Pumps are a significant component in any profitable chemical production operation.

Source: stockphoto mania / Shutterstock.com

Mobile Centrifugal Pumps Assure Flexibility and Safety in EX Zones

René Grywnow

Pumps play a key role in the chemical-pharmaceutical industry. They have a significant impact on determining whether a system is able to produce efficiently and effectively. The commercial damage resulting from a serious pump failure is therefore all the greater due to the resulting production downtime. Mobile, frequency-controlled pumps ensure that production can be resumed as rapidly as possible. Their use also assures better cost-effectiveness and enhanced environmental protection.

Today, modern production operations need to be efficient and effective. Systems should be able to run profitably at high utilization levels and high efficiency ratings, to safeguard the long-term future of a production location. Over the next few years, the chemical-pharmaceutical industry stands to benefit from population growth and the associated increasing levels in demand for its products. Nevertheless, locations and their respective advantages will remain the subject of continuous scrutiny.

Pumps are a significant component in any profitable chemical production operation. as Along with length of service life and a high level of operational availability, Life Cycle Costs are an important purchasing criterion for any production operation. These include maintenance, operating costs, downtime costs, loss of production etc. Another aspect is of particular importance for the chemical-pharmaceutical industry: plant safety for people and the environment.

Pumps are at the very heart of production. When a pump fails, the unscheduled production downtime can incur daily costs that can run into the millions. Production businesses have devised various strategies for achieving the highest possible plant efficiency ratings, even in the event of a serious malfunction. Depending on the approach, companies may keep spare parts or even entire redundancy pumps in their inventory. From a commercial business point of view, inventory is the most expensive option because it ties up capital. However, this plan reduces risk levels and assures continuity of production.

The most commonly used pumps in the industry, with a market share of around 68%, are known as standard chemical pumps. As pump manufacturers comply with the dimensions specified in DIN EN ISO 2858, replacing the pump should be an easy process for the operator. However, in practice, replacing a pump 1:1 is not always feasible because the hydraulic performance capacity of a pump is manufacturer-dependent, and significant deviations can exist within the different sizes of product.

Some operators evaluate the replacement capability of a pump using the NPAI (standard pump replacement capability index). This index characterizes the ratio of QBEP (best point of impeller) and QISO (standard nominal displacement volume). The smaller the deviation, the greater the geometric similarity of characteristics curves, and the more easily pumps can be interchanged.

Developments in drive technology and in frequency converter technology can contribute to making pumps more flexible to use in future, which in turn will help reduce the inventory of spare parts while enabling pumps to be operated in a more energy-efficient manner, thus ensuring higher levels of production reliability. Frequency-controlled pumps can be used in a flexible manner across different sizes which reduces the need to keep replacement units in inventory.

Overview of frequency converters

Frequency converters are easy to install centrally in the switch cabinet (IP20). The performance range depends on the manufacturer and extends

External frequency converter

- Integrated devices in switch cabinets (IP20)
- Field devices in a higher protection class (IP55)
- Retrofitting is not always possible.
  A vacant switch cabinet location must exist
- Performance range 0.25 kW to x MW
- High installation costs
  - Switch compartment
  - Sheathed cables
  - dU/dt or sine-wave filter

Integrated frequency converter

- Great dust and water protection (IP55, IP56 etc.)
- Easy to retrofit
- Performance range
  - up to 30 kW
  - up to 11 kW (II 2 G Ex de IIC T4 Gb)
- Dispenses with dU/dt or sine-wave filter
- Space-saving installation
- No routing of sheathed cables is needed

Tab. 1: Comparison of external and internal frequency converters

Size	Q	H	rpm
65-40-200	15 m³/hr	50 m	2,900
65-40-250			2,900
50-32-125	5 m³/hr	20 m	2,900
50-32-250			1,450
65-40-250			1,450
50-32-160	10 m³/hr	27 m	2,900
65-40-315		30 m	1,450
50-32-250	12 m³/hr	55 m	2,900
65-40-160	15 m³/hr	35 m	2,900
80-50-315			1,450

Tab. 2: Installed pumps that can be replaced by a mobile magnet-coupled centrifugal pump

into the single-digit megawatt range. Alternatively, there are the remote frequency converter solutions. Back in the 1990s, a pump factory, Pumpenfabrik Vogel (now Xylem), unveiled the first remote frequency converter for pumps.

