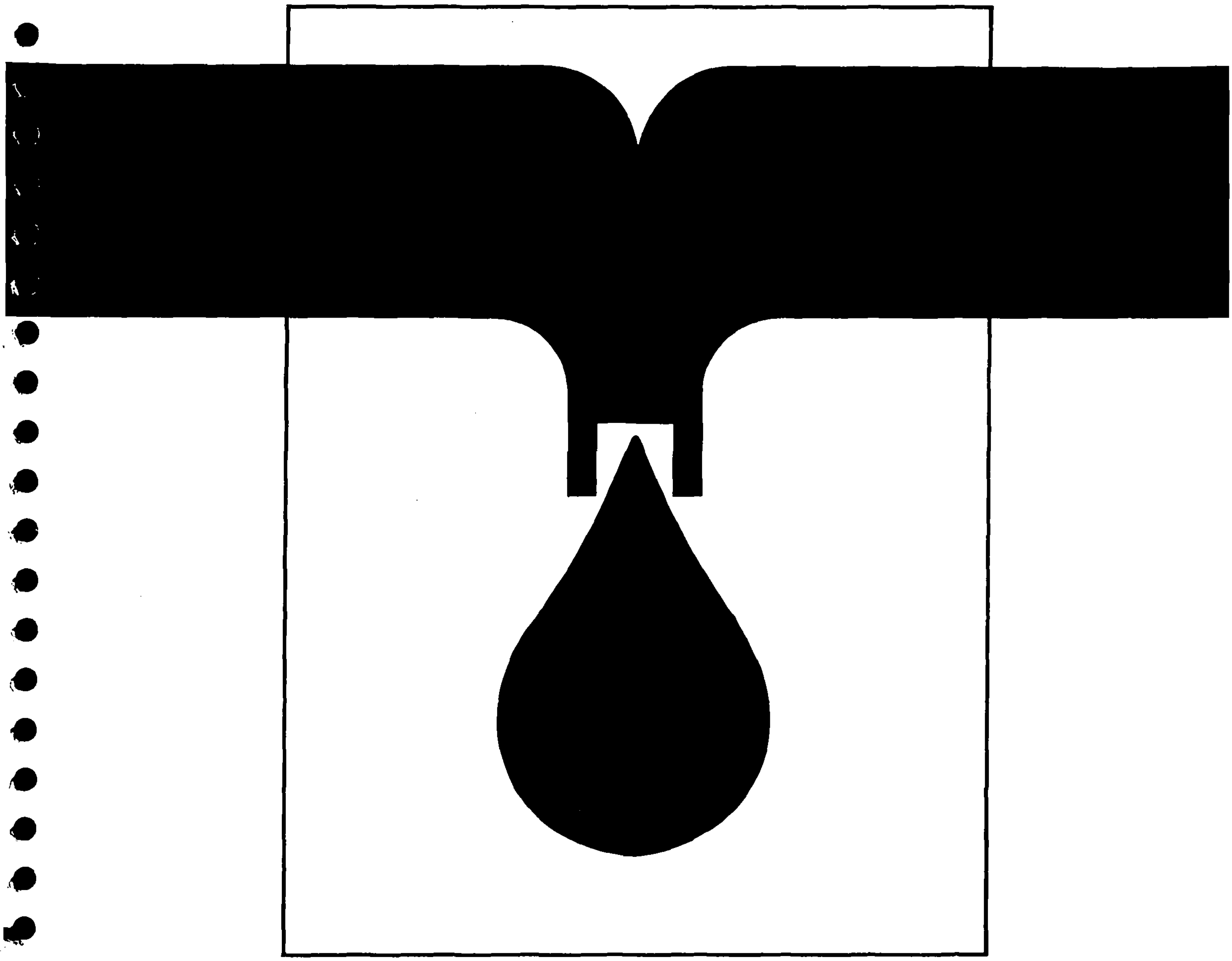
TRAINING MODULES FOR WATERWORKS PERSONNEL



Special Knowledge

2.3 f

Maintenance and repair of blowers and compressors

Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and – if possible – low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

Our grateful thanks are due to

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and
Ing.-Grad. H. Hack

for their committed coordination work and also to the following co-authors for preparing the modules:

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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

Dr. Ing. Klaus Erbel
Head of Division
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Eschborn, May 1987

Title: Design, functioning, operation, maintenance and repair of blowers and compressors

