Scheugenpflug
Part of the Atlas Copco Group

Maximum Performance Through **Vacuum Potting**

The performance of electronic components is compromised by factors such as bubbles in the potting medium. Increasing numbers of applications – particularly in the automotive and electronics industries – therefore require completely bubble-free dispensing methods. This is where potting in a vacuum comes into focus. The widespread school of thought about this technology is that it is too complicated, too expensive and too slow. But a closer look shows that this view is incorrect. This is a mastered technology.

As for costs, the calculation basis is key, since usually the potting and vacuum method is only considered after the required potting quality cannot be achieved reliably any other way. Under total cost of ownership assessments, higher system costs no longer play a key role, since component failure would result in much higher subsequent costs. And now there are proven solutions for high production volumes and/or shorter cycle times.

This whitepaper explains when potting in a vacuum is ideal for your projects and what to be aware of.

#Completely bubble-free potting

Three key questions

Contents

How do bubbles form during the potting process?

There are two reasons why undesired air bubbles may form during potting:

→ The potting material may not displace the air in the component at the desired spots.
→ Preparing and applying the potting material introduces air into the potting process.

Why is it important to avoid air bubbles during potting?

Air bubbles that form when potting electronic components cause a range of problems that, depending on the quality requirements, usually cannot be tolerated or can result in component failure:

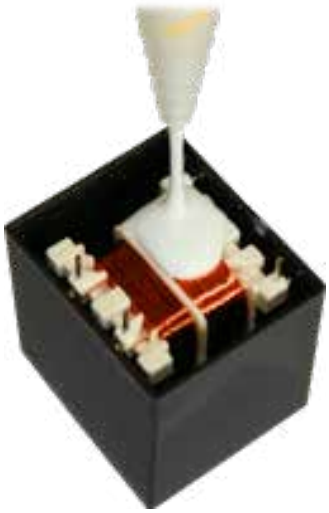
→ Bubbles expand under thermal load, resulting in stresses inside the workpiece. This compromises the component's function and, in the worst case, leads to cracks in its outer layer.
→ Air bubbles have poor thermal conductivity and thus increasingly impair the desired potting function.
→ Air bubbles reduce the insulation quality and thus the high-voltage resistivity of the components.
→ Air bubbles promote corrosion in components.

When is potting in a vacuum advisable?

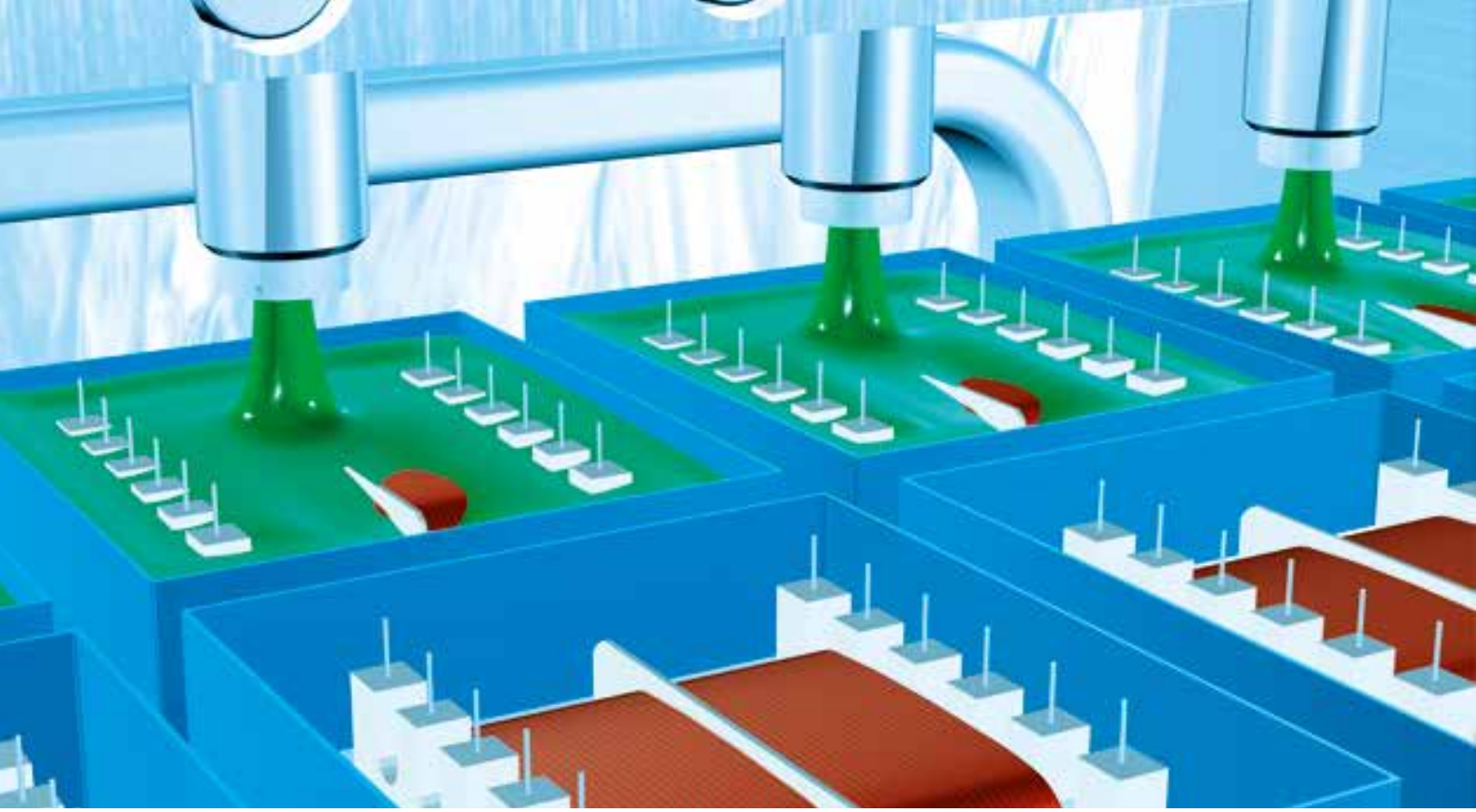
In many applications air bubbles can be tolerated to a certain extent from a functional point of view. However, increasing numbers of electrical components have structural and quality requirements that demand completely bubble-free potting. This short checklist can help you determine when potting in a vacuum is appropriate:

