White Paper
Quality and an attractive price
– The right way to buy valves/valve terminals –

The global market for valves and valve terminals today is so large that it is almost impossible to maintain an overview. Often, price seems the only buying criterion. But it pays to look more closely, particularly with regard to higher productivity and process reliability. Users of Festo's attractively priced and long-lasting high-quality valves benefit in tough everyday practical applications from the meticulous development processes, including numerous simulation tests and the correct choice of technologies and materials.

This White Paper provides information on:

- Care pays for itself: the development process of valves and valve terminals
- Caution: not all manufacturer data is comparable 1 to 1!
- Small differences with a great impact: how to choose the right valves/valve terminals

An overview of good practice: the development process of valves and valve terminals

The development of a valve by Festo or other comparable companies takes on average three years. Good results and high quality depend on all kinds of processes carried out in various different departments.

Phase 1 of development is concerned with pre-process strategy. In this phase, market requirements are evaluated on the basis of future scenarios. Ideas and suggestions are generated by Festo Product Management, customers as well as networks of joint-venture partners such as universities. The project team uses this input to produce the performance specifications. After the clarification, planning and approval stages, the product specifications can be put together, including a project plan, a solution, a budget, a test schedule, a general timeline, etc. In addition to covering functionality and product dimensions, the solution must also consider ergonomics, ease of operation and a uniform product design.

During the subsequent product realisation process (phase 2), a CAD model is produced on the basis of the product specifications and the flow and material optimisation processes. This model can then be used to create detailed and individual component drawings. These are used for a first FMEA analysis[1]. After an initial evaluation of the manufacturing and assembly process, advance quality planning can begin. As soon as the first close-to-series test samples are produced, a number of tests and inspections are carried out, such as:

- Vibration and shock tests to assess the behaviour of the valves during transport or when installed on a dynamic robot arm.
- Examination of valve behaviour to identify possible reciprocal effects within temperature, voltage or pressure ranges.
- IP inspections, preceded by alternate hot/cold exposure tests, to ensure that everything works correctly even at extreme temperatures.
- Tests of valve terminals fitted with all the equipment in order to test flow rates or back-pressure surges when several valves are actuated simultaneously.
- Scans using computer tomography to detect problems such as cavities in valve housings at an early stage

[1] FMEA, *Failure Mode and Effects Analysis*

Once these tests have been concluded successfully, a quality release is issued for the product concept. Work also starts on complete technical product documentation. This is followed by -testing of the assembly system and production process (phase 3). This phase includes the verification of suppliers and ordering processes, updating of master data and transferring this into the production system and preparations for the market launch. The final milestone in this phase, "Pilot series release", marks the start of phase 4, pre-production.

This phase covers another review of service-life tests, building up product stocks and initial marketing activities. It also covers training for sales staff. The start-up of series production is followed by a product audit. This comprises quality, internal and external complaints, ability to deliver, on-time delivery and customer feedback. The results are summarised in a final project report.

Questions which customers should ask themselves

If you are planning to buy valves and have two or more quotations with comparable prices, your choice should be guided not only by component price but also the total cost of ownership and the competence of the suppliers. A careful development process is particularly important when large quantities of products are to be installed in harsh environments. In those cases, you should ask yourself the following questions:

- What tools have been used in the development process in order to achieve optimum product design?
- What tests and inspections have been carried out?
- Do the results of these tests and inspections, when used as the basis for data sheets, allow an equal comparison with other manufacturers' data?
- Have test series been carried out only to verify the values required by the relevant standard? Or have further tests and inspections also been carried out, for example to assess reciprocal effects?

In the following section you will find a description of a small selection of the engineering tools used by Festo during development. In order to obtain the best possible results when developing valves/valve terminals, Festo also uses a wealth of other specially developed software tools, together with an excellent collection of test and inspection equipment, such as an EMC laboratory, computer tomography and a well equipped materials test laboratory.

From standard programs to in-house developments: not every manufacturer uses sophisticated software tools to ensure the highest quality of the end product!