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1. Introduction and uses

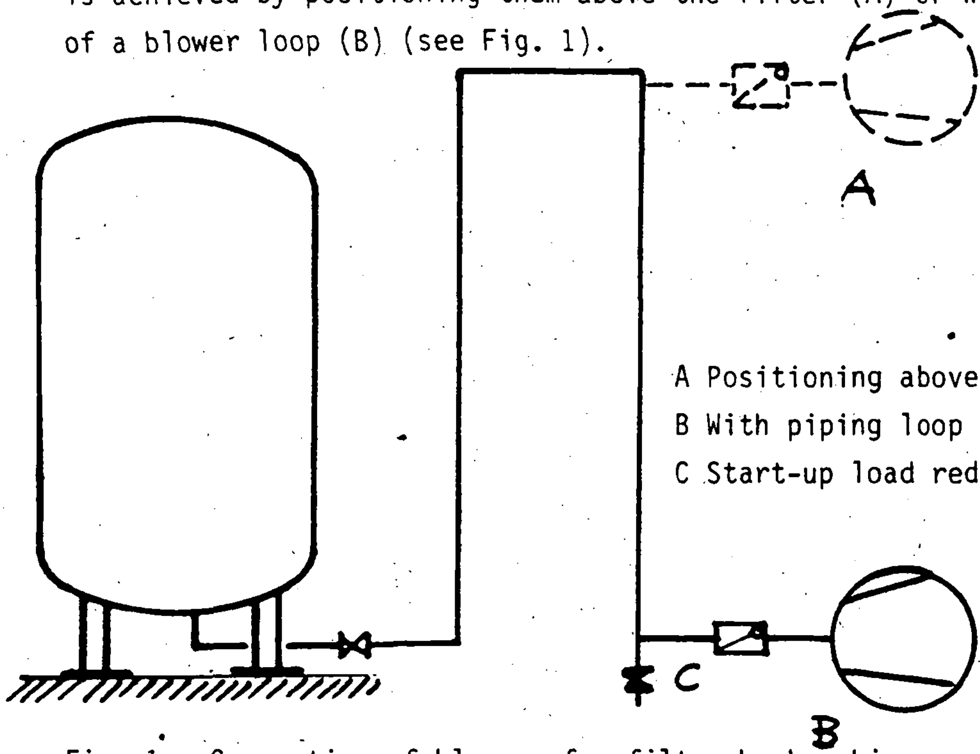
Blowers and compressors are used for various purposes in waterworks.
- During filter backwashing the flushing air removes the sludge from the filter material; the sludge is carried off by the backwash water. In operation, a flushing-air flow of 60 - 100 m^3/h per m^2 of filter area is taken as a basis. The blower used in backwashing must deliver the required volumetric flow against a pressure made up of the filter resistance and the flow resistance in the piping.
- In order to aerate the water to remove iron or manganese, or for the purpose of oxygenation, air is blown into the water. Iron and manganese become separable as a result of oxidation. Two different methods are used for aerating water: Compressed air is either blown into tanks or conveyed into the pipeline with the aid of air mixers. The compressors used to generate the compressed air must be able to compress the required air flow to the water pressure present at the injection point.
- In order to sterilize water using ozone, compressors are required to maintain the ozone gas circulation system.
- In one-way surge tanks, generation of the air cushion requires compressors which deliver a relatively small volumetric flow at high pressure.
- High pressures and small volumetric flows are likewise required for the pneumatic control of pipe fittings.

2. Requirements to be fulfilled by compressors

Compressors should exhibit the following features:

- Oil-free compressed air at the desired volumetric flow rate
- High degree of efficiency in continuous operation and little generation of heat
- Low noise level and little vibration
- Ease of maintenance and reliability in operation

- Blowers must be protected against the intrusion of water. This is achieved by positioning them above the filter (A) or with the aid of a blower loop (B) (see Fig. 1).



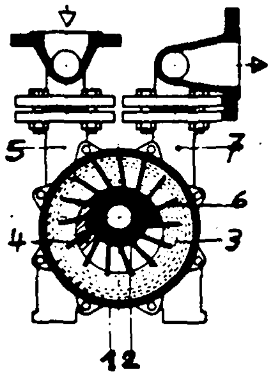
A Positioning above filter
B With piping loop
C Start-up load reduction device

Fig. 1: Connection of blowers for filter backwashing

3. Liquid-ring gas pumps
are rotating displacement pumps.

An auxiliary fluid absorbs the drive power supplied to the rotor and delivers it to the gas to be compressed. The shaft and the rotor are the only moving parts; they do not slide against any stationary components. Fig. 2 shows a cross-section through a pump of this type.