- ☐ The spaces in the component to be potted are extremely small and atmospheric-pressure potting is not possible – **#miniaturization**
- ☐ The complex structure of the component (e.g. many undercuts) does not allow for bubble free atmospheric-pressure potting – **#component design**
- ☐ Sensitive electronics must be fully and reliably protected from outside influences (moisture, dirt, etc.) to guarantee sustainable product use – **#functional quality, #high-performance applications**
- ☐ The potted electronics fulfill their safety functions – **#safety, #reliability**
- ☐ Potting is part of component thermal management, which means that heat must be reliably dissipated – **#functional quality, #high-performance applications, #reliability**
- ☐ Potting should reduce thermal loads in the component – **#functional quality, #reliability**
- ☐ Potting should reduce a component's fire risk – **#safety, #high-performance applications**
- ☐ Potting is used to protect electronic components from corrosion – **#functional quality, #reliability**
- ☐ Components should be potted if potting in a vacuum is increasingly becoming the standard for that component – **#coiled products** (stators, regulators, transformers), **#high-voltage components** (isolators), unprotected wire coils and enameled copper wires

If one or more of these points apply to your products, then they meet the potting requirements, so, if you have previously had bad experiences or if you clearly do not want to take any chances, then potting in a vacuum is the technology that will provide the desired results.



Air bubbles during potting compromise how electronic components function in many ways – whether a component is potted in a vacuum or under ambient air conditions, what ultimately matters are the requirements for a quality component



Potting solenoids with a multi-nozzle dispenser in a vacuum

#Potting in a vacuum

The method

This method works

Unlinke than a technical vacuum with its strong negative pressure, vacuum potting of electronic components only reduces pressure to a maximum of 1 mbar. And with good reason: Reducing the atmospheric pressure any further results in a longer evacuation time and higher energy costs. The vacuum should therefore be specifically adapted to the particular task. Even the size of the chamber to be evacuated (the component size is a factor in this case) affects the evacuation time: the greater the volume of air, the longer the evacuation cycle. With a view toward ever shorter cycle time requirements, the use of high-performance vacuum pumps today allows for optimal evacuation times.

A slight negative pressure also has its advantages in terms of component stability. Not every component can handle a sharp drop in pressure. While coiled material is for the most part unaffected by such conditions, air trapped in a capacitor can cause the component to crack under external negative pressure. Usually the negative pressures during vacuum potting are between 2 and 100 mbar. This alone is not enough to be completely free of air bubbles. At these pressures, traces of air trapped by the potting material can still be found in the component. This air must be eliminated through the potting sequence and must be displaced completely by the rising potting material.

