

# Processing Of Cast-Resins based on Polyurethanes

Stand 2.11.07 ref veröffentlichung vergießfehler eng. trans.

## ***Introduction:***

Many technical applications in different branches of industry require protection against environmental influences, electrical or mechanical interference, and manipulation. In many cases this protection can be achieved by the use of cast resins. ISO-ELEKTRA is manufacturing potting compounds with a wide range of properties. Most of the cast resins produced by ISO-ELEKTRA are based on polyurethanes or polyurethane-epoxy combined systems. The properties of these systems can be adjusted over a very wide region. Therefore an optimal customisation with regard to the customers task is possible. In the following, a short overview on the chemical background of polyurethanes will be given. Subsequently possible potting errors and measures for their prevention will be discussed on the basis of practical examples.

## ***Chemical Fundamentals:***

Polyurethane cast resins are two-component-systems consisting of a resin- and a hardener-component.

The resin component is based on polyols, that are equipped with fillers and additives in most cases. Polyols are compounds with higher molecular mass. They consist in almost all cases of polyethers or polyesters. The main feature of this two classes of substances is the hydroxyl, also called alcoholic, functional group, that is carried in different numbers depending on the polyol.

The hardener component is made up of the isocyanate substance class.

The curing of polyurethanes to polymeric plastics is based on the reaction between the hydroxyl group of the resin and the isocyanate group of the hardener. In the case of so called chains reactions (polymerisation), it is theoretically sufficient to start the reaction at one point in the reaction mixture. For the two component polyurethanes a real close proximity between the two reacting compounds (functional groups) is needed, which means that a homogeneous mixture of hardener and resin has to be achieved by any means.

The isocyanate group is able to react with water. If this reaction occurs, gaseous carbon dioxide is formed within the reaction mixture. This reaction is desired in the manufacturing of polyurethane foams, where the carbondioxide is the blowing agent in many cases. However the reaction is totally undesired for potting applications because the cured cast resin will be more or less loaded with bubbles. This means usually a loss of mechanical and electrical properties of the cured material.

Reaction:  $2 \text{R-NCO} + \text{H}_2\text{O} \rightarrow \text{R-NH-CO-NH-R} + \text{CO}_2$  (gaseous)

Due to this reaction the polyol component of polyurethane cast resins is equipped with water-absorbing materials, mostly zeolites. Suitable zeolites possess a high affinity towards water.

They bind or remove free water from the reaction mixture, securing an undisturbed reaction of the resin component with the hardener component to the polyurethane.

**Modern polyurethane systems are characterised by good working properties. If few basic guidelines are kept in mind during the processing, reproducible potting results with high quality properties of the cured materials can be achieved.**

### ***Manual Potting:***

In the most simple way of casting, both components are weighted accordingly to the required mixing ratio. Then the mixing is done manually. This practice is found for example at construction sites, small series manufacturing, job-works or experimental potting.

For correct processing both components have to be mixed homogeneously (free of streaks) in the required mixing ratio. In addition no air bubbles should be mixed in the reaction mass.

After careful mixing the cast resin has to be processed within the potlife given by the manufacturer. After the potlife is exceeded, air entrapment in the parts becomes very likely, due to the already high viscosity of the resin, if the casting process is not stopped.

### **Curing Error - Streaks**



figure 1: inhomogeneous mixture

#### **Error**

Both components weren't mixed homogeneously in the shown sample plate. The clearly visible streaks are showing unmixed areas of resin / hardener component.

This behaviour may be also caused, if resin and hardener are not fully compatible.

### **Solution**

A flat, ruler like stirring staff of a size adjusted to the mixing vessel has to be used. Apply a slow (approx. 2 rps) circular mixing pattern till the material is free of streaks. Take care to strip off the walls of the mixing vessel continuously.

If filled or pigmented cast resins are used, the resin component has to be stirred up well before adding the hardener.

### **Attention:**

Machine driven, propeller like agitators with high rotational speed are not suitable for mixing cast resins.

In the case of incompatibility of resin and hardener at the beginning of the curing process stirring has to be applied until the curing reaction starts (development of heat). Demixing of the components can be avoided by this way.