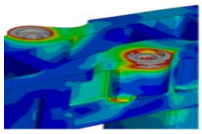
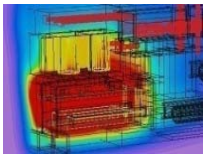
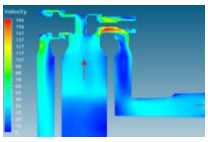
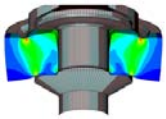
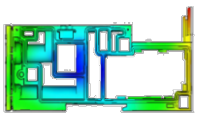
Tools	Area of application and customer questions
Simulation of structural mechanics 	Structural mechanics is used for the computation of deformations, forces and internal stresses in components to prevent damage and leakage problems. The program provides answers to questions such as: • Has allowance been made for housing deformations occurring during the assembly process? Have safety factors been included? • What happens with highly dynamic working pressures? Can these result in cracking or settling, in turn leading to leakages?
Simulation of thermal influences 	Thermal simulation helps to design valves/valve terminals that can withstand extreme situations and prevent failure through overheating. The program provides answers to questions such as: • 100% duty cycle, fast switching position changes, welding environments, cleaning cycles or warm air can lead to temperature rises on printed circuit boards and/or on valve terminals. Can the valves withstand these effects? • Has the circuit been selected correctly and have the components been placed correctly on the printed circuit board? • Have the correct materials been selected with regard to the temperatures involved?
Simulation of air flow 	Flow simulation is essential in order to obtain maximum flow rate performance and the most efficient valves possible. The program provides answers to questions such as: • Can droplet formation occur in the valve due to its geometrical shape? • It is crucial for high energy efficiency that flow rates are as high as possible and pressure drops are as low as possible. Has this been taken into account? • Have the flow-related loads that affect components (e.g. pistons) and that may lead to increased valve wear been determined?
Simulation of seal behaviour 	Freedom from leaks is crucial for reliable valve operation. The Shore hardnesses of the seals affect this. The program provides answers to questions such as: • Thermal expansion of the housing and inadequate seal tolerances with high Shore hardness can cause micro leaks. Has allowance been made for this? • What happens to sealing rings at high operating pressures (e.g. 10 bar) or with dual-pressure operation (vacuum/compressed air)? Can deformations occur, leading to leaks?
Simulation of injection moulding or die casting 	A simulation of the casting process helps to assess quality and ensure a reliable production process. The program provides answers to questions such as: • Do cavities develop in the housing during the cooling process? In the course of subsequent spot tests, for example using computer tomography, the points with an especially high number of cavities are closely investigated. • Component twisting resulting in deformation tolerances can cause leaks. Have simulations been carried out to determine optimum tolerances? • How were the moulding point, degree of distortion, joins, glass fibre orientation and degree of shrinkage determined in order to ensure a stable manufacture process in subsequent series production?

Table 1: Development tools and data gathering

Not all manufacturer data is comparable 1 to 1! – The important points to bear in mind –

If you need a heavy-duty valve terminal for use in a welding environment, metal will be the preferred material. If, on the other hand, a valve needs to be lightweight or corrosion resistant or is intended for an application where low electrical conductivity is necessary, the recommendation will usually be for a plastic valve. When you compare quotations, you should not look only at the price as the various types of plastic are not all the same. In many cases, too, data-sheet values will not be comparable 1 to 1. Here is a short list of points to bear in mind.

Plastics

Plastics are today's promising materials for the future. And while alloys are standardised with regard to their composition and technical characteristics, there is no such standardisation for plastics. There may therefore be significant differences between different media with regard, for example, to stress crack formation or creep behaviour at higher temperatures. Any price difference between comparable products may be due to the fact that a high-tech polymer has been used for one of the products, which may be useful under specific climatic conditions or when the product needs to be resistant to cleaning agents used in the food industry.

Leak testing and IP classification

Leak testing and IP classification are carried out under standardised conditions. You should ask the manufacturer whether he can demonstrate that tests beyond the requirements of the relevant standard are carried out. For example, Festo conducts exposure tests before leak testing and IP classification. During these tests, components are exposed to changing temperatures in order to investigate factors such as creepage with plastics. This is the only way to guarantee that a bolted-together plastic valve will remain leakproof when subjected to varying temperatures and the associated and setting processes.