The potting process always takes place in a vacuum chamber – particularly in the case of coiled material – in three steps:

1. Initial filling with potting material in a vacuum
2. Intermediate venting to press material deeper into the coil
3. Finishing layer in a vacuum

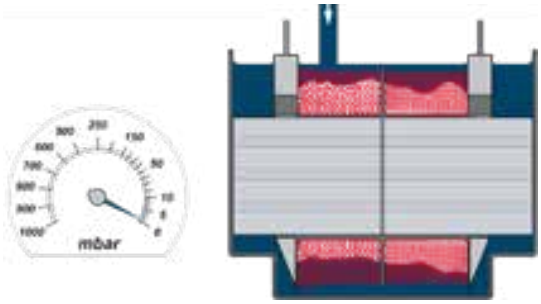
Practical tip: Vacuum potting involves minimal negative pressure, thus eliminating the possibility of component damage.

▷ *Video: Learn more about potting in a vacuum*

1

Filling in a vacuum

The potting material starts to fill the small gaps between the wires.



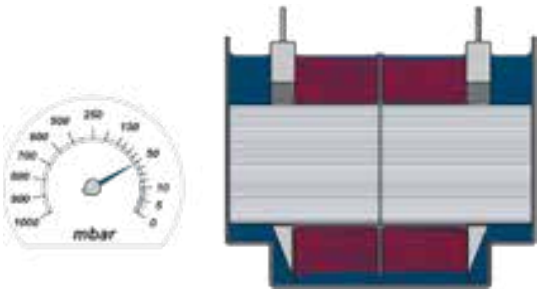
The process steps in the example of potting a coiled product

- *Potting material*
- *Coil*
- *Gaps between the coiled wire*

2

Intermediate venting/pressurization

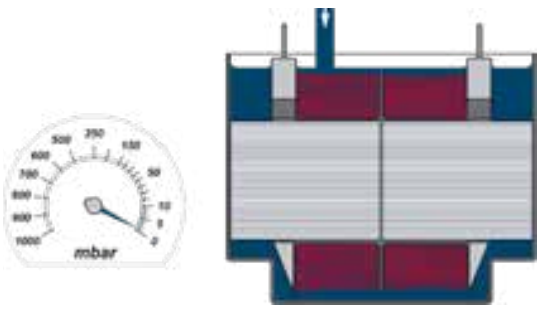
Intermediate venting increases the pressure inside the chamber. This drives the potting medium deeper into the small spaces.



3

Finishing layer in a vacuum

The finishing layer ensures that the component is evenly coated with the potting medium.



UViS 5 user software for efficient system control

These finely coordinated substeps are controls by cutting-edge system controllers. The intuitively operated system controllers visualize all relevant machine data (for example, target and actual vacuum values, good and bad parts, processing times, machine availability). The metering and dispensing system can also be connected to higher-level customer controllers (customer server), for example to exchange data and to control multiple system components centrally using one system. For optimum quality assurance and traceability, all relevant control data is documented and, if required, exported.

#Potting in a vacuum

The process steps

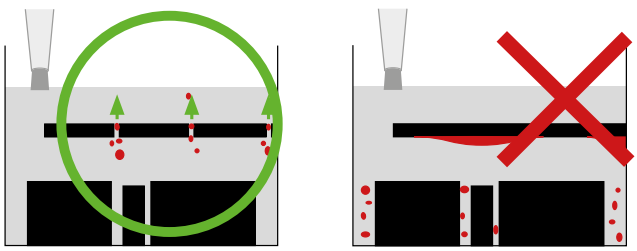
The ideal potting process starts during development

Miniaturization and increasingly more complex components with several undercuts are challenging for absolute bubble-free potting. Even horizontally positioned, wide stretched component parts can trap rising air below them and prevent it from escaping. If, for example, coiled material is placed under such a surface as shown below, the remaining air caught between the wires cannot rise to the surface. Moreover, many coils and gaps to be potted are so small that they can only be filled using the bubble-free vacuum potting process. It is therefore recommended to take pourability for potting into account as early as during the component development stage. Tests in the Technology Center provide clarity here if necessary. If for various reasons this is not possible, potting in a vacuum always gives you peace of mind.

