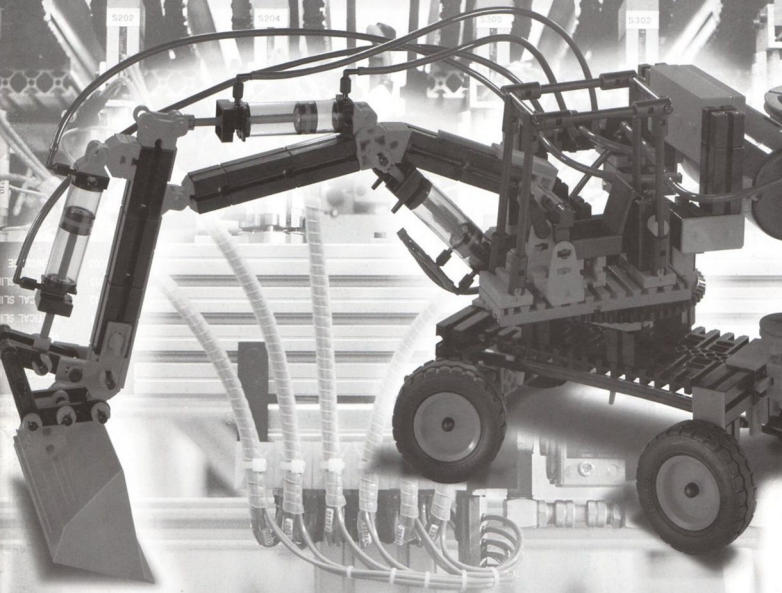
PROFI Pneumatic II

• Begleitheft • Activity booklet • Manuel d'accompagnement

• Begeleidend boekje • Cuaderno adjunto • Folheto



fischertechnik

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1. A bit of history

For thousands of years man has utilized air as a helpful resource, for instance in order to make a fire with a bellows.

The Greek Ctesibios built the first compressed air cannons about 260 B.C. While doing so, he used air which had been compressed into a cylinder in addition to taut strings, and he was thus able to enormously extend the range of the cannon. Therefore it's no wonder that the Greek word "pneuma" – which translates into English as "air" – has lent its name to this technique: "Pneumatics".

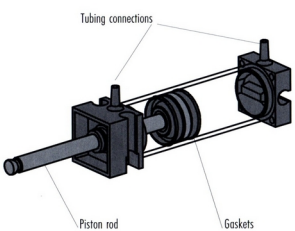
Compressed air-driven devices were utilized – above all in the construction of roads and mining – with the beginning of the industrialization in the 19th century. Modern industry would be hard to image without pneumatics. One finds pneumatically-driven machines and automatic machines everywhere; for instance, they sort and mount various individual components or package commodities.

2. Introduction to pneumatics

Certainly you have also noticed time and again that one can do quite a bit with air. For instance, air can propel a windmill; with air one can inflate a balloon or blow out a candle.
In the science of pneumatics it especially concerns generation motion with air and transferring forces. With our Profi Pneumatic II construction kit we especially would like to explain how pneumatic components function.
And for that purpose we will explain to you – step for step – the individual components, and we will also illustrate how they function. In addition, numerous examples of models are included in the construction kit, and they explain how pneumatics are able to be utilized.

2.1 Generating motion with air

First of all, we will now generate a motion with air. And for this purpose we will utilize a so-called pneumatic cylinder.

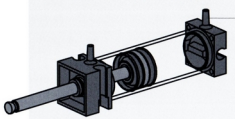


Two different cylinders are included in the construction kit: A smaller cylinder with a black piston rod, and a larger one with a blue piston rod. We will speak about the difference later. We will utilize the cylinder with the blue piston rod to start with.

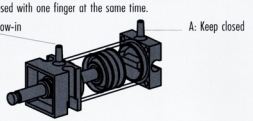
The piston rod is mobile, and sealed with respect to the cylinder wall. The piston rod moves if one blows air into the cylinder through one of the two tubing connections. The connection through which the piston rod travel is marked with "A", while the connection for retraction is marked with "B".

Experiment:

Attach a piece of the blue tubing to Connection A, and blow strongly into it. If you have enough breath, the piston rod will travel through.



Now, blow air through the tubing Connection B, and keep Connection A closed with one finger at the same time.