The rotor (2) is positioned eccentrically with respect to the housing (1). The liquid ring (3) formed by the auxiliary fluid circulates concentrically with respect to the housing axis. As a result of this configuration, the fluid exits from and re-enters the rotor cells in the manner of a piston. The gas is drawn in via the inlet slot (4) and inlet connection (5) in the area of the exiting liquid ring, compressed in the area of the entering liquid ring and ejected following compression via the discharge slot (6) which is linked to the pump discharge connection (7). Depending on the pressure range in which the liquid-ring gas pump is to operate, a single-stage or multi-stage version is used.



1 Housing
2 Rotor
3 Liquid ring
4 Inlet slot
5 Inlet connection
6 Discharge slot
7 Discharge connection

Fig. 2: Cross-section through a liquid-ring gas pump

Gas and liquid circuit
Some of the liquid forming the ring is ejected with the gas through the discharge slot. The pump must therefore be continuously supplied with working fluid in order to ensure that the ring is complete. Only water is used as a working fluid in waterworks.

Liquid-ring gas pumps are used, for example, to deliver air for the purpose of oxygenation, as the compressed air remains totally free of oil.
Such pumps can also be used for aggressive gases such as ozone. Gas pumps of this type are commercially available with deliveries of 1 - 10 000 m^3/h.
The sound pressure level at a distance of 1 m is 70 dB(A).

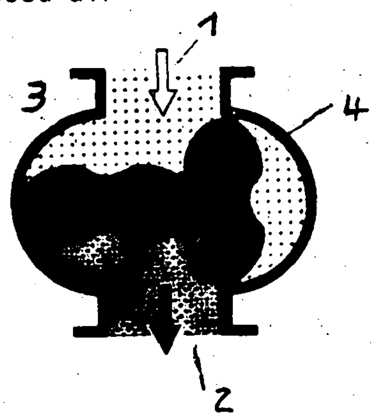
4. Rotary blowers

Rotary blowers can be classified among positive displacement pumps. They consist of a housing with an inlet connection (1) and discharge connection (2), two side walls, a gear chamber (3), two rotors acting as pistons (4) and a set of gears, together with bearings and seals.

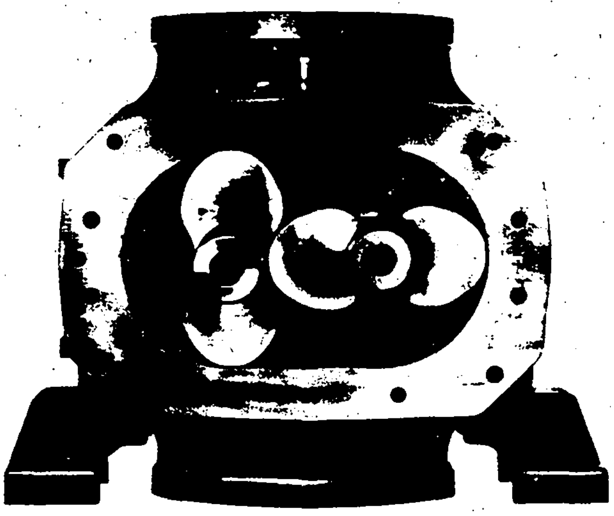
The two rotors, mounted on parallel shafts, rotate synchronously in opposite directions. As a result of the shape and the accurate machining of the rotors there is slight clearance between the rotors and the housing.

When the rotors rotate, the air drawn in is enclosed between the rotor and the housing and transported from the inlet side to the discharge side. One the discharge side, forced displacement occurs against the resistance which results - depending on the system - from flow losses, filter resistance etc. In rotary blowers, therefore, the air is not compressed to an unnecessarily great extent and then expanded; instead, the machine adapts to the respective operating conditions.
The air volume displaced for each rotation of the piston can be calculated from the housing volume and piston volume. The combination of rotational speed and the enclosed air volume yield the delivery volume.

1 Inlet connection
2 Discharge connection
3 Gear chamber
4 Rotating piston
5 Enclosed air



Schematic diagram



View of the delivery chamber

Fig. 3: Rotary blower

Rotary blowers have a high degree of mechanical efficiency. The rotors operate without coming into contact with each other or any other parts, so that the rolling bearings and control gears alone determine the mechanical power loss. Losses are small tanks to the use of rolling bearings together with hardened, ground helical control gears.

Volumetric efficiency is increased as a result of the small clearance between rotor and housing. The rotors require no lubrication, so that the air delivered remains totally free of oil and abraded particles.

