

# FORMULATING, MIXING, DEGASSING, CASTING THE NEW GENERATION OF VACUUM SYSTEMS

Dr. Matthias Kaufmann  
W. HEDRICH Vakuumanlagen GmbH & Co. KG

## I. INTRODUCTION

The permanently increasing demands by the electrical industry:

- ♦ smaller components;
- ♦ improvement of the insulating properties;
- ♦ higher mechanical strength;
- ♦ resistance to outdoor conditions;
- ♦ bubble-free surface, etc.

require the use of "duroplast / reaction resins" *degassed under vacuum*, as e.g. epoxy resin, polyurethane or silicone, enriched with fillers such as quartz powder or aluminum oxide for casting electric components like distribution and bell transformers, ignition coils, switch parts or instrument transformers.

Apart from that, there have been developed new aspects for building resin casting systems in the past years by users having specialized in certain products in the weak and heavy current engineering:

- ♦ Automatic casting, either under vacuum in a casting tank or according to the automatic pressure gelation process in clamping units;
- ♦ Space-saving and thus compact design of the equipment;
- ♦ Efficient and non-polluting processing of resin systems.

This is what we understand by efficient processing:

- ♦ High productivity of the equipment by max. utilization rate;

Avoiding faulty operations by automatic processes;

- ♦ Saving labor;

No or just minor loss of material when cleaning and starting the resin casting equipment;

- ♦ Low maintenance expenditure because of reliable components, long maintenance intervals and for the most part easily available wearing parts.

Processing without affecting the environment means:

- ♦ Water is the main source used as heat-transferring medium.
- ♦ Process cycles in closed systems, so:
  - \* no skin contact with the cast resin constituents.
  - \* no inhalation of vapors.
  - \* no danger by quartz powder dust.
  - \* no contamination of cast resin constituents from the outside during processing.
  - \* no danger of accidents by direct contact with hot constituents.
  - \* no cleaning of the parts coming into contact with activated compound necessary  
or  
\* cleaning using one cast resin constituent (e.g. resin/filler mixture).

Processing of reaction resins in appropriately adapted casting systems has become usual practice for the user based on the experience gained in this technology that meanwhile lasts over years.

Casting systems themselves have not changed much with respect to their "fundamental processing principle" of cast resin constituents.

To mention but a few criteria for example:

- ♦ Preparation of constituents in large mixers for 2 or 3 shift operation.

- ◆ Use of pressure casting vessels or compound pressure accumulators especially for the pressure gelation process.

Of course, production has been substantially improved as equipment engineering was developed, e.g. by introducing the thin-film degassing mixer or the compound pressure accumulator for the pressure gelation process; but the basic concept of the equipment has not changed!

*Let us explain now the new ways we have been covering successfully in the past 4 years with respect to the preparation and casting technology, so that, as already becoming obvious today, all equipment designs known so far seem to be out-dated technology.*

## II. CONTINUOUS PROCESSING OF CAST RESIN

The processing of cast resin compound in batches, which was usual practice over a long time and is still being used nowadays, curtailed the possible applications to a great extent. The main disadvantages to be mentioned are:

- ◆ formation of viscosity
- ◆ low processing temperatures
- ◆ pot life problems
- ◆ limitations in formulation of cast resin systems

A "real" solution was found only in the so-called static mixers, preparing the reactive mixture only short before casting. This was the first step to realize a "just-in-time" process.

To fully occupy expensive production systems, numerous companies went over to produce in 3 shifts, which eventually required a continuous preparation of cast resin constituents.

By adding more mixers, an almost continuous processing of cast resin could be achieved. However, one essential disadvantage is in particular the storage of partially large quantities of mixed and prepared material.

This way of preparation was fundamentally changed by HEDRICH Vacuum Systems, who started to launch out and established a new revolutionary way of proceeding 4 years ago. The following description of a system for continuous formulation and preparation was the development of a "real" On-Demand System.