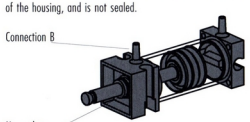


What happens now?
Right, nothing happens. Can you explain to yourself why this is so?

Explanation:

The air in the power part of the cylinder is not able to escape. That's why the piston rod does not move. And so when you blow air into the first connection, the second connection always has to be open – only then is the piston rod able to move. One says that the second connection has to be "deaerated".
The cylinders which we have utilized, and in which the piston rod can be moved as well as filled with air, are called "double-acting cylinders".

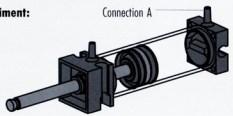
There are also "single-acting", or "unidirectional cylinders". Their piston rod can only be moved in one direction with air. One often utilizes a spring for the motion in the other direction. The small cylinder with the black piston rod is a unidirectional cylinder. It is located where the piston rod comes out of the housing, and is not sealed.



Here the air escapes if one blows air into the cylinder through Connection B. That's why its piston rod is able to be moved easier than the blue rod. You will soon learn what this is good for.

2.2 You can compress air

Experiment:



Once again, take the cylinder with the blue piston rod, and pull this completely out. Keep Connection A closed, and try to push the piston rod through. What did you observe?

Observation:
The piston rod is only able to be pushed in a short distance. If you let go, it springs back.

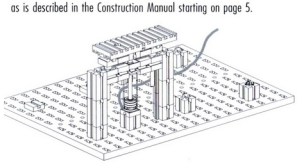
Answer:
The air in the cylinder is able to be compressed. The more it is pressed together, the larger the pressure in the cylinder is. You can also measure and calculate this pressure. The unit for pressure is called "bar" or "Pascal".
The formula for calculating the amount of pressure is:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{or, in short:} \quad p = \frac{F}{A}$$

Therefore, the amount of pressure depends on how much force we exert on the round area in the inside of the cylinder.

2.3 More power through more pressure

Next, we want to determine which forces we are able to exert with our cylinder. For this purpose you will construct a small lifting platform – as is described in the Construction Manual starting on page 5.



Now we will conduct a few experiments with this model:

Lifting Platform Experiment 1 (see Construction Manual p. 5): First of all, try to move the lifting platform upward by breathing air into the cylinders through a tube. Despite maximum effort this will not function.

Lifting Platform Experiment 2 (see Construction Manual p. 7): Now, utilize a second cylinder with blue piston rod, attach it to the building board next to the lifting platform; extract the piston rod completely, and connect the tube to Connection A, which leads to the lifting platform's cylinder.

Push the piston rod through. What happens? – The lifting platform moves upward. Pull the piston rod out again, and you will see that the lifting platform moves downward again. So far so good.

But what happens, for instance, if you place a book on the lifting platform, and then try to lift it upward?

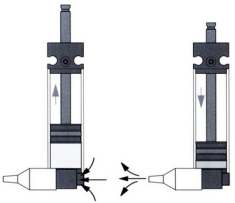
First, you have to compress the air in the cylinder quite a bit before the book moves upward. In addition, the lifting platform is no longer able to be completely extracted. How does that come about?

More force is required in order to lift the heavy book upward. You can only obtain this force by increasing the pressure in the lifting platform's cylinder. The compressed air requires less space in the cylinder. Thus said, there is no longer enough "compressed air" available in the cylinder in order to completely extend the lifting platform. We must be able to pump more compressed air into the cylinder.
And for this purpose we will utilize the so-called check valve.

2.4 The check valve

The check valve is simply attached to Connection A on the cylinder. The tube can be connected to the check valve.

Now, if you extract the piston rod from the cylinder, the check valve sucks outside air into the cylinder.
If you push the piston rod further inward, the air is pumped out into the tube through the second opening in the check valve, while the firstconnection remains closed. Now we have constructed an air pump similar to that which you have on your bicycle.



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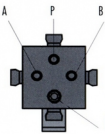
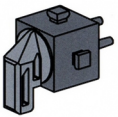
Lifting Platform Experiment 3 (see Construction Manual p. 7):
Now connect the hand pump to the tube which leads to the lifting platform. As a result, now you can pump so much air into the lifting platform's cylinder that this (cylinder) is completely extended.