This type of blower is used primarily for filter backwashing in waterworks.

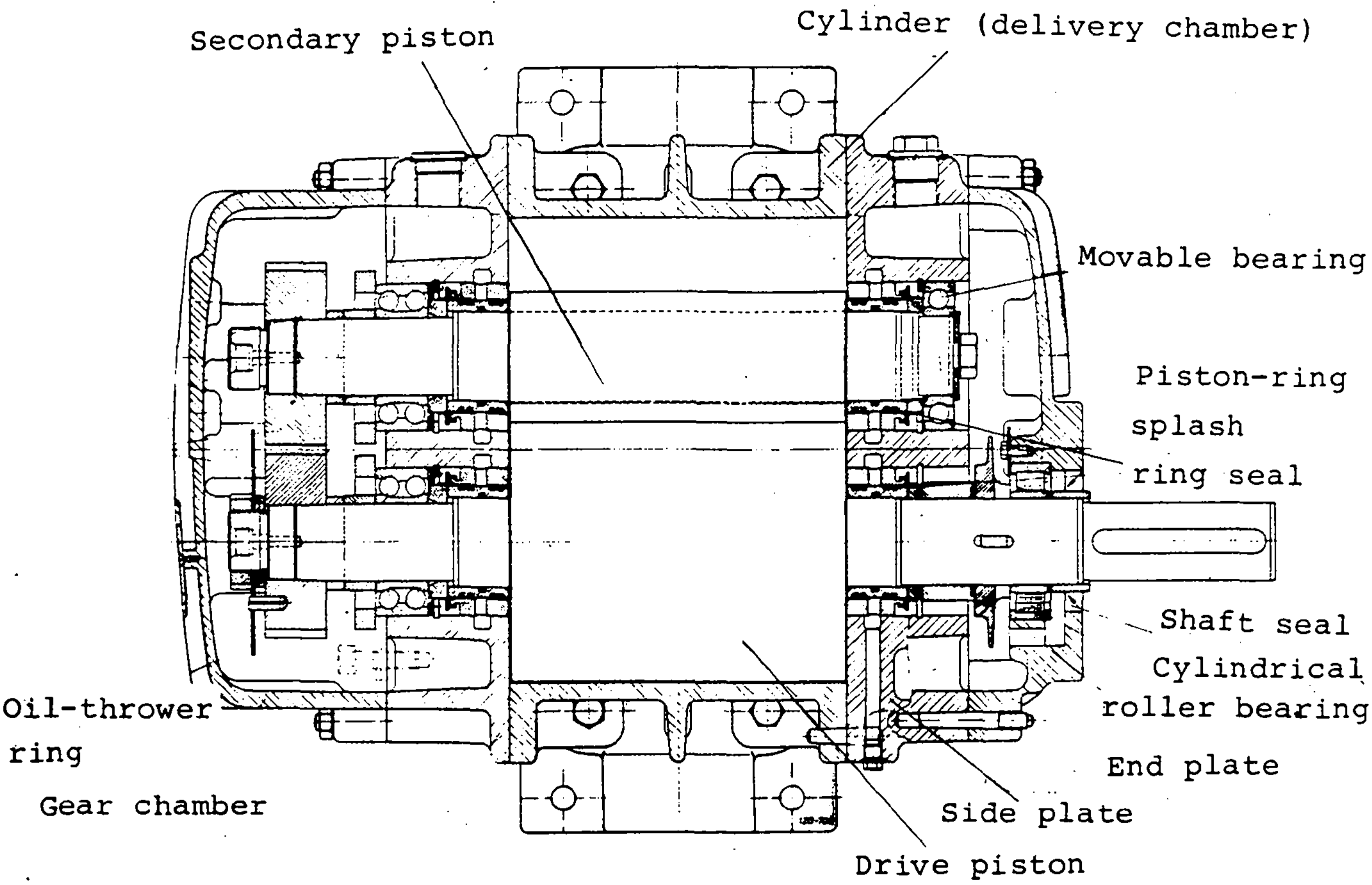


Fig. 4: Longitudinal section through a rotary blower

Rotating pistons (rotors)

The rotating pistons are dynamically balanced. Small blowers have steel pistons and steel shafts drop-forged in one piece, while larger blowers have grey cast iron pistons and steel shafts. Any cavities in the cast iron pistons are sealed to prevent contamination.

Housing

The housing is made of high-grade grey cast iron. Even under extreme loads such blowers require no cooling of the housing.