### **Curing Error: Entrapment of Air bubbles**



figure 2: Air bubbles were mixed in this sample

#### **Error**

Air bubbles were stirred in during the mixing of the resin and hardener components. Single larger air bubbles are a good indication of this failure.

#### **Solution:**

Stirring has to be applied in a slow ( 2 rps), steady circular movement, for a sufficient time (refer to producers specification). Do not use a fast agitator. Remaining air bubbles can be removed from the surface of the mixture by carefully blowing (hot) air on the surface of the cast resin, while it is still liquid.

#### **Attention:**

Machine driven, propeller like, agitators with high rotational speed are not suitable for mixing cast resins. Round rods (thermometer, screwdriver) or unsuitable for stirring.

### **Curing error: – Foam**

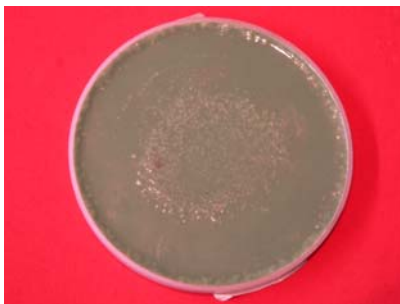


figure 3: Contamination with humidity/water

#### **Error**

Many small foam like bubbles indicate humidity in the cast resin.

#### **Solution:**

Package should be sealed airtight or consumed within one day after opening. Cast only dry components. Condensation of air moisture at the parts should be avoided, maybe by predrying. (For instance polyamide has an especially high humidity uptake).

#### **Attention:**

Entrapped air bubbles work as seeds and intensify the humidity induced formation of foam.

## ***Systems For The Manuel Processing***

If mixing by hand with a stirring bar isn't practicable, due to the number of parts, there is an "intermediate" solutions between processing by hand or machines. For this purpose polyurethane cast resins are offered in prefabricated working packs which contain both - resin and hardener.



figure 4: ISO – PUR K 711 S 80 cast resin with good thermal conductivity

### **Double chamber bags:**

Double chamber- or two chamber-bags contain the hardener and resin compound in the correct mixing ratio. For processing a separation bar has to be removed and the bag is kneaded afterwards until a homogeneous reaction mixture has formed. Then the

bag is opened and the cast resin is poured into the component. Mixing errors are excluded, because the hardener and resin components are already weighted. Reasonable sizes for the use of these bags are between 100 ml and 2500 ml. Although the number of parts that can be processed by this method is limited, because the bags have to be kneaded by hand. If double chamber bags are used, the air entrapment is also reduced to a minimum, because the mixing process is conducted within the closed bag. The mixing process can be controlled if the bag is transparent and hardener and resin have different colours. If the mixture is homogeneous and free of streaks it is ready for processing.



figure 5: ISO – PUR F 754 Standard material for many different potting and gluing applications in a double cartridge.

### **Double cartridges**

The cylinders of double cartridges can be arranged parallel (figure 5) or coaxial. Via combination of different cylinder diameters it's possible to get different mixing ratios. For processing, the cartridge filled with resin and hardener component, has to be

put in the application gun. The mixer has to be put on the cartridge and then the material can be discharged from the gun by pressing the trigger. Usually double cartridges can be provided in a range of 40 ml to 1000 ml.

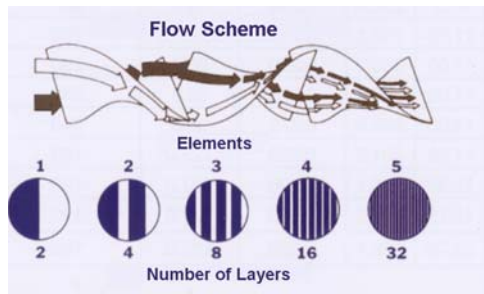


figure 6: mixing principle of a static mixer

By pressing the components through a

### Static mixer

they are separated, rotated by 90° and merged again several times, depending on the number of mixing elements. The components are mixed by this procedure. Special attention has to be paid to the choice of the mixer. The number of mixing elements and also the diameter of the mixer has to be selected carefully according to the viscosity of the processed components, the mixing ratio and the desired speed of discharge. Basically better mixing results will be obtained with tall mixers containing many mixing elements. But the handling behaviour will be declined. A standard static mixer with 16 mixing elements will achieve a mixing of 65.536 times. To avoid a curing of the cast resin within the mixer, the curing speed/reactivity must be adjusted carefully.