### A. Continuous Preparation with "On The Fly" Degassing Mixer - OTF-D/MD

Apart from the proven processing principle in batches with the good quality characteristics as known, this preparation process can also be even improved by thinking about the following:

- ◆ cast resin constituents shall only be degassed, if they are actually needed.
- ◆ cast resin constituents shall experience the least possible thermal and mechanical stress.
- ◆ the expenditure incurring for the equipment has to be reduced.

The result was the fundamental development of the "on-the-fly" thin-film degassing mixer OTF, that has already proved its efficiency at numerous customers and can either be used as mixer and degasser OTF-MD or only as degasser OTF-D for unfilled or pre-filled constituents.

It is necessary to take into account the conditions for degassing that are also determined by the properties of the material itself. One important parameter for this is the viscosity.

For very low-viscous constituents, e.g. unfilled hardener or silicone constituents, a static "on-the-fly" thin-film degassing mixer may be sufficient.

Such kinds of degassers are also used in oil purification systems. The liquid to be degassed is distributed over a large surface by means of gravity, with permanently renewing surface.

However, for preparation of highly filled cast resin, this principle cannot be applied. In addition, the constructive design of an equipment should not be limited to "one certain material" for processing; flexibility is very important for future products.

Therefore, a universal unit is requested, with low, medium or high viscosity, unfilled or pre-filled, that achieves the required parameters for a certain kind of production.

Among others, these might be:

- ◆ flow rate (liters/min.)
- ◆ degree of degassing/requested equilibrium pressure
- ◆ max. admissible viscosity
- ◆ gas and moisture content of cast resin constituents taken out of the drum.

Based on these criteria, Hedrich may propose the dynamic "on-the-fly" thin-film degassing mixer which is exactly fit for this demand.

Cast resin constituents can be supplied to the "on-the-fly" thin-film degasser very flexibly and adapted to the demands of the customer / the condition of the constituents when supplied, as e.g.:

- ◆ Supply of the "on-the-fly" degasser with pre-filled cast resin constituents after taking them out of barrels or containers. The resin supplier already delivers the constituents in pre-filled condition in those containers.
- ◆ Supply to "on-the-fly" degasser out of the "on-the-fly" formulation unit described in chapter 2.2.

When processing directly out of the original drum, the cast resin constituent is sucked into the "on-the-fly" thin-film degasser after passing through a shortage protection on the basis of flow regulation by means of pressure difference. Shortage protection checks, if material is available when opening intake valve and signals in time, when the empty drum needs to be exchanged.

Feasible would also be to supply the constituents to the "on-the-fly" thin-film degasser by means of a feeder pump, as this was realized e.g. when using an upstream "on-the-fly" formulation unit.

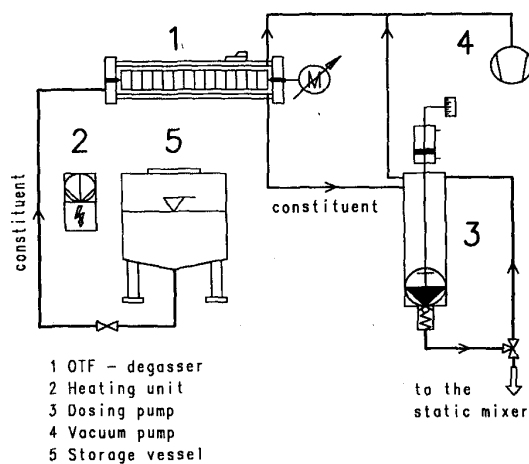


Figure 1 Functional Principle of the Hedrich "On-The-Fly" Thin-Film Degassing

After that, cast resin is fed over rotating inner parts of the horizontal degasser and degassed quickly and completely after passing through just once, owing to the large surfaces created.

