3 Design of Mixing Units

3.1 Usual Operational Area

3.1.1 Central Mixers

Mixing volume:	0,5 ... 100 ... 1000 ... 3000 litres
Mixer speeds:	5 ... 200 ... 1000 ... 3000 rpm
Product Viscosity:	low viscous to medium viscous
Mixing Product:	liquid

3.1.2 Planetary Mixers

Mixing volume:	0,5 ... 10 ... 500 ... 1000 litres
Mixer speeds:	5 ... 30 ... 150 ... 300 rpm
Product Viscosity:	medium viscous to high viscous
Mixing Product:	liquid / pastes / powdery

3.2 Examples for mixing products

3.2.1 Chemical Industry

- Adhesives
- Lubricants
- Grinding medias
- Sealing products
- Soldering pastes
- ceramic substances
- Paints
- Explosives

3.2.2 Pharmaceutical Industry / Cosmetic Industry

- Creams / Ointments
- Lotions
- Gels

- Tooth Pastes
- Eye Shadows
- Perfumes
- light curing finger nails

3.2.3 Food Industry

- Flavourings
- Fruit Concentrates
- Chocolate Products
- Salad Dressings
- Delicatessen salads
- Cream Cheeses
- Marinades
- Spice Mixtures

3.3 Application of Mixing Units in Ex-Zones

3.3.1 Introduction

In the past it was sufficient to design the electronic construction parts of a mixing unit according to their intended application in ex-zones. Since this transition period ended on June 30th 2003 all mixing units have to be designed according to ATEX regulations [2]. As a result (in the following) also all mechanical components of a mixing unit will have to comply with the special requirements of an operation in Ex-zones. Further information on explosion protection see [3, 4, 5, 6].

3.3.2 Ex-Protection in Mixing Units

Stirring and mixing units are classified as *Other Operating Equipment(supplies) of Group II*. Table 3 shows a survey of the design significant datas.

Classification of areas, the establishing of temperature classes and explosion groups is the responsibility of the operator. The result of the danger assessment is to be recorded in the explosion protection document and up-dated continually. This data allows the equipment manufacturer to design the mixing unit accordingly. The following is a prerequisite for the design of agitation and mixing equipment for ex-zones.

Table 3: Design Requirements for Stirring and Mixing Equipment for Ex-zones

Ex-zone respective Category	Customer to provide
Temperature Class	Customer to provide
Explosions Group	Customer to provide
Flame Protection	Manufacturer to provide: Motors Control Cabinet Sensors

- Use of conductive rollers for mobile mixing bowls
- Installation of a level monitoring in the double jacket of the heatable mixing bowl
- Installation of a flow control for inline-homogeniser
- Installation of conductive material for wall scraping devices
- Sufficiently large wall distances of stirring tools
- Sufficiently large clearance space of inter combing mixing tools
- Inspection of certain construction elements (i.e. life factor of the roller bearing)
- Use of suitable seals
- Assembling of control cabinet and operating elements
- Assembling of additional aggregates (i.e. vacuum and hydraulic)

A wall distance of approx. $> 5\,mm$ is required for slow running stirring tools (i.e. anchor stirrer), whereas the wall distance for high speed stirring tools (i.e. propeller stirrer) should be a minimum of $50\,mm$.

When installing seals it has to be guaranteed that either the friction surface of the seal is $A_R < 100\,cm^2$ or the circumferential speed at the sealing surface is $u_R < 1,6\,m/s$ [7].

Generally the main control cabinet is located outside the Ex-zone which is less cost intensive as it may house such a frequency transformer and other electric components, which do not necessarily need to be attached to the machine. In addition an ex-proof control cabinet with the required operating elements will be fixed on or close to the mixing unit.

Furthermore any additional aggregates, as for instance hydraulic and vacuum pumps, are to be placed outside the Ex-zone if at all possible.

According to ATEX-regulations an inspection by a known certification agency (i. e. TÜV) is required for Ex-zone 0 and Ex-zone 20 mixing units.

For Ex.zone 1 respectively Ex-zone 21 the manufacturer of a mixing unit is merely requested to deposit the documentation of a machine at a specified location. These files will only be checked in case of damage [8].

3.4 Components of Mixing Units

3.4.1 Vacuum Equipment

All mixers and mixing plants can also be supplied to operate under vacuum conditions. The machines would be supplied with:

- cover designed for vacuum operation
- viewing port fitted with wiper
- suction valve for liquids and powders with good flow properties
- vent valve complete with filter
- liquid separator
- manometer
- vacuum pump

The vacuum pump is of standard design providing an absolute pressure of approx. 200 mbar.