Now we have only one problem. If we want to lift the lifting platform upward, the air has to be pumped into the cylinder through the lower connection. If the lifting platform is to be lowered again, the air has to be directed through the upper connection. Of course, it is much too troublesome to constantly change and reconnect the tube. There is a much better solution.

2.5 The hand valve

This valve has 4 connections:

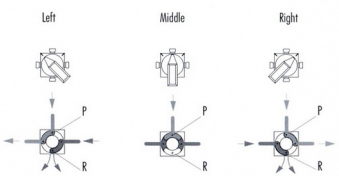




The middle connection (called Connection "P") is the supply for the compressed air. The left and right connection pieces (A and B) are for the tubes to the cylinder. The short connection on the lower side is the deaeration ("R"). This enables the air to escape, which comes back from the cylinder (the so-called "exhaust" or "outgoing" air). The valve has three switch positions (middle – left – right). In the science of pneumatics, a valve with 4 connections and three switch positions is called a 4/3-way valve.

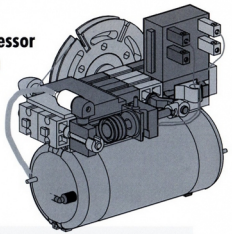
Lifting Platform Experiment 4 (see Construction Manual p. 8):
Close the valve as described in the Construction Manual.
If the switch is in the middle position, all connections are closed, and the lifting platform does not move. If you turn the valve switch to the left, and then pump with the air pump, the lifting platform lifts upward. If you turn the switch to the right, you can move the platform downward again.

The following figures explain how the air flows into the different switch positions through the valve:



2.6 The compressor

Of course, pumping by hand is tiring after a while. There is a much more elegant solution for this. Build the compressor as described in the Construction Manual on page 11.



Lifting Platform Experiment 5 (see Construction Manual p. 9):
Now attach the compressor on the base plate of the lifting platform model to the two specially provided red modules. After that, connect the compressor to the lifting platform instead of the hand pump.
It is important that you utilize a 9V alkaline battery as power supply. A "normal" 9V block conks out after only a few minutes. Of course, the "fischertechnik Accu Set" (Art. No. 34969) – which has considerably more power than the 9V block, holds much longer and is able to be charged over and over again – is much more suitable.

After turning on the compressor, you have to wait ca. 15 seconds until the air chamber is filled. Then you can move the lifting platform up and down without having to constantly pump by hand at the same time.

We utilize the small pneumatic cylinder with the black piston rod as a pump for the compressor. The piston rod of this unidirectional cylinder is able to be moved easier than the piston rod of the large cylinder, and is thus able to be propelled by means of the fischertechnik motor. The air chamber ensures that there is always enough compressed air available for operating the pneumatic cylinder. The pressure generated by the compressor amounts to ca. 0.5 bar. The compressor cylinder piston always has to be able to move smoothly. If necessary, it can be sparingly lubricated with a small drop of acid-free oil (e.g. silicone oil). If the compressor will not be used for a lengthier time span, it is recommended to remove the drive belt, because this wears out over time and can thus slip through.

Lifting Platform Experiment 6 (see Construction Manual p. 9):
Utilize the compressor without air chamber. In addition, lay out a 20 cm-long tube, which extends from the check valve directly to Connection P of the hand valve.

What changes during operation of the lifting platform?

Observation:
The lifting platform "bucks" during extension as well as during retraction, because the pump intermittently pumps air into the system. The air chamber equalizes this pressure surge. That's why the motion with the air chamber is much more uniform.

2.7 More power through more surface area

Exercise:
Try to find out with what weight the lifting platform can be loaded so that the weight can just barely be lifted.
How can you lift even heavier weights?

Lifting Platform Experiment 7
(see Construction Manual p. 10):
You will utilize a second pneumatic cylinder for lifting heavier weights. As illustrated in the Construction Manual, install the second cylinder in the lifting platform, and connect it in accordance with the Tubing Plan illustrated there.

Exercise:
Why is the weight which you can lift about twice as much as with one cylinder?

Answer:
Based on our formula $\mathbf{p = \frac{F}{A}}$ you attain the formula $\mathbf{F = p \cdot A}$ through conversion. The force which one is able to exert is therefore dependent on pressure and on the area which the pressure affects. The pressure which the compressor generates is always constant. If we utilize two cylinders instead of one cylinder, the area which the pressure affects is twice as large. As a result, the force as well as the weight which one can lift are doubled.