Weighting errors are excluded if cartridges are used due to their prefabricated nature. Additionally air entrapment is very unlikely.

Beside from the hand triggered guns to discharge the cast resin, there are also pneumatical systems. If these systems are equipped with timing devices, simple dispensing tasks can be handled.

## ***Machine Potting***

If there are medium to large numbers of components, that have to be cast, mixing and dispensing equipment of different manufacturers has to be used. Basically the set up of such systems is very similar all the time.

Working Principles:

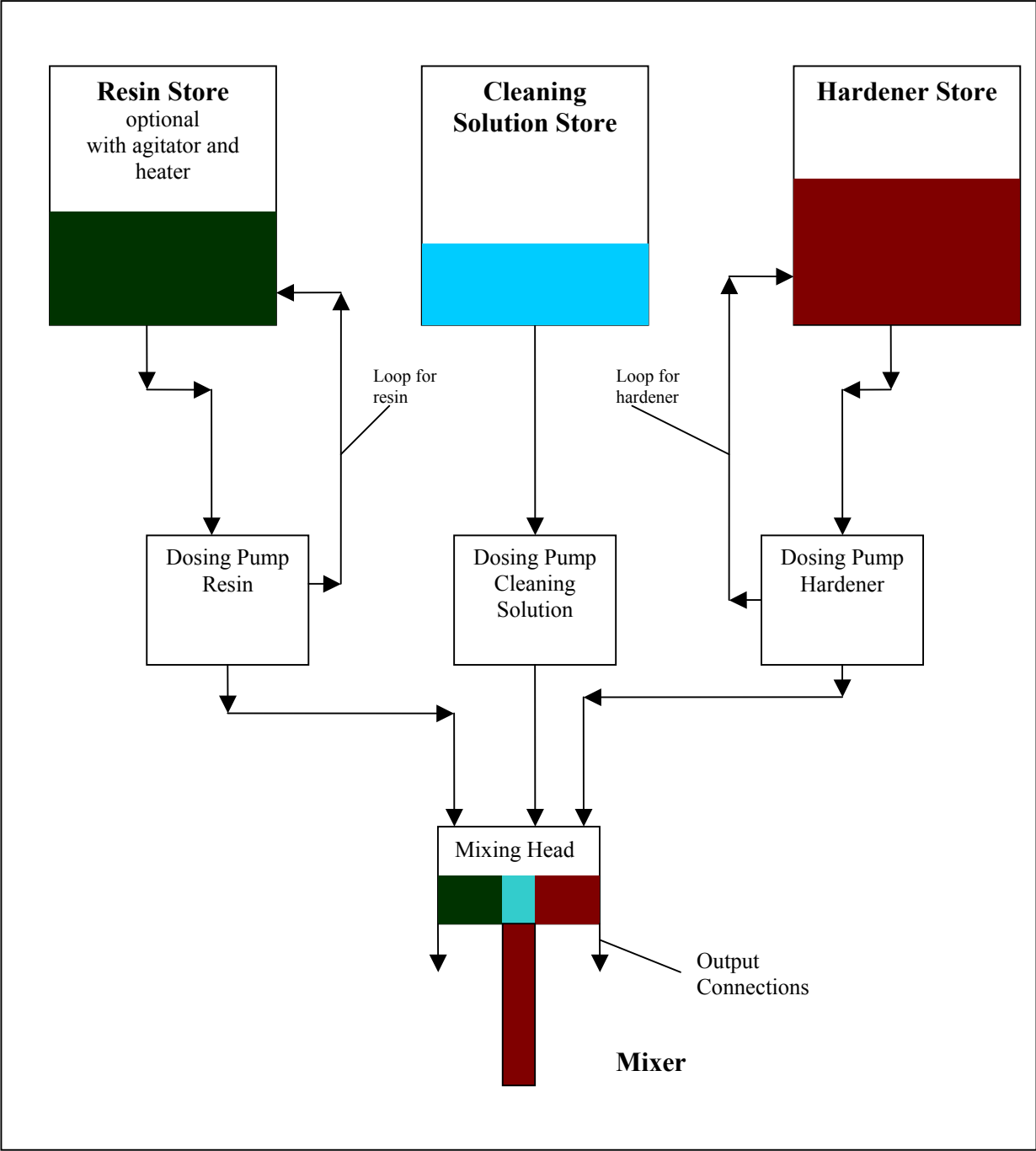
- Via special dosing pumps (piston or toothed wheel) the resin and hardener components are conducted to the mixing head in the proper ratio.
- The pumps are kept running by a monitoring device, until the desired amounts of the cast resin has reached the part to be potted.
- Within the mixing head both components of the cast resin are merged
- Some dispensing equipment offers the possibility to clean the mixing head via compressed air or special cleaning liquids.