Vacuum operation can be gainfully employed for a de-gasification process or when mixing air sensitive products. The vacuum pump may also be used for transferring liquid or powdered products into the mixing bowl. A vacuum would be drawn and the pump then shut down, the products is sucked into the bowl via the suction connection; with large quantities these steps would need to be repeated until the required quantities are transferred. When transferring powdered products it is possible to suck these in under the liquid level thereby avoiding dust formation. This is particularly interesting when handling health hazardous products.

Care must be taken not to transfer products when the vacuum pump is in operation as this might lead to products being sucked into the pump.

As an auxiliary equipment the vacuum cover can also be supplied with feeder funnel and shut-off valve.

3.5 Electrical Engineering

3.5.1 Introduction

Herbst mixers are generally delivered as complete sets which automatically include the necessary electronic components and the range of these components depends on the demand of the operating company. This could be a simple control box with the necessary components or a sophisticated measuring and control system for more complex operations.

It is of advantage for the operator not to have interphase problems between the different components.

Furthermore the electronic equipment can be laid out specially for operations in ex-zones (ATEX 94/9). It is common use to mount the main control box outside the ex-zone and to have an additional ex-proof control box with the necessary operating elements on the mixer. If wanted the main control box can also be built ex-proof.

3.5.2 Temperature measurement

A frequent requirement in the mixing process is the recording of the product temperature. The reasons may be manifold; the product temperature should, for example, be kept constant or should not exceed or lie below the minimum or maximum value. In the course of the mixing process the product temperature must go through a certain temperature profile. It is imperative that the correct product temperature be maintained in order to obtain a representative set value for the temperature control.

The positioning of the temperature sensor plays an important role in measuring the product temperature in the bowl. Generally the temperature elements are mounted stationary; they are mounted on a fixed location which can be through the bottom, the jacket or the cover of the bowl in order to have contact with the product. Especially with medium to high viscosity products this may present problems because no representative measurements can be obtained of the height of the bowl due to the varying temperature. Also the flow pattern of the stirrer may have a considerable influence on the locally registered temperature. Furthermore, a temperature difference between the bowl jacket and the middle of the bowl has to be registered. Operating several temperature sensors may cure this problem considerably.

An optimal temperature value can be obtained by moving the sensor constantly through the product during the mixing process. This is the case for example with planetary mixers. The sensor and a transmitter are integrated in the stirring tool. The stirring tool moves through the product on a circular path as well as circulating around it's own axis. An additional wall scraper transports the product constantly from the wall to the middle of the bowl. Herewith an optimal heat exchange is guaranteed and the sensor measures a representative product temperature. The sensor is placed above the product surface and several infrared diodes transmit the values to the receiver (without any contacts). The transmitter is operated by battery, which lasts approx. 3 years. The standard measuring range lies at approx. -55 °C and +125 °C. Standard accuracy is 0,125 °C. Figure 4 shows the sensor with the transmitter.

This measuring system has proved to be successful. Even product deposits on the sensor unit, i. e. creams, do not influence the transfer of temperature values. Even on existing mixing units this temperature measuring system can be installed later, it's instrumentation and control techniques can be supplied and fitted individually to suit the specific mixing process.

Alternatively a slip ring transmitter can be employed with higher temperatures.

Figure 4: Temperature Measuring System with Infrared Transmittance
a) (on the left) installed in the Planetary Mixer
b) (on the right) Sensor

3.5.3 Program control

There is a constantly growing demand for a constant quality of the mixing process. The quality of the product should be guaranteed even with personnel changes or frequent changes of products. Furthermore the end user often asks for a quality certificate, i. e. a mixing protocol, from the producer. This should not present any problem thanks to control techniques. Programming may correspond to the product which results in a smooth mixing process. Important parameters, such as temperature, pressure and revolutions can be registered and considered by means of modern sensors. Single components of the mixer, like drive, vacuum pump, heating or homogeniser may be controlled individually. This guarantees an optimal mixing process. The revolutions of the stirrer could be controlled either depending on the present product viscosity or the shear sensitiveness. For degassing of the stirred product or sucking in additional mixing components the vacuum pump may be connected and the planetary mixer will open on it's own towards the end of the mixing process. Even dosage, discharging and cleaning can be integrated into the programming, so that the personnel does not have to attend to the machine at all times. Thus several mixers may be operated, respectively different works be carried out, at the same time, which results in saving time and costs. Important phases of the program may be signalised optically or acoustically. Registrating measured values guarantees best safety techniques, i. e. switch off the stirrer when the temperature limit is exceeded.