Flow data

Always check when comparing flow rate data that this is based on the same standard, such as ISO 6358, and that data has been measured or converted in accordance with this standard.

Switching times

Not all manufacturers have the same views when it comes to ways of defining switching times. Switching times always start with the triggering of a switching pulse, but the definition of the end of the switching time varies. Some manufacturers quote the time until the standard nominal flow rate is reached, or at least a certain percentage of this, while others take the time until the control slide has completed its full switching travel. You should therefore ask the manufacturer whether response times have been determined in accordance with the specifications of ISO 12238 or whether another standard such as JIS B 8375-1981 has been used.

European manufacturers usually measure in accordance with ISO 12238. This measures the switching time as the time taken from the moment a switching pulse has been triggered until 10% of the defined measuring pressure has been reached.

Minimising risk through further tests

Today, high quality is a must for every valve manufacturer. What varies greatly between manufacturers is the number and variety of tests and the equipment available. Not every supplier has its own EMC laboratory, scanning electron microscopes, computer tomographs etc.

Fig. 1: Testing the electromagnetic compatibility of valves in Festo's EMC laboratory

Festo, for example, carries out flow tests with valve terminals fitted with their maximum equipment level, not just with single valves. This allows precise measurement of back pressures or pressure drops when several valves are actuated simultaneously. Tests in areas such as extreme temperature, control voltage or maximum pressure are also carried out as standard. You should also consider whether or not additional quality tests of this kind have been carried out choosing valves/valve terminals. This is particularly important in industries such as the automotive industry where every hour of downtime costs several thousand euros.

Small differences in your choice of valves/valve terminals - with a great impact!

As a decision-maker, you know your interests. At the same time, you should not forget the needs of your end customers or equipment suppliers. As a basic principle, valves or valve terminals must meet the necessary technical requirements such as flow rate, function, available installation space, IP class etc. The section below advises you on what other factors you should bear in mind.

Exploiting modularity to implement optimizations

Different customer applications or requirements often use different electrical interfaces. For example, there may be a bus system in one installation and the common low-cost multi-pin connector solution in another. Would you like to avoid any possible space problems in your control cabinet or in your installation and be able to use the same mounting holes every time? Then you should ensure that, even with changing electrical interfaces, the footprint of your valve terminal remains constant.

Does a customer wish to expand the installation and does the valve terminal need to vacuum compatible? Or do you simply need an additional pressure zone with low pressure? In this case, it can be helpful to have a simple and fast means of changing between external and internal pilot air. This is the only way of avoiding the potential problem of not having sufficient pilot pressure for the valve.

In those cases where valves are triggered via a bus system, it can be interesting to have expansion options which can turn a central installation concept into a decentralised concept. This can provide a solution if you have problems with cycle times – and this changeover can be made even after the system has been installed.

To sum up: check that the valve terminal you choose has options for expansion. This can save you having to buy a new valve terminal.

Cutting energy costs

Energy costs are an ever more important factor in production operations. With valve terminals, the crucial factor is the cost of compressed air. Power-saving functions for valve actuators are a good idea and important for thermal reasons, but the potential for cutting energy costs is much less than with compressed air. With regard to pneumatic components, you should consider what air quality is specified for your valves/valve terminals. If, for example, the air quality specification calls for a maximum particle size of 5 µm, the necessary fine-mesh filters will cause considerably higher pressure losses. The graph on page 6 shows that with a primary pressure of 6 bar and a flow rate of 4000 l/min. (for approx. 13 valves each consuming 300 l/min.), the resulting pressure loss Δp will be 1.25 bar. With a 40 µm filter, this pressure loss Δp will be considerably smaller. In order to achieve a secondary pressure of 6 bar, the primary pressure only needs to be increased by 0.85 bar. This difference of nearly 50% will be reflected in a saving of air consumption. The costs savings possible with a pressure loss of 1 bar and a holding current reduction circuit can be seen in the column "Reducing pressure losses and electricity consumption" by clicking on the brochure:

›› Energy efficiency@Festo – Solutions for a profitable and sustainable future ‹‹

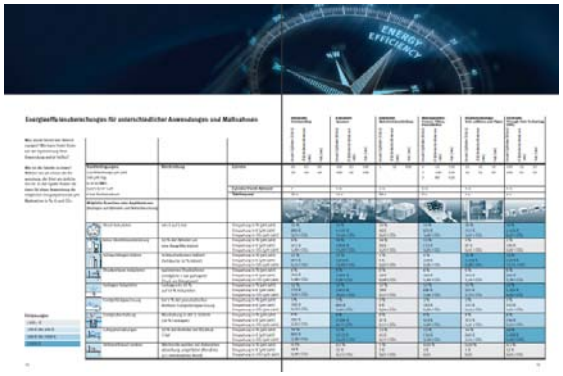
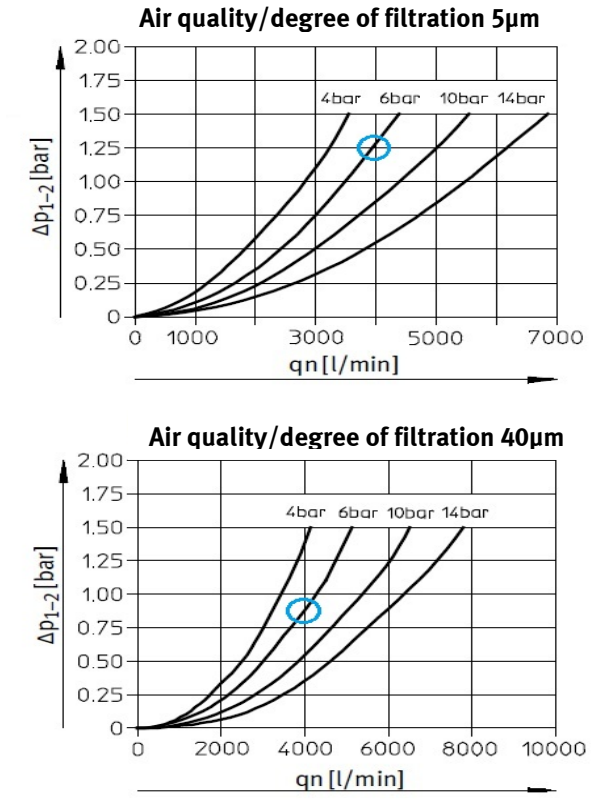


Fig. 2: Table on page 12 with energy efficiency calculation

Pressure zones are another way of optimising air consumption. Low-cost seals allow you to match the air flow precisely to varying requirements. Check the maximum possible number of pressure zones.

Manufacturers such as Festo also offer reverse valve operation. By using two different pressures for advance and return strokes, you can achieve a further energy saving (of up to 50% compared with standard operation). At the same time, exhaust capacity and speed are also increased.



Graphs 1: pressure losses with 5 µm and 40 µm filters

Servicing for an easier life

Would you like to minimise servicing times and costs as well as installation times? Then good, clear labelling of pneumatic and electrical connections is a must. Check whether you can fit label holders. This reduces the time spent searching for connections. And there is no need to drill additional holes for label holder attachments.

Visual aids such as LEDs or QR codes provide additional help in identifying and correcting a problem faster. Products can now be identified quickly, easily and reliably with a barcode/QR code reader on a mobile phone. This virtually eliminates mistakes when buying spare parts. What is more, features such as captive screws and seals, larger bolt heads etc. make the work of service technicians easier. These features should be available not only in special configurations but as standard – after all, looking for a lost securing bolt in or under a large machine frame when changing a valve costs unnecessary time and energy.