The requirements profile for frequency-controlled pumps from an operational point of view is as follows:

- External frequency converter (switch cabinet)
- Remote frequency converter
  - EX zone (up to 11 kW)
  - Non-EX zone (up to 30 kW)
- Monitoring options
  - Standard monitoring
  - Extended monitoring
  - Data interchange
- EMC (electromagnetic compatibility)

The list of requirements is long and varies from one sector to another.

The following example describes a frequency-controlled mobile pump in a potentially explosive zone (Zone 1, temperature class T3).

Housing materials	Metallic pumps • Stainless steel • Uranus® B6 • Hastelloy® B or C • Pure nickel • Titanium • Hygienic design	Non-metallic pumps • PFA
Pump type	Non-self-priming pump Self-priming pump	Non-self-priming pump Self-priming pump
Version	Non-EX zone EX zone	Non-EX zone EX zone
Motor	Without frequency converter With frequency converter • EX zone up to 11 kW • Non-EX zone up to 30 kW	Without frequency converter With frequency converter • EX zone up to 11 kW • Non-EX zone up to 30 kW
Containment shell	Stainless steel, Hastelloy® C, Titanium, eddy current-free containment shells (ceramic or high-performance plastics, e.g. PEEK)	PTFE, PVDF, Alloy 600
Anti-friction bearing	SiC (silicon carbide) WoC (tungsten carbide)	SiC (silicon carbide)
Monitoring operations	Containment shell thermocouple (temperature) Dry-running monitoring Flow metering Pressure monitoring Drive monitoring	Containment shell thermocouple (temperature) Dry-running monitoring Flow metering Pressure monitoring Drive monitoring

Tab. 3: Configuration option for mobile pumps

Mobile pumps can be used in EX areas in many different ways, e.g.:

- For unloading tanks
- As emergency pumps to reduce the need for standby pumps
- For batch processes
- In the pharmaceutical and biotechnology industry
- As mobile process pumps
    - To transport alkaline solutions, acids, solvents etc.
    - To transport media laden with solids, with a solid content of up to 30%

A mobile centrifugal pump should facilitate seamless operation

The customer requirement for a frequency-controlled mobile pump can be as follows: The operator wanted to have a pump that could quickly replace various in-situ standard chemical pumps in the event of a serious system failure. The goal in this specific example was to remove the defective pump in the event of a pump malfunction and to resume production with the help of a mobile, flexible pump. Use of this pump therefore enables production operations to be maintained while the failed pump is repaired in a specialist workshop.

Pump requirements:

- Zone 1, temperature class T3 (200°C)
- Maximum temperature of the medium during production operations up to 140°C
- Density between 820 and 930 kg/m3
- Viscosity in normal operation similar to water
- Pump failure:
    - Temperature between 50 and 70°C
    - Non-toxic medium
    - Viscosity 20 to 90 mm2/s
- Existing pumps and operating points, see Tab. 2

To ensure safe operation in the EX zone – Zone 1, temperature class T3 (200°C) – the customer wished to have a unit that can be operated on