No experience in programming is necessary in order to operate the control panel because it is controlled electronically. The actual process parameters (i. e. revolutions, temperature and pressure) are shown constantly on the display. The mixer can be operated by program control or manually.

The programs may be adjusted at any time to varying demands, which is important for example in the research and development area. For external data processing the actual parameters may be transferred to a PC via interphace; alternatively the planetary mixer could be fitted with it's own printer or tape deck.

The basic programming of the control system will be made customer orientated. The programs may be arranged for different products, saved, modified and recalled at any time. Changes of programs may be carried out by the operator on the control panel. The following figure shows a possible version of the control unit.

Figure 5: Unit for Program Control
[Simatic OP7]

3.6 Design of the Machine

3.6.1 Choice of Fabrication Material

All parts in contact with the product are of stainless steel. The steel quality depends on the medium to be mixed respectively on the customer requirements.

In Table 4 you find frequently used stainless steel qualities.

Other parts which are not in contact with the product are also (as far as possible) made of stainless steel.

Special materials are possible upon request.

Table 4: frequently used stainless steel qualities

Material No.	Shortname (EN 10088-2)	ASTM / AISI	BS
1.4301	X 5 CrNi 18-10	304	304 S 15
1.4404	X 2 CrNiMo 17-12-2	316L	316 S 11
1.4541	X 6 CrNiTi 18-10	321	321 S 31
1.4571	X 6 CrNiMoTi 17-12-2	316TI	320 S 31

AISI = American Iron and Steel Institute, ASTM = American Society for Testing and Materials, BS = British Standard

3.6.2 Surface Design

All parts in contact with the product are hand ground and polished. If necessary the surface may also be electrical polished.

For special applications a coating, i. e. with Teflon, is possible.

3.6.3 Regulations and Guiding Rules

All Herbst mixers are projected and fabricated in line with the latest regulations and guiding rules. These are in accordance with the guide lines of the chemical industry and relate to GMP and FDA. Furthermore an authorization of the CE-stamping can be obtained.

The Ex-zone is designed according to ATEX 94/9 and the mixing units have to undergo a single inspection by the technical surveyor (i. e. TÜV) if requested for zone 0 / 20.

3.6.4 Safety Standards

Herbst mixers are fitted with the necessary safety equipment, such as guards, bowl control by proximity switch and manually operating controls of the bowl and the level adjustment of the mixer head.

Mixing units located in ex-areas (zone 1/21) are fitted with additional safety measures such as internal bowl wall scraper elements made of conductive material and level control of double jacketed bowls.

3.6.5 Suitable design to allow ease of cleaning

All parts in contact with the product are designed in such a way that easy cleaning is possible. The surface shape is also subject to easy cleaning. Gaps are being avoided or arranged in such a way that they do not represent problems when cleaning.

3.6.6 Qualification and Validation

A qualification, i. e. a functional test of the unit, has to be arranged (as preparation) prior to the unit validation.

The qualification consists of the following partial steps:

- Design Qualification DQ
- Installation Qualification IQ
- Operational Qualification OQ
- Performance Qualification PQ

The unit operator provides the specification requirements for the new mixing unit in the Design Qualification (DQ). These requirements constitute the design and construction basis which are confirmed in the Installation Qualification (IQ). The specification design and installation as listed in the accompanying DQ & IQ Certificates are to be checked for completion and conformity.

This check, if not otherwise specified, is carried out visually. The unit design drawings, the IQ check list, the control circuit diagram and the documentary files serve as examination material.

To be checked:

- Unit components
- Feed and discharge connections
- Materials and substances in contact with the product
- Documents
- Drawings

The installation qualification (IQ) as well as the function qualification (OQ) can be carried out by the manufacturer, whereby both steps occur in close contact with and in the presence of the end user.

The OQ test program is the documentary evidence that the unit operates, trouble free and with repeatable results all in accordance with the customers approved design and specification. For these mechanical functional tests drinking water is used as the test medium.

To be tested:

- Safety equipment
- Unit behaviour on power failure
- Function of the main components
- Function of display elements and sensors
- Function of alarm equipment

After a successful operational qualification (OQ) further qualification / validation steps, such as Process Qualification (PQ) which provides documentary proof that the unit fulfils all specified requirements under process condition, may be required by the operator.

Validation is the acceptance of an operating unit. Test runs have to prove that the applied process and operation allow for a uniform and trouble free production.