#### Advantages of Continuous Preparation with "On-The-Fly" Degassing Mixer OTF-F/MD

- ◆ No mixing of well degassed and poorly degassed compound.
- ◆ Degasser has extremely large degassing surfaces that can also be used for temperature regulation.  
⇒ Degassing possible within **extremely short time**.
- ◆ For being sucked out of the drums, the constituents can be stored at low temperature though keeping them "flowable".  
⇒ Sedimentation is reduced when using pre-filled systems.
- ◆ Constituents are only subject to vacuum for a short time, contrary to conventional mixers with material being exposed to vacuum and being stirred / circulated for hours or even for days.  
⇒ **Minimization of thermal and mechanical stress.**  
⇒ **Valuable substances required for good hardening of the cast parts are maintained.**
- ◆ The basic design of this equipment is already capable of performing in uninterrupted 3-shift operation.  
⇒ **Less investment**
- ◆ Contrary to a mixer, the "on-the-fly" degasser only takes up a small quantity of resin or hardener (just a few liters)
- ◆ Material is only degassed, if it is actually needed for casting,
- ◆ If operating interruptions become necessary, the equipment can provide degassed material for casting immediately after it is started again next time.
- ◆ **Flow rates up to 150 l/h can easily be achieved in the standard design. If requested, higher flow rates may be operated as well.**

## B. Continuous FormulationI with "On-the-Fly" Formulation Unit - OTF-F

The continuous formulation unit OTF-F was the latest development of a completely new generation of casting systems that has been developed by us in the past years.

- ◆ Flexibility of the equipment relating to the processing of various resin systems with different formula;
- ◆ Improvement of product quality by reduction of thermal and mechanical stress to reaction resins;
- ◆ New conditions for processing reaction resins;
- ◆ Reduction of energy consumption;
- ◆ On-demand system

The essential reasons for this were:

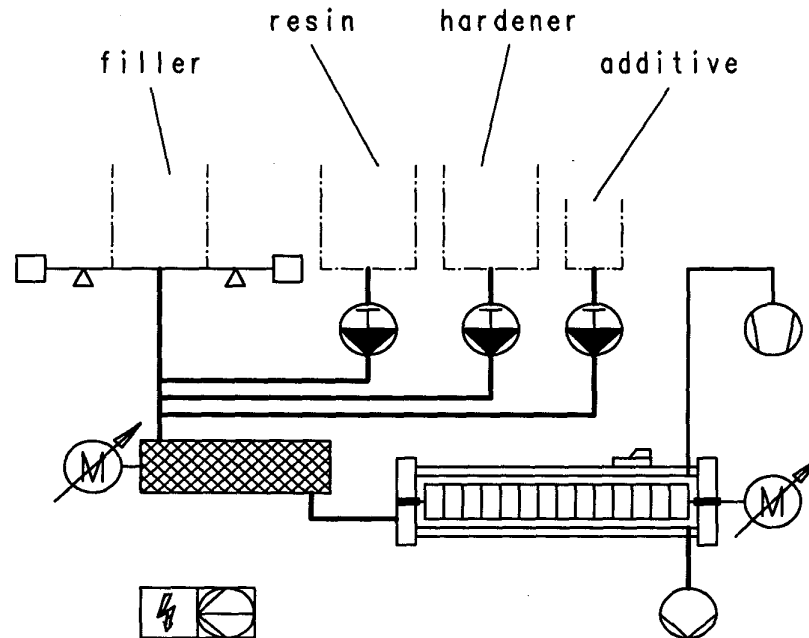


Figure 2 Functional Principle of the Hedrich "On-The-Fly" Formulation Unit OTF-F

The units yet available on the market did not allow a "real" continuous preparation of a mixture or pre-mixture. It was tried to avoid this disadvantage by arranging several mixers switched in series, which required a quite high expenditure for the equipment, though.

With the continuous "on-the-fly" formulation unit, a decisive improvement could be achieved in preparing the mixtures.

Applying this processing principle, the mixture is continuously prepared within a few minutes, the constituents resin, filler, flexibilizer or even additional

hardener and accelerator, color being added continuously to the formulation unit.

