

Cleanroom Manufacturing.

Medical technology is one of the most sensitive applications in machinery and plant construction since medical products do not allow any compromises in production safety, traceability of the qualification processes or product liability. This means details really count when developing an injection molding machine for cleanroom manufacturing.



The specially adapted injection molder for cleanrooms integrates the two essential sector specific requirements in its philosophy: cleanliness and precision

The Right Machine for GMP

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For many years leading business scientists have been predicting a boom in the health sector and medical technology. For example futurologist and economics theoretician Leo Nefiodow sees biotechnology and medical technology as the next major economic drivers, comparable with the booms that fundamental innovations such as petrochemicals or information & communications technology have triggered (Kondratieff cycles). This makes it even more important to develop appropriate technologies and applications and bring them to market swiftly. Following this reasoning Engel Austria GmbH, Schwertberg, Austria, have succeeded in integrating the two essential requirements for the manufacture of medical plastic parts – cleanliness and precision – into their machine design philosophy with an injection molding (see Title picture) that they adapted specially for cleanroom operation.

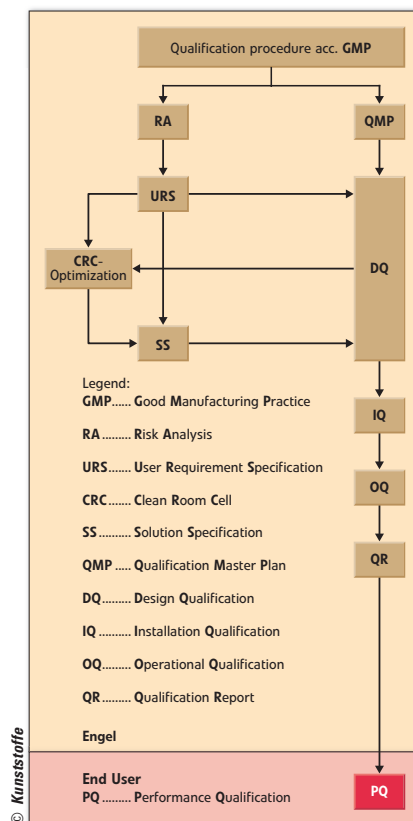


Fig. 1. The project to develop equipment suitable for technical medical applications was based on a cGMP qualification master plan

Systematic Documentation Prevents Penalties

Probably the biggest challenge in cleanroom production is developing a production system strategy that holds particle emissions, which can lead to contamination of the product, within their prescribed limits. So that this can be proved in individual cases, the law lays down rules and directives which impose a duty to prepare systematic documentation. This is because in spite of very extensive regulations within the European Union for the marketing and commissioning of medical products and their accessories such as the Medical Products Law (Medizinproduktegesetz – MPG), EU directive 93/42/EEC and 98/79 EWG for “In-vitro diagnostica”, actually placing them on the market is at the risk and judgment of the manufacturer. In the event of a liability dispute it is the manufacturer who has to produce seamless proof that the production conditions were in accordance with the regulations. Where this proof cannot be produced without any gaps, the responsible criminal prosecution service will instigate proceedings under product liability legislation.

The quality management systems for developers and manufacturers of medical

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products are defined in DIN-EN-ISO 13485:2003, cGMP (Current Good Manufacturing Practice) and by the US FDA (Food and Drug Administration). According to the cGMP regulations not only do all active ingredients have to be qualified, but also all components coming into contact with the active ingredient or components, which could come into contact with bodily fluids. The same rules apply to components and assemblies whose function is decisive for a safe dosing of the active ingredients. Since modern medical products contain a great number of injection molded parts, the overwhelming majority of the injection molding production is subject to technical process validation as well as plant and construction qualification. The qualification serves as documentary proof that the injection molding machine fulfills the required specification with adequate safety margins and meets the appropriate standards and directives. It ensures that to a very high degree possible errors will be recognized and that measures to address these can be instituted.

For this reason Engel has installed a DIN ISO-14644 Class 6 cleanroom (see box page 127) equipped to and qualified under the requirements of cGMP in its application technology center at its main works in Schwertberg in order to be able to systematically study cause and effect in particular machine design details. The investigations carried out there followed the target of developing equipment options for technical medical products based on the small and medium sized Victory and E-Motion series.

Tiebarless Clamping Unit for Side Mold Mounting

The project was started with a defined program of work based on a qualification

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master plan according to cGMP (Fig. 1). The starting point was risk assessment, that is the systematic identification of potential particle emitters in and on the machine. The risk assessment covered both cleanroom as well as process substance risks, where all problems were recorded, assessed and possible solutions defined. That brought on the one hand the systematic and in the event of a liability claim essential proof that the injection molding machine had met all the requirements of cleanroom suitability. On the other the measures taken reduced the contamination of the cleanroom and had a positive effect on operational costs, for example in lowering the energy consumption and the number of filter changes by reducing the air change rate. As a result a comprehensive documentation of the qualification is available that represents the basis for a complete process substance qualification including all the elements of the manufacturing chain, for example mold, peripheral equipment such as conveyors and packaging or quality control elements.