Fig. 3: Try out this sample QR code out by simply scanning it with your smartphone

If you need manual overrides on valves for adjusting cylinder sensors or other operations, the detenting type is very helpful. However, these can also represent a risk for service technicians and general safety. A valve whose manual override has been left detented by a technician during commissioning can lead to a lengthy search for software or electrical problems, while careless pressing the wrong manual override can result in a safety risk for people and machines. If you wish to avoid these situations, make sure the solutions you choose allow changes to be made simply and conveniently even after installation, for example by making it possible to turn a detenting manual override into a non-detenting one or disabling manual overrides completely.

Backup: a reserve to deal with surprises

If you are building an installation or machine for the first time or if you often need to provide for individual customer wishes on a series-produced machine, it is advisable to have one or two reserve valve positions and options on a valve terminal. Note how many valve positions are available with a fixed-grid or modular valve terminal and whether a size mix of valves or vacuum operation is possible. That will enable you to react quickly if you need an additional valve or the flow rate of the current valve provides to be too small, and the cylinder therefore advances too slowly or if, unexpectedly, vacuum is required. Make sure you compare the performance of the valves of different manufacturers and their suitability for vacuum.

You should also check the maximum permissible air pressure on a valve terminal. Otherwise, if you suddenly need an operating pressure higher than the usual 6 bar, this may be a problem. You should therefore choose standard solutions which go up to 10 bar. This provides you with a safety margin which offers options for higher performance. A pressure which has inadvertently been set too high can also cause leaks at valves, thus shortening their service life. With a standard 10 bar pressure, you may in certain cases even be able to use a smaller valve, which saves space and money. A 10-bar standard will significantly reduce the number of complaints received because of valve problems.

Be on the safe side with quality – taking a close look is well worthwhile!

Even very low-cost valves and valve terminals vary greatly in quality. A decision in favour of high-quality valves and valve terminals in this price bracket does not have to mean substantially higher cost – it may even be less expensive. By choosing extremely well-tested material properties, a high degree of modularity and a wealth of standard features such as 10-bar operation, it is possible to prevent many problems. For example, where an actuator actually needs a pressure of more than 7 bar, or if there is a need to switch vacuum or speed up a process by reversing operation in order to exhaust a cylinder faster.

There are therefore a number of questions that you should put to component suppliers to make sure that you feel you have made the right choice of valve or valve terminal. These questions relate both to the development process and the choice of materials, and also to detailed and comparable manufacturer data, the selection of the best valve design for a given application and other characteristics. The range of services which a manufacturer can offer and the available safety margins may also be used as criteria in choosing better products.

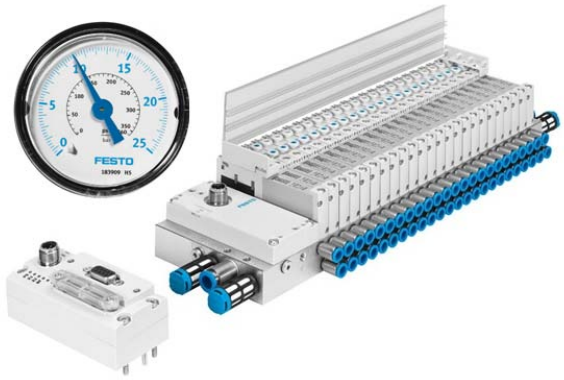


Fig. 4: Valve terminal VTUG for pressures up to 10 bar, with manual override capable of subsequent modification, a CTEU fieldbus node and a label holder

Criteria for installation operators

The main criteria affecting the decisions of end customers are usually factors such as energy efficiency, services, fast product documentation using QR codes, process reliability and long service life backed up by manufacturers' R&D tests, and fast availability.

Criteria for OEMs

Of course OEMs want to meet the requirements of system operators. Above and beyond this, they generally attach great importance to a high degree of modularity, which reduces the need to keep supplies of spare parts while it also enables them to react quickly to requests for expansion options and additional functions.

These factors very quickly generate a savings effect, particularly for users who install large quantities of valves or valve terminals. For OEMs, this fact is a good argument to use with customers – and gives the security of knowing that high-quality products mean a significant reduction in the numbers of complaints. Good advice which helps users to choose optimum solutions with an excellent price/performance ratio always pays for itself.

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