Of course, all volumetric flows to the formulation unit are exactly monitored volumetrically or gravimetrically. This ensures a preparation of pre-mixture or mixture in the exact stoichiometric ratio.

The constituents are processed directly out of barrels, large containers or silos, depending on the way the unfilled liquid constituents / fillers are supplied and stored. Constituents do not need to be heated in these storage vessels. Heating-up process is also effected continuously as the material flows to the "on-the-fly" formulation unit.

The formulation unit itself is provided with an integrated mixing and conveyor screw and allows a homogeneous mixing of all constituents supplied.

In conjunction with the topped "on-the-fly" thin-film degasser, practical tests run by an independent institute have proved successfully by the time that a complex filler drying, as up to now required especially when processing resins for high-voltage engineering, is no longer necessary. So, not only the quality is improved, but also a considerable part of the expenditure for the equipment yet required is saved.

#### Advantages of Continuous Formulation with "On-The-Fly" Formulation Unit OTF-F:

- ◆ *Minimization of thermal and mechanical stress.*  
⇒ *No formation of viscosity*
- ◆ *Evaporation of important, mostly high-volatile fractions is prevented*  
⇒ *High product quality is maintained.*
- ◆ *Casting material is only formulated, if it is actually needed for casting.*
- ◆ *Large amounts of cast resin do not need to be stored at temperature and under vacuum.*  
⇒ *On-demand system*  
⇒ *Considerably reduced energy consumption compared with a conventional equipment.*
- ◆ *Long down times for preparation of new cast resin, as required for batch-type mixers, are not necessary.*  
⇒ *Considerably less difficult scheduling of production as no lead times are required.*
- ◆ *Filler drying, yet required, is no longer necessary.*
- ◆ *Less maintenance, cleaning expenditure, less space required and less investment;*  
⇒ *Major arrangements like platforms and stairs are not necessary.*

### III. Dosing of Cast Resin Constituents with High Pressure Dosing-System - HPD

During the past years, there was a tendency towards the use of highly filled and highly reactive cast resin systems.

#### The advantages resulting from this development are obvious, they are among others:

- ◆ better mechanical properties;
- ◆ better thermal conductivity;
- ◆ less expensive cast resin systems;
- ◆ shorter cycle times, higher machine utilization rate and production.

However, as it is known, a higher portion of filler results in a considerable increase of viscosity of casting compound. Today, processing viscosities of more than 100.000 mPas are no longer unusual.

The conventional processing technology using low-pressure dosing pumps require large cross sections of the static mixer and all following components to ensure the desired throughput of several liters per minute.

Therefore, this equipment concept takes up a large quantity of reactive compound in the area from the static mixer to the casting valve.

Consequently, this concept does not meet the requirements of highly filled and highly reactive casting systems since on one hand the reaction is accelerated by the accumulation of large quantities (reaction heat) and on the other hand major material losses occur in case the production is interrupted for cleaning.

#### Aim of our further development:

*Processing device for highly reactive and highly filled reaction resins with smallest possible cross sections of the components which contain reactive compound.*

#### Result:

Development of the HPD high-pressure dosing system which we would like to describe below.