Control gears

The control gears are of the helical type, are hardened and ground and are manufactured with the utmost precision. The gears are adjusted and secured via a taper-type pressure connection, so that excellent true running and reliable adhesion are guaranteed.

Seals

Between the delivery chamber and the bearing chambers, the series designed for air and neutral gases have rectangular labyrinth seals with splash rings and a generously dimensioned neutral chamber (condensate duct), the latter being the decisive factor ensuring clean, oil-free delivery. The drive shaft penetration point has a radial seal.

Lubrication

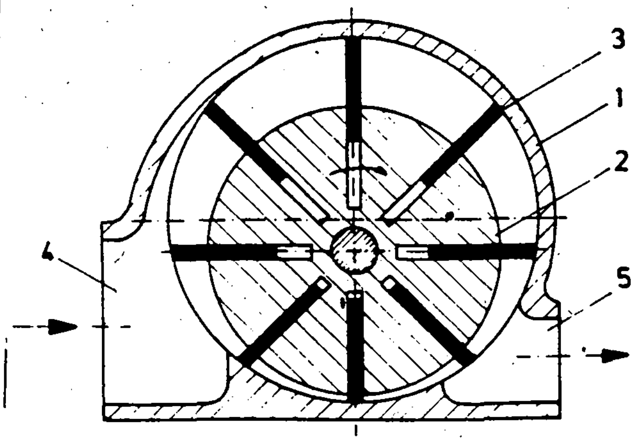
Rotary blowers normally have splash lubrication. The oil-thrower rings and the control gears convey the lubricant to the rolling bearings. In special cases, where high operating speeds do not permit splash lubrication, at high operating temperatures with oil recooling or in conjunction with the sealing-oil circuit of an axial face seal, provision is made for centralized oil circuit lubrication.

Accessories for the rotary blower

The noise emissions of a rotary blower are considerable; at a frequency of 1000 Hz they attain around 85 dB a distance of 1 m.

By fitting silencers on the inlet and discharge sides, as well as a sound insulation hood for the entire blower, this figure can be reduced to 70 dB.

5. Sliding-vane compressors



1 Housing
2 Rotor
3 Sliding vane
4 Inlet opening
5 Discharge opening
6 Start of discharge opening

Fig. 5: Cross-section through a sliding-vane compressor

Fig. 5 shows a schematic cross-section through a sliding-vane compressor. A rotor (2) is mounted eccentrically in a cylindrical housing (1). The rotor has radial slots to accommodate sliding vanes (3). These vanes can move easily in the slots. As the rotor turns, the sliding vanes are forced outwards against the housing as a result of the centrifugal force. With the cylindrical housing on the outside and the rotor on the inside, the vanes form cells, the volume of which continuously changes during rotation as a result of the eccentric mounting of the rotor. The inlet opening (4) is located at the point of maximum cell volume. The discharge opening (5) is located on the opposite side, where the cell volume has been reduced in accordance with the compression ratio.

Each compressor is designed for a specific compression ratio, which is dependent upon the start of the discharge opening (6).

In the case of "dry-running sliding-vane compressors" the vanes are made of self-lubricating graphitic material.

Sliding-vane compressors with oil lubrication are not suitable for use in waterworks.

6. Side-channel compressors

1 Hollow ring
2 Inlet opening
3 Discharge opening
4 Air outlet

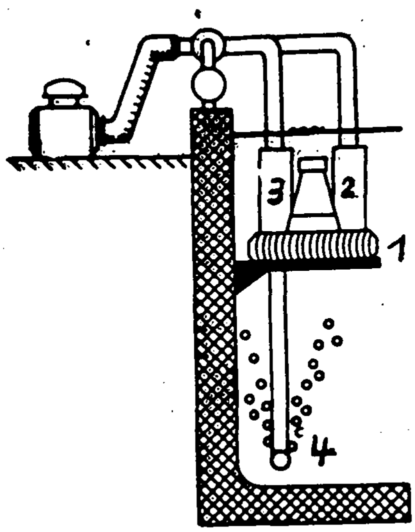


Fig. 6: Side-channel compressor for the aeration of water tanks

The inexpensive side-channel type compressors can be used as an alternative to rotary blowers in the case of small capacity requirements and relatively small delivery heads. The typical purpose for which these units are used in drinking-water treatment is the aeration of open tanks with a maximum blow-in depth of 2.00 m water column.