**There are major differences in the mixers of different companies:**

### **Machines with static mixers**

Working principle: The mixing tube is immovable and the mixing takes place via the movement of the cast resin. The principle was already described in detail in this article (see above). The dosing of the components is achieved by toothed wheel – or piston-dosing pumps. The task of the pumps is to supply the single components to the mixers in the appropriate amounts according to the pre-set mixing ratio. The casting is controlled by a timing device, that keeps the pumps running until the desired amount of material is dosed.

Figure 7: configuration scheme of mixing and dispensing equipment



## **Machines with static – dynamic mixers**

Working principle: The mixing tube is movable. The mixing process takes place via the movement of the cast resin and the movement of the mixer. The dosing of the components is achieved by toothed wheel – or piston-dosing pumps. The task of the pumps is to supply the single components to the mixer in the appropriate amounts. Additionally the mixing elements are rotated within the mixer. As speciality the company Hilger & Kern offers a magnetic controlled monitoring of the rotational movement of the mixing elements.

## **Machines with dynamic mixers**

Working principle: The mixer is movable. The mixing process takes place via the movement of the mixer. The forward motion of the cast resin by the rotation of the mixer is negligible.

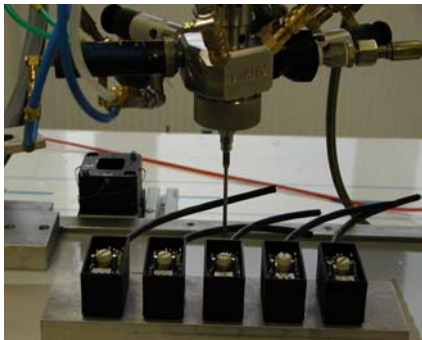


figure 8.: Dynamic mixer for automated casting of technical components ISO – CAST A765 self-extinguishing according to UL 94 V0

In the mixing head both components are brought together in the adjustable mixing ratio. Then the components are mixed within the mixing chamber. The dead volume in the mixing chamber is small. Therefore it is much easier to process fast curing cast resins in small volume components compared to static mixers.

Casting machines can be delivered with more or less substantial accessories, depending on the size of the production series and on the available budget.

The accessories may allow a faster processing. For example threeaxial systems and robotic devices are in use to cast in different positions. For quality assurance, devices for monitoring pressure, fill level of the component storing tanks and volumetric flow rate in the pipes can be used. A decision has to be made by the user how much equipment is used with the potting machine depending on his quality requirements.

If filled or pigmented cast resins are used it is necessary to equip the tanks of the filled component with a stirrer.

**Basically it is possible to get good casting results with any type of potting machine independent of the applied mixing principle.**

## ***Faults in the cured casting and possible causes for these faults***

If problems are occurring during the casting of the parts to be potted, it is possible to draw conclusions from the appearance of the faults and depending on the used mixing principle.

### **Air loaded Material**



**Figure 9.** *Definite appearance of bubbles in the whole casting*

Resin as well as Hardener storage tanks are often pressurised to reduce the delivery rate of the pumps. Due to this, the pumps are able to work solely as dosing pumps. Dosing errors can be minimised by this method.

### **Failure:**

If the storage tank is constantly pressurised or the pressure isn't removed during stirring operations the hardener or resin compound is loaded with air. During discharge of the air loaded cast resin from the mixer the material is slightly expanded. The air loaded in the material also expands and forms clearly visible and unwanted bubbles. If the storage tank is pressurised with insufficiently dried air this effect is strengthened.

Independent from the mixing principles, the look of the failure is similar.