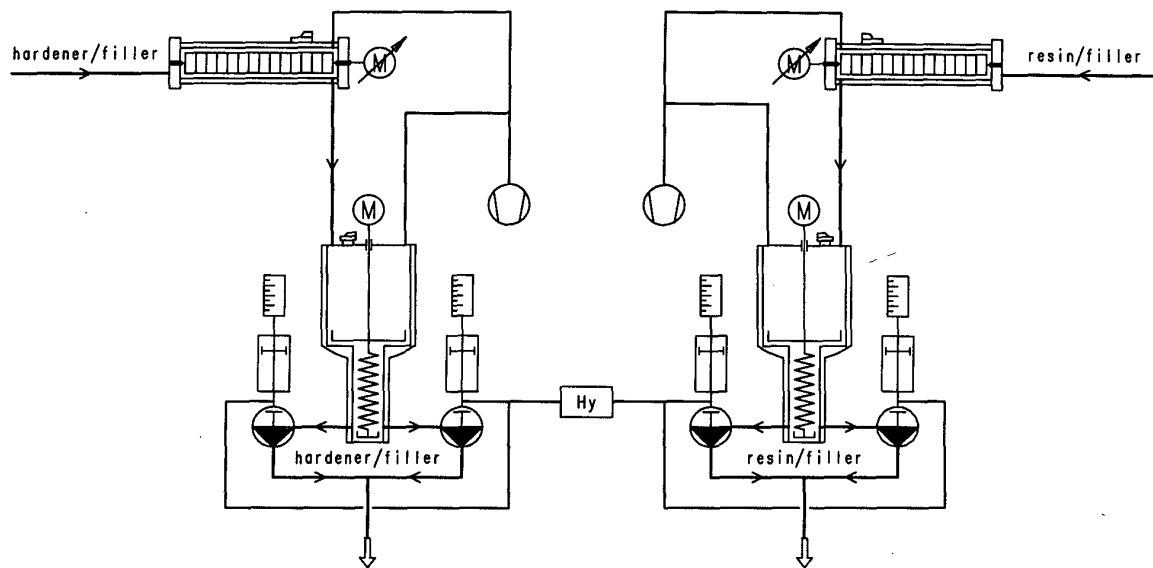


Figure 3 Functional Principle of the HPD High-Pressure Dosing Pump

In conventional piston dosing pumps, a high counter-pressure is produced on the outlet side due to the loss of pressure in the following components (static mixer, valves and pipes) whereas vacuum is present on the inlet side.

Naturally, it is not possible to seal components coming into contact with constituents containing abrasive fillers by elastomer seals, so, a more or less wide gap remains between piston and sleeve for manufacturing reasons.

The pressure difference occurring when dosing causes the constituent to be dosed to flow back through the gap (backflow) which affects the dosing accuracy. Therefore, it is understandable that a correct stoichiometric ratio cannot always be kept.

This applies to dosing pumps completely made of ceramics (in case highly abrasive constituents are used, even ceramics is subject to wear and consequently results in a gap between piston and sleeve) as well as pumps having other kinds of seals.

This problem is solved by a direct-hydraulically driven piston dosing pump of the high-pressure dosing technique, which has nearly the same pressure on the inlet and outlet side.

The identical pressures have the following advantages:

- ◆ *No stress of the piston by abrasive media.*
- ◆ *No backflow.*
- ◆ *The dosing accuracy is considerably improved; the complete dosing stroke is electronically controlled with an accuracy of 1 micron !*
- ◆ *Practically no wear.*

The high-pressure dosing pump arose from the developments of the DUO pressure accumulator which Hedrich started 5 years ago. Originally, this device had especially been developed for the pressure gelation process.

Meanwhile, high-pressure dosing pumps have been used by customers for several years without need to open the pump for maintenance purposes.

Based on the excellent results, high-pressure dosing pumps are meanwhile used for all applications in Hedrich vacuum casting systems.

These pumps are designed as individual pump for each preconstituent or two alternately operating pumps for each constituent.

The latter arrangement allows a continuous compound flow without interruption which occurs during the suction stroke of the conventional dosing pumps.