The side-channel blower is a special type of radial blower with a simple and robust design. In such units, the air is compressed in a circular hollow ring (1) formed by the walls of the side channel. The inlet (2) and discharge (3) openings are located to the left and right of the interruption point in the side channel. When the impeller rotates, the air in the chambers - formed by vanes - is forced outwards and is compressed by the centrifugal force.

The compressed air flows into the side channel and subsequently enters another vane chamber. This process is repeated several times between the intake and the discharge of the air, i.e. the air undergoes multi-stage compression during its movement through the side channel and the blade chambers.

The continual deflection of the air in the side channel naturally results in losses, which means that the efficiency of these blowers is inferior to that of rotary blowers. In individual cases, however, this disadvantage may be offset by the low cost of such units.

7. Screw compressors

In special cases, pressures higher than 0.6 - 0.8 bar are required for air backwashing. Screw compressors start to become an economical proposition above back pressures of around 0.8 bar.

Screw compressors are special rotary compressors which operate according to the displacement principle with internal compression. As it moves from the inlet connection to the discharge connection, the air being handled is compressed to the final pressure in chambers of ever-decreasing size and is subsequently forced out into the discharge connection. The compression process is adiabatic and thus somewhat more ideal than is the case with rotary blowers. The physical properties of screw compressors are the same as those of rotary blowers.

8. Positive-displacement piston compressors and diaphragm compressors

Air-cooled positive-displacement compressors are used in waterworks for pneumatic steel storage tanks and one-way surge tanks, as well as for generating compressed air for control purposes. If the compressed air is to be used for control purposes, a compressed-air reservoir must be connected downstream of the compressor unit.

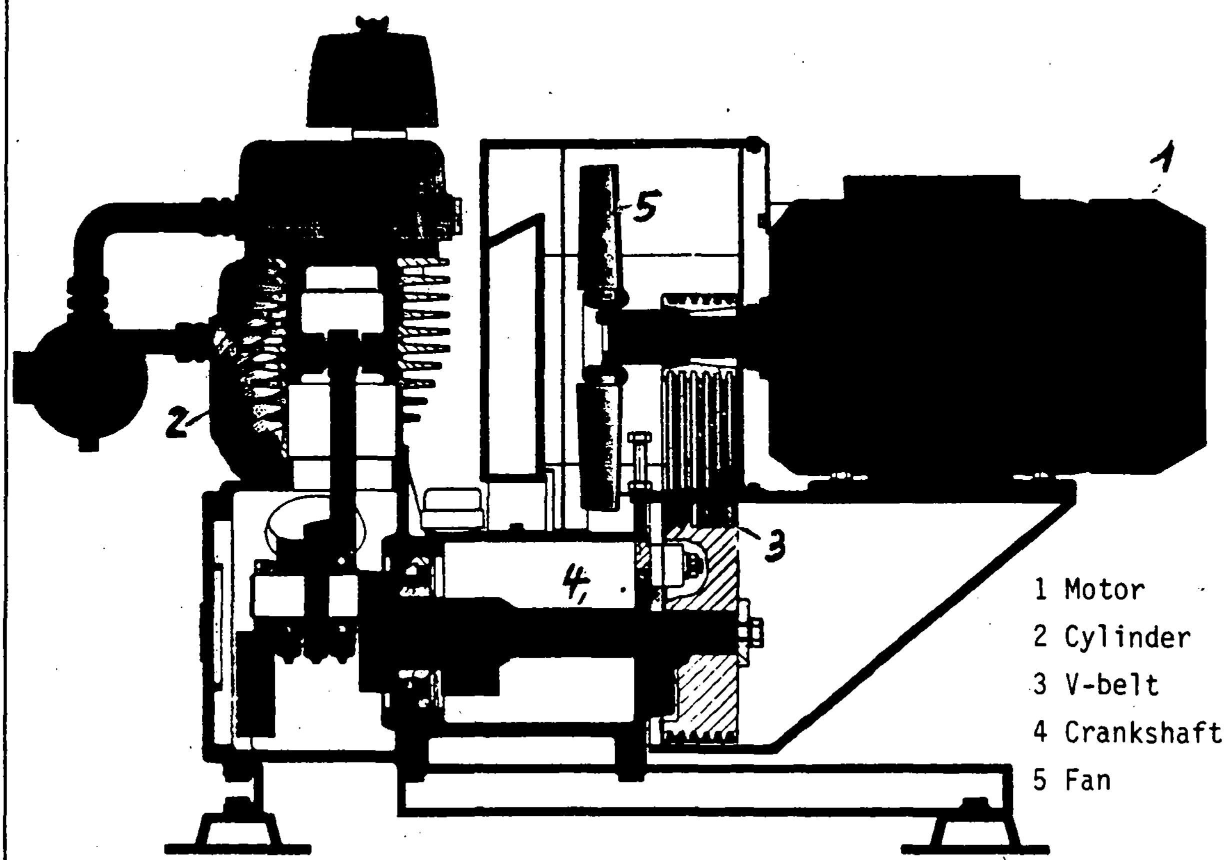


Fig. 7: Cross-section through a positive-displacement compressor

The striking feature of the compressor shown in Fig. 7 is its compact design.