### **Solution:**

- Keep the storage tanks only pressurised as long as necessary.
- Stirring devices should be used only if the tanks are unpressurised or evacuated.
- Only dry pressured air should be used.
- Pressurisation of storage tanks shouldn't be used, if sensitive resins are processed. Alternatively it is possible to add a simple feed pump (e.g. a membrane pump) that is supplying the primary pressure between storage tank and dosing pump.
- If the material is already air loaded it can be degassed in vacuum resistant vessels by evacuating.

## **Unfavourable pressure conditions within the resin- and hardener-pipelines (dispensing start-failure )**



**figure 10:** *dispensing start-failure with static mixer*

### **Error**

If there are substantial differences in the viscosity of resin and hardener and if the mixing ratio is rather extreme, it's possible that there are different pressures within the



pipelines. As a consequence it is possible that one component is delivered into the mixer before the other .

Then unmixed amounts of resin or hardener are pumped into the components, if static mixers are used. In figure 10 unmixed hardener was pumped in the device to be potted. The hardener reacted with air humidity forming carbon dioxide. This leads to the clearly visible forming of bubbles in a small area of the cured cast resin.

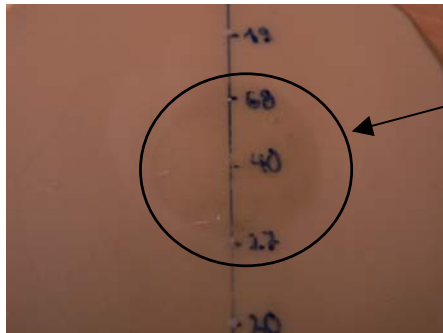


figure 10: dispensing start failure dynamic mixer

If static-dynamic or dynamic mixers are used the error is expressed in the form of areas of different hardness in the casting. This is displayed in figure 11: There is an excess of hardener in the marked area, displayed by a difference in the colour of the potting. In addition there is a difference in the hardness of the cured cast resin of 100 % (Shore D 40 instead of Shore D 20).

### Solution:

- Already before the purchase of the casting equipment there should be a close co-operation between the producer of the cast resin and the producer of the mixing and dispensing machine to optimise the casting system for the particular task.
- If there are errors in already existing potting machines, often problems can be solved by adjusting the cross-section of the connection pipes or the performance of the dosing pumps to minimise the pressure differences between resin and hardener parts of the machine.
- Often small pressure related errors can be eliminated by adjusting the output performance of the machine.
- Air is compressible. Therefore one has to make sure that there is no air in the pipe of the machine because the presence of air can lead to continuous pressure fluctuations. As a consequence there may be constant changes in the mixing ratio of the resin and hardener compound, leading to mixing errors.

### Serious Mixing Errors



Figure 12: Large areas of not sufficiently mixed cast resin

#### Error

After long breaks a cast resin can be partially cured within the mixing tube, if a static mixer is used. After continuing work with the potting equipment it is possible that the mixing elements of the mixing tube are barred from gel-particles. This may lead to a dramatic loss of mixing efficiency in the mixer.

If several mixing elements are affected, the cast resin will be mixed insufficiently. As a consequence errors like the one displayed in figure 12 are occurring. The clearly visible bubbles are formed by the reaction of unmixed parts of the hardener compound with humidity (air, see above: chemical fundamentals). Besides this, there will be sticky parts with an excess of resin.

Similar errors can be observed with static-dynamic mixers, if break times are transgressed or if there is a failure in the drive mechanism of the mixing elements.

Dynamic mixers can be driven electrically or pneumatically. Strong fluctuations in the pneumatic system of the machine can also lead to mixing errors.

### **Solution:**

- Mixing head or mixer should be flushed/washed before breaks. In the process less cleaning agent with a high throughput speed is more efficient than much cleaning agent with a low speed. Optimum results can be achieved by using a combination of cleaning agent and compressed air.
- Modern potting equipment can be delivered with a potlife monitoring device. The potlife of the used material can be pre-set in the machine. If the potlife is exceeded the equipment will warn the user or deliver a “blind shot” of the cast resin to remove material exceeding potlife from the mixer.
- For static-dynamic and dynamic mixers there is equipment to monitor the drive of the mixer automatically. In the case of a breakdown warnings will be sent to the operator.