Too complicated? It doesn't matter. Jut remember: If the power of one cylinder is not enough, add a second cylinder.

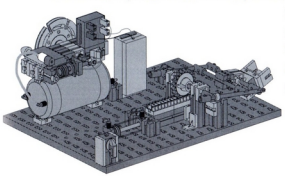
And with that we are at the end of our introductory chapter. As you can see, the science of pneumatics is actually quite challenging. But it is also incredibly exciting. That's why we will immediately turn to the construction kit's other models. Lots of fun!

3. Pneumatic play models

In this chapter we want to deal with a few other functions which are often pneumatically-conducted in the "right technique". We will also build ourselves a model of each specific function in order to better understand how everything functions.

3.1 Catapult

In the first chapter it was mentioned that the Greek Ctesibios constructed the first compressed air cannons as early as 260 B.C. We have long since been able to do what he could. Do you have any idea how this was able to function? Then try to build a model without any instructions. Otherwise, you'll find our proposal in the Construction Manual on p. 13.

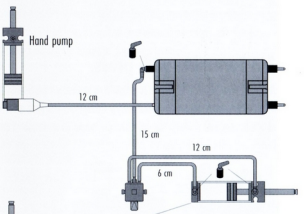


In our model the compressed air is generated by means of the compressor. Before you operate the catapult for the first time, you have to wait ca. 15 seconds until the air chamber is full and the full pressure is available to you. Then you can simply hurl a block module (15) throughout the area.

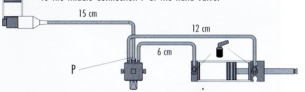
Exercise:
Hopefully the catapult functions well. But now try to propel the module block even further. Think about what the various possibilities are. What functions best?

Possibilities:

- Instead of the compressor, utilize the hand pump, and pump the air chamber full with that. Then open the hand valve and observe how far the module block flies.



- Connect the hand pump, without air chamber, directly to the middle Connection P of the hand valve.



Open the valve so that the catapult's cylinder can extended, and thereafter press the hand pump's piston rod downward as quickly as you can.

With what did you achieve the best result?

3.2 Sliding door

Certainly you have also walked through a sliding door quite often. These doors are either electrically or pneumatically operated. For instance, the doors in public transportation buses are frequently opened and closed with compressed air. You can even hear the typical "hissing" when the compressed air escapes. No you will also build a sliding door, which will be initially opened and closed by means of a valve. You will find the instructions for this on page 17 of the Construction Manual.

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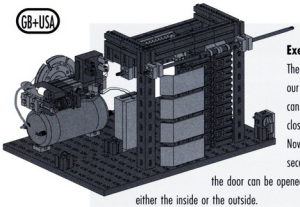


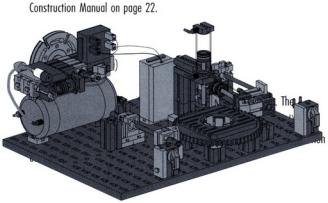
Exercise:
The disadvantage of our door is that you can only open and close it from one side. Now you will install a second valve so that the door can be opened and closed from either the inside or the outside.

Answer:
See Construction Manual page 21 .

While doing so, you have to pay attention that every valve is returned to the middle position after operation. Otherwise the door cannot be operated by means of the second valve.

3.3 Turntable with press

Machines with which one is able to produce or assemble components in factories are quite frequently pneumatically driven. Our machine consists of a turntable and a press. You will build the model as is described in the Construction Manual on page 22.



Experiment:
The two functions "turning" and "pressing" shall be executed in succession. How many components can you process in one minute? Operate the valves successively and do the necessary timing.

Are you able to do this so quickly that the compressor "runs out of breath"; i.e. that it cannot produce enough air to operate the cylinder at this speed?

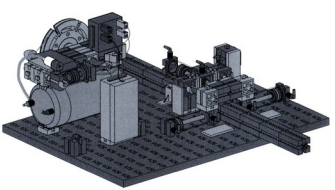
Exercise:
In reality such systems are not actually controlled by hand. How does one actually control such systems?

Answer:
Instead of the hand valves, valves which can be opened or closed by means of an electric impulse are used. These (valves) receive their impulses from a programmable control mechanism called "SPC" (Stored Program Control). The programmer provides input concerning the sequence in which the valves are to be operated, stores (saves) all of the information – and, "lo and behold", the system functions without someone having to constantly open and close the valves.