An important point in the list of requirements was the improvement of the air flow properties in the area of the mold. This was aimed at reducing turbulence which can produce uncontrolled local concentrations of particles (Fig. 2). The tiebarless clamping unit offers a good starting point for implementing this improvement. With

a modified casing air flows through the clamping unit can be nearly ideal (“laminar flow”). Other advantages stem from the fact that only a small number of components are used and the moveable platen guides have been completely enclosed through a sideways relocation (Fig. 3). This means that product contact surfaces and near product surfaces are well protected from contamination. In order to simplify cleaning it is possible to equip the clamping unit with a quick release system and to not use threaded holes or to fill these flush with the surface with special plugs. The im-

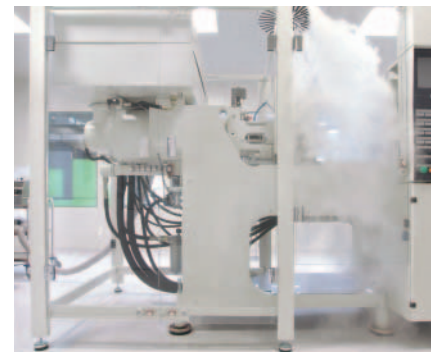


Fig. 2. Through improved air flow properties in the area of the injection molding tool, turbulence and local particle concentrations are minimized

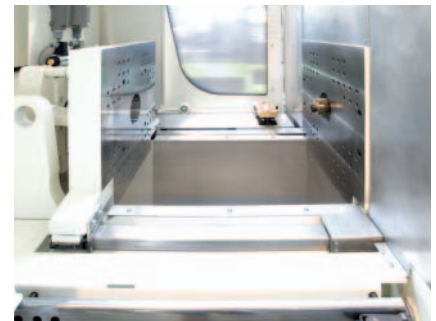


Fig. 3. The guides for the moveable platen have been completely enclosed through a sideways relocation



Fig. 4. Thanks to the closure of the tank with bellows, the entire hydraulic system works as a closed system



Fig. 5. The patented GMP barrel concept prevents emissions in the cleanroom

proved ergonomic design also makes access to the mold area easier.

The mounting of the tooling is a particularly critical factor in minimizing contamination, since molds are typically fitted from above with the help of a crane. In cleanrooms however it is often not possible to use a gantry crane due to the ceiling construction and headroom. A simple and very clean solution is to mount the mold from the side, which in a tiebarless machine is possible without restrictions in the mold height.

The fact that many cleanrooms have restricted headroom due to technical requirements also affects the dimensioning of the laminar flow boxes mounted on the machine as well as the equally high standing conventional linear robots. Tiebarless machines allow for the positioning of a 6-axis industrial robot within the protective casing without the need for additional headroom. In this way the robots can have unrestricted access to the tooling space. Thus side part removal and a compact manufacturing cell no longer represent a contradiction in terms.

Since the friction between the mold medium supply lines represents a potential particle source, attention was paid to the selection of optimal materials and a



Fig. 6. The cladding made from glass and smooth profiles is easy to clean



Fig. 7. Typical technical medical parts

(photo: Engel)

Cleanroom Class from A to F

The deciding criteria for production quality are not only the particle number and size (dead matter) on the product, but also the size of the bacterial load (living matter). The number and size of the particles, based on the volume of space surrounding the product, is defined by the cleanroom class. The Federal Standard 209e which was withdrawn on November 29, 2001 divided cleanrooms into classes from 1 to 100,000. In this way the maximum particle number with a reference size of $\geq 0,5 \mu\text{m}$ per 1ft^3 volume of air was defined. The currently valid international standard "DIN EN ISO 14644-1" defines analogue classes from ISO-9 (lowest standard) to ISO-1 (highest standard) with a reference particle size $\geq 0,1 \mu\text{m}$, per 1m^3 volume of air. The EU cGMP code of practice (current Good Manufacturing Practice) defines cleanroom classes from A to F, where the reference size currently is $\geq 0,5 \mu\text{m}$. The limit for the colony count in each case is taken from Annex 1 of the cGMP guidelines.

suitable routing solution was developed. The unhindered side access, due to the absence of tiebars, into the clamping unit for tooling change and for part removal allows the cleanroom head space and therefore the total acclimatized cleanroom volume to be reduced.

Another obvious particle source is the standard open hydraulic tank. Due to machine movements the tank has to be able to breathe - a particle fountain par excellence. The solution for this is to seal the tank using bellows (Fig. 4). In this way the complete hydraulic system works as a closed system.

Suppression of Injection Unit Emissions

The qualification process was not restricted to just the clamping unit, but also covered the injection unit and its potential for emissions. It is often the case that in order to reach a zero defect tolerance the processing windows are very narrow. An inline injection system which is enclosed with smooth, easy to clean surfaces as standard counteracts possible defect sources. In order to minimize air turbulence which is disruptive in cleanroom applications, fanless servo motors are used. The question of how to deal with the hot gaseous plastic emissions from the nozzle area and generally with the heat radiation has also been

solved: The barrel including the nozzle and heater has been enclosed. This patented GMP barrel concept (Fig. 5) is based on a double walled stainless steel pipe which stops the release of emissions into the cleanroom. A positive side effect of this, as described above, is a reduction in the running costs.

The cladding has been constructed without exception from glass and smooth profiles (Fig. 6). Every surface can be opened so that the entire machine is simple to clean. The optimal air flow construction helps to minimize dead spots due to displaced air.

The concept is rounded off by many solutions to fine details. For example an easy to clean bulkhead separates the clamping unit from the injection unit. The water manifold is let seamlessly into the cladding. Servo motors solve the problem of air turbulence, guide covers and stainless steel cladding contribute to minimizing point contamination. Furthermore FDA approved hydraulic oil and lubricants are available.

The Structured Way to the Goal

The cGMP qualification model forms the basis for the individual development steps on the way to a cleanroom capable injection molding machine. The risk assessment and the drawing up of a qualification control plan are the starting point. The details of the feature and requirement specifications go into the design qualification so that the cleanroom and the integrated functional areas it contains can be process optimized. This is followed by the installation and function qualification. The qualification report forms part of the scope of delivery for the machine. After installation the final performance qualification is conducted by the end user.

The result of the two year development program is a cGMP qualified machine concept with which cleanroom suitability can be guaranteed at any time in the complete production cycle (Fig. 7). The machine series including automation accessories will be available from K 2007 onwards. ■

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