Mixing errors caused by an initial incompatibility of resin and hardener can be avoided, if static mixers are used and the potlife of the cast resin is sufficiently long: A tube is attached at the end of the static mixer. After the tube a second mixer is attached. In the first mixer a pre-mix is happening. In the tube both components are starting to react removing the incompatibility of resin and hardener. In the second mixer the reacting compound is homogenised again.

The dwelling time of the premixed material has to be long enough to guarantee an initial reaction between resin and hardener. After a second mixing the components won't separate again.

Incompatibilities between resin and hardener can be ruled out during the planning phase by careful planning and choice of the proper cast resin compounds.



fig 13: too large static mixer compared with the volume of electrical part to be sealed

## Problems during casting due to unfavourable geometry of the parts.

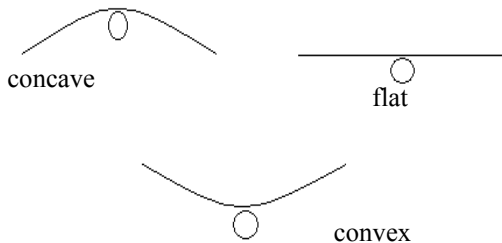


figure 14: Geometry of the parts

### Error:

If there are components in the cast assembly with a convex bottom side, trapped air bubbles will be released without any problems.

**But if the bottom side of the parts is flat or even concave the release of bubbles may be difficult. Bad spots as shown in figure 14 may be the consequence.**

Such blowholes can be avoided easily, if the parts to be potted are investigated for such critical spots, before the beginning of the mass production and a suitable casting procedure is established.

### Solution:

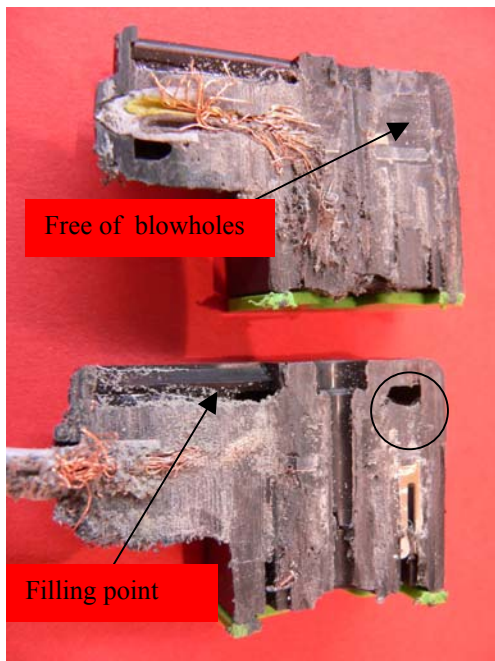


Figure 15: The potting in the upper component is alright. A blowhole can be seen in the other component

The parts in figure 15 were potted in a horizontal and a sloped position.

In the horizontal position blowholes were formed often at the marked spot. Simply by carrying out the casting at a part that is sloped, the forming of blowholes could be ruled out.

If there is a concave bottom side somewhere within the part, most of the time a sloped position is the only way to get a casting free of blowholes.

Parts with flat bottom sides can be vibrated for a short time directly after the casting was done, to make bubbles rise out of the casting more quickly.

In case that the parts are closed to the bottom and no leakage of the cast resin is to be expected and if there is enough buffer time in the production process, it is possible to elongate the potlife of the cast resin. Due to this the degassing of the resin is ensured.

In addition the adhesion of the cast resin to many surfaces can be promoted by a longer potlife.

The addition of special degassing additives is advisable if the parts to be potted are very complex and hard to degas. Normally the producer of the cast resin can recommend suitable compounds or make the addition already during the production of the cast resin.

#### Summary:

Two component cast resins based on polyurethanes can be processed easily by hand or with machines, if attention is paid to a few basic working guidelines.

In the planning of the casting process and also in the production process it has to be made sure that the mixing of the cast resin is giving a homogenous mixture. Also a contamination with air and humidity has to be avoided. If attention is paid to these rules, satisfying casting results will be obtained.

To avoid problems in the production process, special attention has to be paid to the optimisation of the cast resin and the potting equipment with regard to the parts to be potted, already in the planning phase. For this an intensive dialogue between the producer of the cast resin, the producer of the potting equipment and the user is needed.