#### Advantages of the High-Pressure Dosing Technique HPD:

- ◆ *Because of identical pressures no backflow.*
  - ⇒ *Extremely long service life*
  - ⇒ *Especially suitable for highly filled / highly abrasive cast resin constituents*
  - ⇒ *High dosing accuracy for many years*
  - ⇒ *No passive check valves*
  - ⇒ *Practically wear-resistant*
- ◆ *The high dosing pressure allows to reduce the static mixer and all following components.*
  - ⇒ *Low quantity of reactive compound (reduction up to 80 %);*
  - ⇒ *Heating-up / cooling-down within minutes;*
  - ⇒ *Static mixer is also located directly at the mold;*
  - ⇒ *Saving operational costs by reducing waste;*
  - ⇒ *Different molds can be cast with reproducible filling profiles, independent of any fluctuations in viscosity.*
- ◆ *Electronic synchronization*
- ◆ *Freely adjustable casting speed throughout the whole filling process.*
- ◆ *Freely adjustable gelation pressure*

#### IV. REDUCTION OF CYCLE TIME

It is known that in the automatic pressure gelation process the cast resin compounds are supplied into hot molds (mold temperatures 120 to 160 °C are usual) and then begin to gelate whereas at the same time pressure is applied on the mold, until the casting has a sufficient stability to be easily demolded.

The cast resin compound is stored with a relatively low temperature before flowing into the mold. In the past, an important reason was certainly the pot life of the cast resin compound because pressure gelation vessels were still used in many cases.

For the processing itself, it is however an advantage (and not only for reducing the cycle time) to allow the cast resin compound to flow already with higher temperature into the molds. On one hand, this allows to accelerate the gelation process and on the other hand, more favorable curing conditions are present in the mold since "relatively cold places" in the mold are avoided.

Since, in case 2-constituent casting plants are used, it will also be desirable in the future to store the constituents at low temperature in the casting equipment, the problem of heating up the cast resin compound "on the fly" to the mold intake temperature only occurs just before the compound flows into the mold.

However, an important aspect is that the complete process remains stable, i.e. the critical limits for a too high reactivity of the cast resin compound while being in the equipment (and not yet in the mold) must be considered.

In parallel with the common development of the Ciba Co. and Linn - High Term Co. which heats up the cast resin compound with a microwave heating device, Hedrich had started a development with devices similar to a heat exchanger some years ago and these devices are today already successfully integrated in many systems.

The UFC-heater (Ultra Fast Compound heater) developed by Hedrich operates on the basis of a special heating/cooling technique with a heat transferring medium. The cast resin constituents are heated up on the fly to the required casting temperature either before or behind the static mixer.

Today, temperatures up to 100 °C are usual as inlet temperature into the mold. Of course, this temperature must be adapted to the reactivity of the cast resin system.

The use of the heating/cooling technique in connection with highly efficient heat exchangers became only possible by the development of the high-pressure dosing pump. As already mentioned, the high feed pressures produced by the high-pressure dosing pump allow the pipe cross sections and size of static mixer and other components to be reduced. This is useful for the design of the UFC heater.