Once the decision has been made to use vacuum potting, the focus shifts to production. And here one thing is crucial: For completely bubble-free potting, the entire preparation, feeding and dispensing process must take place in a vacuum. After all, air bubbles are undesirable in more than just the finished potted component. They can cause a variety of problems even during potting - always at the expense of productivity. If the air bubbles reach the dispenser, they may cause errors in the quantity of potting material required and distort the mixing ratio. The consequences range from irregular production results to an increase in rejected components. The potting material is therefore already prepared in a vacuum. To prevent the degassing of micro-bubbles during vacuum potting, make sure that preparation takes place at a lower vacuum pressure than that used during the subsequent vacuum potting procedure (e. g. 5 mbar during preparation, 50 mbar during vacuum potting).

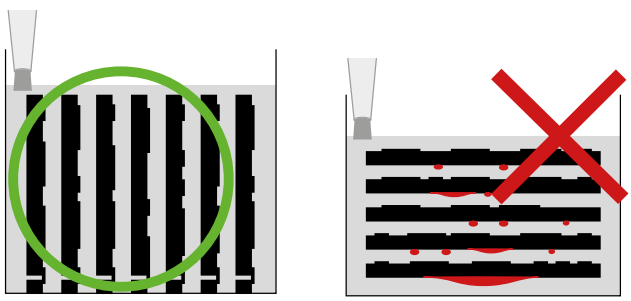
Practical tip: The component design plays a large role in the future potting process. The smaller the gaps to be potted are and the more complex the component is, the more likely potting in a vacuum will be used.

Vent holes



Horizontal workpiece surface with and without vent holes

Optimized arrangement of flat modules



Vertical arrangement compared to horizontal arrangement of workpiece surfaces

LiquiPrep LP804 material preparation and feeding system

Practical tip: For completely bubble-free potting, the entire potting material preparation and feeding process must be carried out in a vacuum.

Video: Learn more about bubble-free material preparation with LiquiPrep LP804

Material preparation is key

For completely bubble-free potting results, make sure that the entire potting material preparation and feeding process is carried out in a vacuum. A high-end processing system (such as LiquiPrep LP804) removes the dissolved air through thin-film degassing. An agitator provides degassing support in a vacuum tank by circulating the potting material. This lets the dissolved air rise to the surface of the potting material where it comes in contact with the surrounding vacuum. The degassing effect starts at the uppermost surface layers of the material. This much is true: The lower the viscosity of the material, the easier it is for the trapped air bubbles to rise.

The degassing effect starts as soon as the system is being filled with potting material – as shown in the picture – or later during circulation of the material via the tank cover. This is particularly true when the material flows over a wide-stretched discharge plate and the tank wall – as in the case of LiquiPrep LP804.

Picture at left: Efficient thin-film degassing through conical tank and large discharge plate

Picture at right: The right material temperature control is important for potting productivity

Adequate heating in many cases further reduces the viscosity of a material and accelerates the degassing process. In addition to faster and easier processing, air bubbles in the material rise faster, making any required evacuation easier. However, keep in mind that filled media tend to settle faster in the form of sediment in this case. This process can be counteracted by appropriate agitation and circulation of the potting material. To achieve a continuous and constant temperature, all process components, including storage tanks, material feed lines, pumps and dispensers, etc., should be heated. Caution is advised in the case of potting compounds that cure when heated. Conducting a series of experiments with such potting media is recommended before using them in production.

To prevent introducing more air during the feeding process, all screw connections, material feed lines, pumps and valves must be hermetically or vacuum sealed.

The material preparation requirements depend on the potting material used. Particularly with 2C materials, there are resin systems that cure by moisture. To trigger a reaction, all it takes is to expose the potting medium to the ambient air (air humidity) for an extended period. On the other hand, moisture can lead to undesired secondary reactions in certain resin systems. When the resin is mixed with the hardener in 1C materials, the hardener reacts with the moisture absorbed by the resin. This leads to the formation of CO_2, and the material starts to foam. The unmixed hardener also absorbs moisture, enabling the formation of crystals. In the worst case, these crystals clog the machine filter. Adequate storage, completely emptying the drum and preparing the material in a vacuum can minimize such risks. If possible, moisture-sensitive resin compositions should be kept under vacuum in a preparation system after opening. Contact with moisture can thus be completely prevented.

Gentle preparation of the potting material in a vacuum is important in order to prevent damaging the material. For example, an excessively high vacuum value during preparation can cause outgassing of the material components. Make sure that the vacuum value is not below the permissible vapor pressure shown on the material data sheet.