We will deal with how you can automate such systems with fischertechnik in Chapter 5.

3.4 Linear feed

In the previous model the turntable was always "clocked" a step further during operation of the valve. The possibility also exists to gradually clock the motion forward in a straight line. For information concerning construction of the "Linear Feed" model, see the Construction Manual on page 26.



You can see that the linear feed requires much more effort to realize than the turntable. Now we need three pneumatic cylinders.

Exercise:
Can you imagine how such a feed mechanism is utilized in reality?

Answer:
For instance, in sawmills for transporting logs which will be sawn off at a specific length.

Of course, in real systems the function would also be automated. But our manual operation is completely sufficient for understanding how this principle functions.

4. Pneumatic play models

In addition to the functional models which we dealt with in Chapter 3, the Profi Pneumatic construction kit includes four other models with exciting game functions. This concerns the models "Pipelayer", "Snowplow", "Shovel Loader" and "Excavator". In reality, functions as they appear in these models are not executed pneumatically bur rather hydraulically. In the science of hydraulics one utilizes oil instead of air in order to move cylinders. In contrast to air, oil is not able to be compressed. As a result, one can transfer substantially greater forces with hydraulics than with air.

The force of pneumatics is completely sufficient for our play models. In addition, perhaps you can imagine that one could create quite a mess when playing around with oil, especially if it gets onto the wall-to-wall carpeting, for example. If one would utilize water instead of oil, the danger exists that the cylinders would calcify. The utilization of distilled water is also not to be recommended, since this could lead to health injury in the event of being swallowed. Therefore we will remain instead with compressed air and be pleased at how the compressor rattles, and at how the valves hiss when the outgoing air escapes from the cylinders during operation. Of course, these models are able to be combined ideally with other construction kits. And so, for instance, you can load the "dumper" from the Cars&Trucks kit quite well with the pneumatic Excavator, or with the "low-loader" vehicle from "Super Trucks" you can transport pipes which are unloaded with one of the harbor cranes and then laid with the pneumatic Pipelayer. Have lots of fun while building and playing.

Remarks:

- Especially with the Excavator it is important that you wait ca. 15 seconds after turning on the compressor until the air chamber is completely filled and the full pressure for lifting the excavator arm is available. Otherwise it is possible that it won't be able to move. When you have repeatedly carried out several functions successively, you should also allow the compressor to take a break so that the air chamber can be filled again.

- At any rate, if you have had these models in operation for a longer period, it is worth it to utilize the "Accu Set" (Art. No. 34969) as power supply instead of the 9V block. The battery pack holds power considerably longer than a 9V block, and can be repeatedly charged. Installation in the models is possible without problem.

5. Even more pneumatics

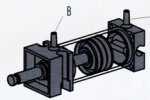
The fascinating subject of pneumatics is not yet at an end with this Profi Pneumatic construction kit. If you are also now anxious to automate the pneumatic models, then the Pneumatic Robots (Art. No. 34938) construction kit is just the right thing. There the models are no longer controlled with hand valves, but rather with electromagnetic valves which are connected to the "Intelligent Interface". These models can then be programmed and controlled by means of PC with the LLWin software. This is technology at its finest. Of course, you can utilize the components from the Profi Pneumatic construction kit, and also upgrade and expand the models. For instance, you can also build a "double compressor" with two motors and two air chambers which are able to produce twice the amount of air. This enables endless possibilities.

In case you want to obtain more specific information on the subject of pneumatics, we recommend the book "The amazing world of pneumatics". It is published by the Vogel publishing house and is available in bookstores ISBN 3-8259-1912-9). It provides extensive insights into the world of pneumatics and its history, as well as numerous applications and developments throughout the approximate 200 page length.

Maybe you will once again encounter the science of pneumatics during your schooling or your profession. Then you will notice that "genuine pneumatics" also function just as well in principle as in the fischertechnik construction kits, and that this subject has been familiar for quite a while.

6. If something does not function properly

What is worse than a model which has been built to completion and connected, and then doesn't function? That's why we would like to provide a few tips at this point regarding what the cause could be in isolated cases and how you can eliminate the flaw.