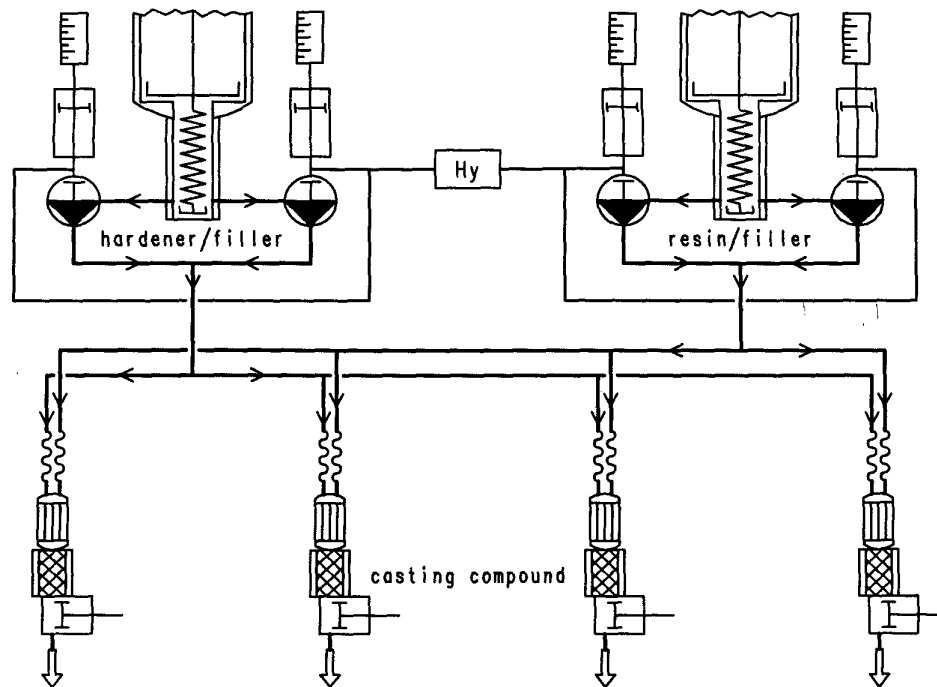


Figure 4 Functional Principle of UFC Heater

Besides the heating, the UFC-heater also offers the decisive advantage that the cast resin compound contained in the UFC heater, after filling of the mold, can be cooled down/brought to a standby temperature. It is thus possible to work with very high mold inlet temperatures without endangering the process stability.

With a heatable/coolable pour-in beam, the cast resin compound can thus be completely checked, heated and cooled until it flows into the mold. These are optimum processing conditions for the pressure gelation process.

Generally, the UFC technique can be used for all pressure gelation productions. Especially for thick-walled parts, a considerable reduction of the cycle time can be achieved.

Here, the difference is the long heating-up phase of the cast resin compound flowing into the mold in the conventional casting process. The heat must be transported from the outside of the mold through the cast resin to the inside of the mold.

The cast resin compound itself is a bad heat conductor, so this process takes a long time.

Therefore, higher temperatures at the intake of the cast resin compound are an advantage.

**Advantages of the UFC Heating/Cooling Technology:**

- ◆ *Shorter mold occupation times.*
- ◆ *A reduction of the total cycle time by 30 % and of the gelation time by 50 % is possible.*  
     ⇒ *Increase of production.*  
     ⇒ *Less investment for casting equipment with clamping machines, however, with same planned production capacity*
- ◆ *Uniform and favorable curing conditions in the mold.*  
     ⇒ *Quality improvement of castings.*  
     ⇒ *Lower tension and voltage peaks in the cured cast resin compound.*
- ◆ *Variable, presettable inlet temperatures of the cast resin compound into the mold.*  
     ⇒ *Steady process guidance.*
- ◆ *Low viscosity of cast resin compound at high intake temperatures*



⇒ Better flow conditions in case of complicated molds.

#### V. DOSING OF CAST RESIN COMPOUND WITH MASS DOSING

In the electronics and automotive industry, large amounts of components are manufactured with low filling volumes. Basically, they are flyback and bell transformers, diode splits as well as ignition coils.

The high output rate of parts as well as the great demands made on the uniform filling, according to the SPC (Statistical Process Control), requires a highly precise dispensing system to several parallel casting nozzles.

Exact dosing of cast resin compound per part (shot dosing process) is then effected by means of the mass dosing system (MDS).

Dosing accumulators are directly arranged behind the static mixer and are used to measure out the reactive compound into equal volumetric portions before casting. This arrangement allows simultaneous casting of several ignition coils so as to considerably increase productivity.