*Perfect **mixing** depends on the materials*

In vacuum potting, mixing 2C materials takes place directly in the mixing tube prior to application. The resin and hardener are homogeneously mixed. The static mixing tube made of synthetic material is an inexpensive and effective option. This type of tube contains several helical mixing panels placed one after the other. The 2C potting material flowing through the tube is fragmented a billion times, depending on the number of deflection surfaces present and is then merged again with a phase offset until uniform mixing and thus curing is guaranteed by the reaction of the resin and hardener. Static mixing tubes are inexpensive for a variety of reasons. For example, since it is possible to dispose of and replace a mixing tube with a new one after a shift change, laborious cleaning is not necessary. There is also no risk of cured residue in the mixing tube soiling the newly added potting material. This system is maintenance free and the mixing tubes are affordably priced.

Practical tip: Static mixing tubes guarantee homogeneous mixing of two-component materials using a helical mixing shaft.

The agitators are always adapted to the particular material to achieve optimum results

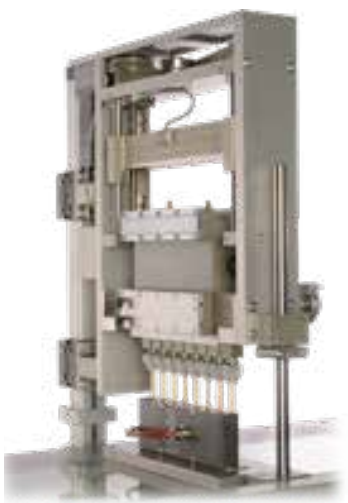
▷ *Video: Learn more about static mixing principle*

Piston dispenser arrangement with multiple outlets

The **metering and dispensing system** determines the productivity

The key criteria here are precise and reproducible dispensing quantities of components A and B of the 2C materials. It becomes inaccurate where the dispensing is affected by pressure, temperature or viscosity fluctuations. A volumetric metering principle with mechanically defined mix ratio and monitoring of quantities to be metered increases process reliability and guarantees consistently high quality. Particularly in the case of vacuum potting, the metering and dispensing system must be perfectly synchronized to the material preparation and potting process. A user-friendly metering and dispensing system should be designed in such a way that both components only come in contact after dispensing, for example in a static mixing tube. This prevents the resin and hardener from reacting in the metering head or failure in the complete metering and dispensing system. High output and short cycle times are achieved through multi-nozzle dispensing, i. e. with systems with up to twelve outlets. Controlled release from mixing tubes or direct nozzle controls for a flexible line design is possible. No-part no-fill requirements can easily be achieved this way.

Practical tip: Multi-nozzle dispensing, superior dispensing accuracy through volumetric dispensing and low-maintenance, robust designs make today's cutting-edge vacuum systems extremely effective.



Multi-nozzle dispenser for high production output

▷ *Video: Learn more about bubble-free material dispensing with the Dos P-X multi-nozzle dispenser*

#Potting in a vacuum

Real-world example: complete potting of a stator

Stators built into the electric drives of e-bikes, for instance, are usually fully potted. The potting is used for optimal electrical insulation and heat dissipation solution. In addition, the coils are fixed in place by the potting material to prevent short circuits in the event of vibrations. The stator is protected from dust, moisture and chemical substances. The **#functional quality** is guaranteed by absolutely bubble-free potting in a vacuum.

As preparation for the potting process, the stators are first heated up in a furnace. Heating the components eliminates residual moisture, which can negatively impact the potting result. It also improves the flow of the potting material down on the warm housing walls. By adjusting the temperature of the potting material, the viscosity is reduced and the fluidity is improved.

The design and shape of the workpiece also plays a major role in the future potting quality. At the same time, the solenoids must be covered completely with material during the potting process. During the production process, it is also important to make sure that electrical contacts are not covered with potting material. This is where precise insertion of the material is necessary. The material is therefore applied across multiple dispensing points to ensure even distribution of the material inside the workpiece. These points must be accessible without any constraints and must be taken into account when designing and shaping the workpiece and designing the system. Since no two stators are alike, all relevant parameters, such as the sufficient potting quantity for complete coverage or the material curing time, are determined through testing in the Technology Center before production runs. All these requirements are now easily fulfilled by potting in a vacuum. The **#functional quality** of the stators is thus guaranteed for long and trouble-free operation under a wide range of climatic conditions. And vacuum potting with our integrated solutions also meets high **#design requirements**.