Flaw	Possible cause	Remedy
The compressor only functions very slowly. The motor comes to a standstill as soon as pressure should be generated.	You did not use an alkaline battery. The compressor cylinder has "run dry", and is also only able to be moved by hand with difficulty. In this case considerable abrasion is detected in the cylinder pipe.	Utilize a 9V block alkaline battery or the fischertechnik Accu Set (Art. No. 34969) In case the gasket in the piston is not warped yet, lubricate the cylinder with a small drop of acid-free oil. Otherwise replace the worn out cylinder.
The compressor motor is running, but the flywheel does not move.	The rubber sealing ring is worn-out or greasy and slips through.	Clean the rubber sealing ring and the tip of the adapter with a bit of soap and water. If necessary, replace the worn-out rubber sealing ring.
The compressor appears to run normally, but the triggered pneumatic cylinder moves only very slowly or not at all.	**Air chamber is empty.** **The compressor does not build up enough pressure or doesn't build any pressure at all. Check:** Close all exits on the air chamber, and fill the air chamber with compressed air (ca. 15 seconds). If you open a connection piece, you should be able to hear a loud hissing. If the hissing is only very slight, or if there is not any hissing at all, there isn't enough pressure available. **Possible causes for defective compressor:** **The air chamber leaks. Check:** As above, fill (air chamber) with compressed air and hold it under water. If bubbles rise it is leaky. **Check valve is defective. Check:** Using a hand pump (see p. 11), pump air into a cylinder with 5-6 strokes. By checking in the water, ensure that the fully-pumped cylinder is sealed (no air bubbles visible). If the piston rod of the fully-pumped cylinder slides back slightly, or if it does not extend properly, the check valve is defective. **The compressor cylinder leaks.** **Check:** Using the hand pump (see p. 3), build pressure in the compressor cylinder at Connection A, and hold it under water. If bubbles rise, the cylinder is leaky. **Note: If you check at Connection B, bubbles continue to rise.**  **Hand valve leaks. Check:** Place the valve into the middle position. Successively build pressure at all 3 connections, and hold the valve under water. If lots of bubbles rise to the surface, the valve is leaky. **Pneumatic cylinder leaks. Check:** Successively build pressure on both connections, and hold the cylinder under water. If lots of bubbles rise to the surface, the cylinder is leaky.	Place all valves into the middle position and wait ca. 15 seconds until the air chamber is filled. Check possible causes for the defective compressor. Replace air chamber. Replace check valve. Replace compressor cylinder. Replace hand valve. Replace pneumatic cylinder.
The compressor and all cylinders are in working order. Nevertheless, one of the cylinders doesnot extend.	**The tube is clogged at one point.** **Check:** Connect every tube individually to the compressor. You can hear and feel whether air flows through.	If necessary, replace the clogged tube.

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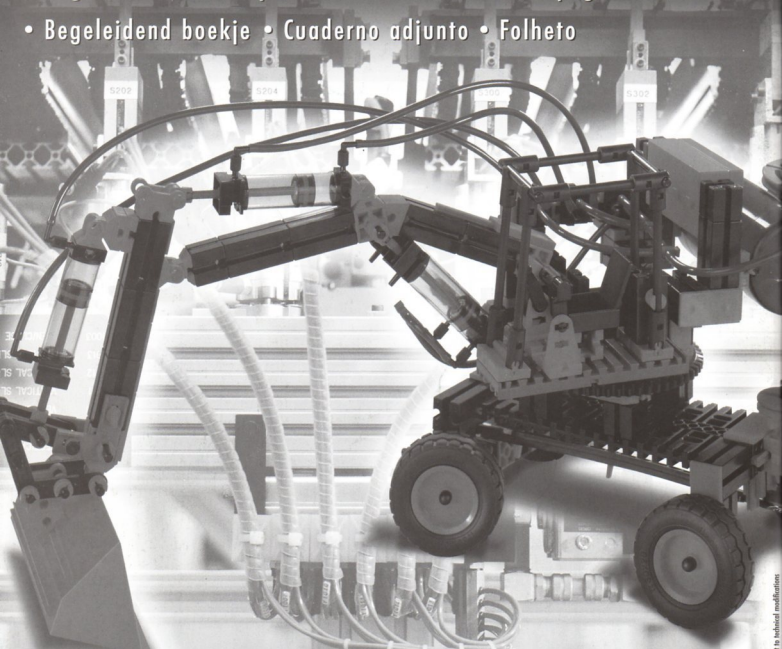

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