The motor (1) is located directly behind the cylinders (2) on a bracket and drives the crankshaft (4), positioned somewhat lower, via V-belts (3). Electric motors of various types can therefore be used. A fan (5) on the motor shaft provides cooling air.

The downward stroke of the piston causes atmospheric air to be drawn in via the intake filter and cylinder head on the top of the piston. The resultant partial vacuum causes the automatic inlet valve to open; it closes again automatically once bottom dead centre has been reached. The upward movement of the piston compresses the air and forces it out via the automatically-opening discharge valve.

In the case of single-stage compressors the air enters the piping system via the aftercooler.

With multi-stage compressors, the air is cooled in an inter-cooler (finned tube in the case of small units) and then further compressed in the next compressor stage.

The crankshaft necessary to produce the piston movement, together with the sliding surfaces in the cylinder, are lubricated with oil. The compressed air therefore contains small quantities of oil vapour. In the case of oil-lubricated compressors, therefore, an activated-carbon filter must be connected upstream of the drinking-water system to act as an oil separator. In order to keep the temperature as low as possible, the cylinder head and cylinder have cooling fins.

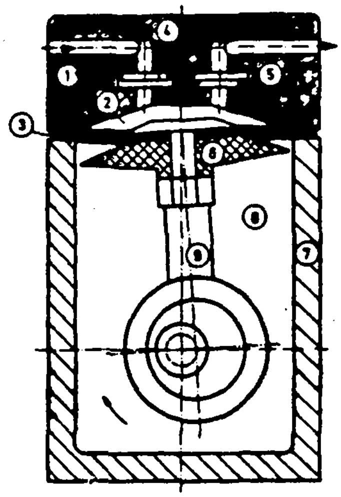
Positive-displacement compressors may be of the single-stage or multi-stage type, depending on the operating pressure. On account of the forces and vibrations occurring, the compressor is secured to a baseplate together with the motor. The unit is mounted on rubber buffers to absorb vibration.

Diaphragm compressors

Diaphragm compressors can be used for the purpose of oxidation as well as for pneumatic steel storage tank systems and deliver compressed air which is totally free of oil. Some versions can be used as vacuum pumps.

Diaphragm compressors are a special type of piston compressor.

Diaphragm compressors may be of the single-stage or multi-stage type, depending on the operating pressure.



1 Diaphragm head
2 Delivery chamber
3 Diaphragm
4 Inlet valve
5 Discharge valve
6 Connecting-rod head
7 Compressor housing
8 Working chamber
9 Connecting rod

Fig. 8: Diaphragm compressor

The mode of operation of a diaphragm compressor can be seen from Fig. 8. A plastic diaphragm (3), secured between the compressor head (1) and housing (7) so as to form a pressure-tight seal, separates the delivery chamber (2) from the interior of the housing, which contains the membrane operating mechanism in the form of an eccentrically moving connecting rod (9). The head of the connecting rod is likewise connected to the diaphragm so as to ensure a pressure-tight seal (6). The connecting rod causes the diaphragm to move up and down. Air is drawn in and compressed with the aid of the inlet and discharge valves (4, 5).
It is clear from this description that the parts of the compressor coming into contact with the air do not come into contact with contamination from the working chamber. The compressed air is thus free of lubricants.
The diaphragm, which is the only major wearing part, is made of a plastic such as neoprene with a fabric insert. Such diaphragms have a relatively long service life.

Fig. 9 shows the use of a compressor in a one-way surge tank system and as a compact compressed-air unit for supplying fittings with control air and operating pneumatic tools.