Advantages:

- Completely bubble-free potting of the smallest spaces
- Optimized cycle times
- Quality control and traceability of potting quality

Your requirements

Perfect insulation and heat dissipation

Our expertise

The perfect solution

For components with smallest potting spaces

- Material feeding unit: LiquiPrep LP804
- Dispenser: Dos P-X
- Process automation: VDS P

Video: Learn more about LiquiPrep LP804

Info: Learn more about Dos P-X

Info: Learn more VDS P

#Potting in a vacuum

Real-world example: isolator potting

During the production of isolators, bubbles in the potted workpiece cannot be tolerated. Since these high-voltage components must meet the highest **#functional quality** and **#safety requirements**, potting in a vacuum is increasingly used in this process. If there are still problems with moisture in the workpiece, which can negatively impact the potting result, a process is available for drying the workpieces prior to potting. Additional challenges during isolator potting include workpiece handling (size and weight of workpieces) as well as the volume of potting material needed – usually > 500 ml/workpiece. In addition, quality control of the dispensing procedure is important due to the safety-related function of the isolators. A failure or malfunction can result in the risk of serious or fatal injury. Quality control by monitoring the relevant dispensing parameters (such as shot weight to control the dispensing volume) has proven its worth.

Usually a 2C silicone, which cures at room temperature, is used as the potting material. For these workpieces, it is advisable to always conduct pre-production tests in the Technology Center. In this case all critical process parameters, such as the ideal vacuum in mbar, are determined. In principle, the value selected is as high as possible to achieve the shortest possible cycle times with optimum quality results. With these test results and high-performance potting systems even large workpieces can be potted completely bubble-free and economically. **#Functional quality** and **#safety** under all operating conditions are thus guaranteed with regard to the potting result.

Advantages:

- Completely bubble-free potting of large workpieces
- Optimized cycle times
- Quality control and traceability of potting quality

Your requirement

Maximum safety

Our expertice

The perfect solution

For large components with high quality requirements

- Material feeding unit: LiquiPrep LP804
- Dispenser: Dos P050
- Process automation: VDS U

Video: Learn more about LiquiPrep LP804

Info: Learn more about Dos P050

Info: Learn more about VDS U

Picture at left: Designing, planning and testing the potting project

Picture at right: Implementing the potting process in the production environment

#Potting in a vacuum

Project and services

The perfect potting result is due to teamwork

For vacuum potting, various relevant parameters must be taken into account. In addition to production line technology, the earliest possible dialogue paired with the know-how and experience of your system partner are key. Employees from your company engineering/design, production, quality management and purchasing departments complete the team. After all, process-safe and efficient dispensing is always a team effort. This should start with the design and shape of the workpiece during the development stage, because then critical requirements related to potting will already be defined. During production, in addition to preparation, mixing, metering and dispensing, all production steps related to the potting process must be taken into account. This whitepaper focuses on complete bubble-free dispensing in a vacuum. However, when producing electronic components, pre-treatment and cleaning of dispensing bottles and – after dispensing – workpiece assembly, curing and inspection and test routines are also extremely important. It has been proven to be worthwhile to always take a holistic approach to the production process.

Maximum productivity through a comprehensive network of experts

From completely bubble-free potting to maximum productivity

High-performance metering and dispensing systems ensure completely bubble-free as well as quality potting results. But optimum productivity in electronics manufacturing means so much more – and this is where our services come in:

1. When your product requirements and production quantities change, our modular stand-alone and integrated solutions offer you new options.
2. If you are developing groundbreaking components, testing should be done to validate assumptions before production. Our **Technology Center** is ready for you.
3. We work closely with our **Potting Material Manufacturer Network** to solve your material issues.
4. Your employees have a lot of control over how to get the most out of our systems. Our **Academy** offers a comprehensive training and instruction program to show them how.
5. Our **After Sales** team ensures that you have optimum system availability – worldwide, remotely and on site.
6. And whether you want to start immediately with vacuum potting or want to accumulate some experience first, our **Equipment Rentals** are an attractive option.
7. Or you can choose to subcontract small batches. When potting small quantities, **Subcontracting** is always worth considering as a stopgap solution until delivery of the ordered system, or when production peaks need to be absorbed on short notice. Our dipotec subsidiary will gladly assist you with this option.

When atmospheric-pressure potting cannot meet your quality demands, vacuum potting is a relatively inexpensive, uncomplicated and fast alternative. And if vacuum potting is the ideal solution for you, we can use our knowledge, expertise, high-performance technology and experience to help you while also ensuring that you are able to implement this potting technology as economically as possible so that your products can meet quality demands.

Would you like to learn more about vacuum potting?

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