## ONLINE VOLUME AND FORMULATION CHECK

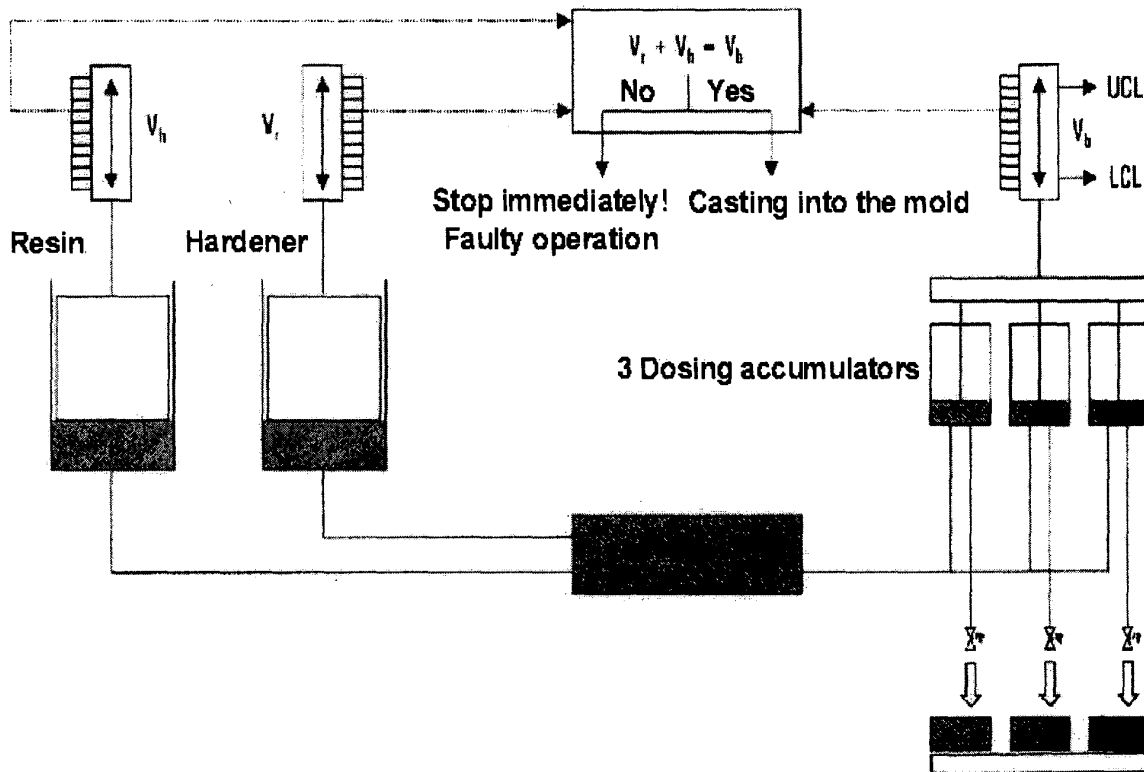


Figure 5 Functional Principle of Cast Resin Distribution with Electronic Dosing Supervision

Depending on the type of casting chamber system, up to 45.000 components can be cast on an equipment per day. To ensure the dosing accumulators are uniformly filled, an electronic comparison of set/actual value is made before casting. For this purpose, the volume fed by the dosing pumps is compared with the volume filled into the dosing accumulators. Casting cycle is released only, if both volumes are almost identical within tiny preset limit values.

**Advantages of the Mass Dosing System (MDS):**

- ◆ *Measuring out cast resin compound to several casting nozzles.*
- ◆ *Casting of individual shots out of the dosing accumulators*  
     ⇒ *High production capacity*  
     ⇒ *Filling profiles in case of complex geometries*
- ◆ *Filling of dosing accumulators directly by the dosing pumps*
- ◆ *No-pressure circuit of mass dosing system's drive*  
     ⇒ *Supervised, uniform filling*  
     ⇒ *No dependence of sensors or drives.*

- ◆ *Volumetric supervision of filling process*  
     ⇒ *Depending only on the direct, most important parameter: the volume.*

## VI. CONCLUSIONS

Just as in all technical and materials-processing fields, the request to design systems so as to allow them to be used immediately on demand is also taken into account more and more in cast resin manufacturing.

The Hedrich innovations, e.g. "on-the-fly" formulation, "on-the-fly" degassing basically meet those demands for an "On-Demand system".

Consequently, long lead times are no longer necessary for production equipment, production scheduling is facilitated, production times are generally reduced.

This means, casting equipment engineering has grown to become a modern and up-to-date equipment technology.