1 One-way surge tank

2 Compressor

3 Drive unit

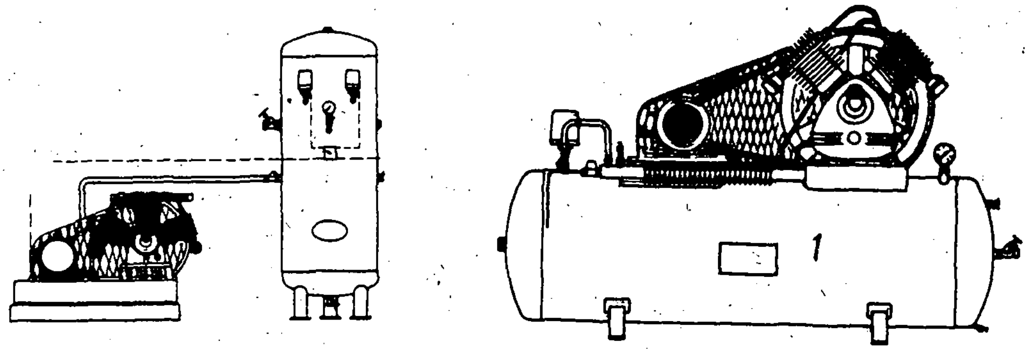


Fig. 9: One-way surge tank system   Compact compressed-air unit

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The government-owned GTZ operates in the field of Technical Cooperation. Some 4,500 German experts are working together with partners from some 100 countries in Africa, Asia and Latin America in projects covering practically every sector of agriculture, forestry, economic development, social services and institutional and physical infrastructure. – The GTZ is commissioned to do this work by the Government of the Federal Republic of Germany and by other national and international organizations.

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- appraisal, technical planning, control and supervision of technical cooperation projects commissioned by the Government of the Federal Republic of Germany or by other authorities
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- provision of materials and equipment for projects, planning work, selection, purchasing and shipment to the developing countries
- management of all financial obligations to the partnercountry.

The series **"Sonderpublikationen der GTZ"** includes more than 190 publications. A list detailing the subjects covered can be obtained from the GTZ-Unit 02: Press and Public Relations, or from the TZ-Verlagsgesellschaft mbH, Postfach 36, D 6101 Roßdorf 1, Federal Republic of Germany.

TRAINING MODULES FOR WATERWORKS PERSONNEL

List of training modules:

Basic Knowledge

- **0.1** Basic and applied arithmetic
- **0.2** Basic concepts of physics
- **0.3** Basic concepts of water chemistry
- **0.4** Basic principles of water transport
- **1.1** The function and technical composition of a watersupply system
- **1.2** Organisation and administration of waterworks

Special Knowledge

- **2.1** Engineering, building and auxiliary materials
- **2.2** Hygienic standards of drinking water
- **2.3a** Maintenance and repair of diesel engines and petrol engines
- **2.3b** Maintenance and repair of electric motors
- **2.3c** Maintenance and repair of simple driven systems
- **2.3d** Design, functioning, operation, maintenance and repair of power transmission mechanisms
- **2.3e** Maintenance and repair of pumps
- **2.3f** Maintenance and repair of blowers and compressors
- **2.3g** Design, functioning, operation, maintenance and repair of pipe fittings
- **2.3h** Design, functioning, operation, maintenance and repair of hoisting gear
- **2.3i** Maintenance and repair of electrical motor controls and protective equipment
- **2.4** Process control and instrumentation
- **2.5** Principal components of water-treatment systems (definition and description)
- **2.6** Pipe laying procedures and testing of water mains
- **2.7** General operation of water main systems
- **2.8** Construction of water supply units
- **2.9** Maintenance of water supply units Principles and general procedures
- **2.10** Industrial safety and accident prevention
- **2.11** Simple surveying and technical drawing

Special Skills

- **3.1** Basic skills in workshop technology
- **3.2** Performance of simple water analysis
- **3.3a** Design and working principles of diesel engines and petrol engines
- **3.3b** Design and working principles of electric motors
- **3.3c** –
- **3.3d** Design and working principle of power transmission mechanisms
- **3.3e** Installation, operation, maintenance and repair of pumps
- **3.3f** Handling, maintenance and repair of blowers and compressors
- **3.3g** Handling, maintenance and repair of pipe fittings
- **3.3h** Handling, maintenance and repair of hoisting gear
- **3.3i** Servicing and maintaining electrical equipment
- **3.4** Servicing and maintaining process controls and instrumentation
- **3.5** Water-treatment systems: construction and operation of principal components: Part I - Part II
- **3.6** Pipe-laying procedures and testing of water mains
- **3.7** Inspection, maintenance and repair of water mains
- **3.8a** Construction in concrete and masonry
- **3.8b** Installation of appurtenances
- **3.9** Maintenance of water supply units Inspection and action guide
- **3.10** –
- **3.11** Simple surveying and drawing work

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