Source: CP Pumpen

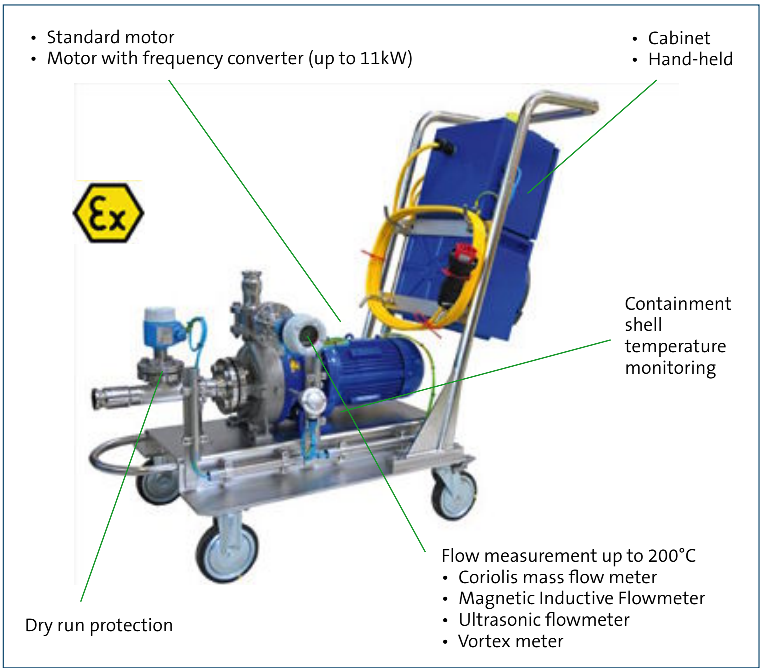
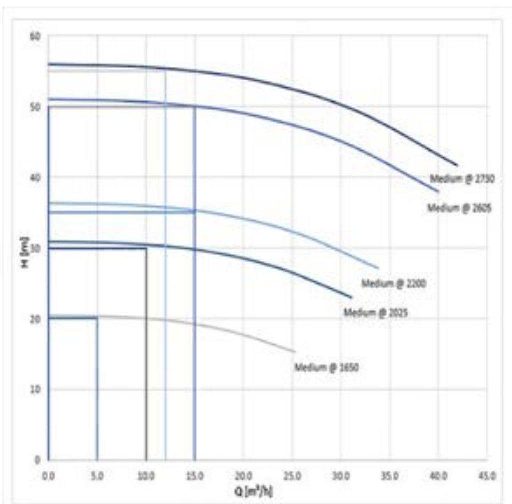
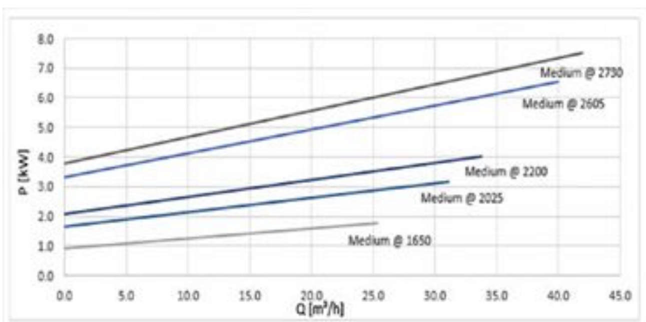


Fig. 1: Options for a mobile pump for the EX range (Zone 1, temperature class T4, components up to 200°C)





Source: CP Pumpen

Fig. 2 (above): Q-H diagram
Fig. 3 (below): Q-P diagram: Presentation of the different performance P2 levels (including power losses at different operating points, densities and viscosities)

location without needing to be integrated in a higher-order control system. Tab. 3 shows the configuration options of the mobile pump.

The chemical factory decided in favor of the following version of normally-aspirated magnet-coupled chemical process pump:

- Housing material 1.4581
- Containment shell Hastelloy® C4
- Containment shell thermocouple
- Fluid level limit switch (suction end) up to 200°C
- Coriolis flow measuring up to 200°C and viscosities of 1 to 1,000 cP
- Pressure gauge (suction and pressure side) 0 to 10 bar absolute

Fig. 2 and Fig. 3 show the characteristics range that can be covered by the mobile pump. In the event of a malfunction of one of the installed chemical process pumps, this pump can cover its function fully, i.e. it can fulfill all operating points with their different densities and viscosities. The mobile pump is limited by the motor used and the power intake required at the operating point. A motor reserve in the EX zone (safety factor) must also be taken into account. Depending on the size of the motor, this can be up to 20%.

There is a level switch on the suction end of the pump which detects potential flow rate interruptions and then promptly shuts down the pump. This ensures that the pump cannot run dry, and that neither the pump nor the containment shell reaches a critical temperature, both of which are factors which absolutely must be avoided in a potentially explosive environment.

Temperature monitoring prevents secondary damage

The mobile centrifugal pump was equipped with a metal containment shell made of Hastelloy® C4. This makes it possible to fit a temperature sensor on the atmosphere side. Eddy currents are induced during the operation of a magnetic coupling with metal containment shell. These cause the containment shell next to the magnets to heat up. During normal pump operation, this heat energy is dissipated by the medium flowing through the pump. As a consequence, the surface temperature of the containment shell only increases slightly. Nevertheless, the containment shell has the highest surface temperature of any component on the pump.

In unauthorized operating statuses such as

- when operating against a closed slide valve,
- when running dry or
- when a magnetic coupling desynchronization occurs,

no medium is pumped, and thus there is no cooling effect.

This causes the surface temperature of the containment shell to rise rapidly. This can be measured using the thermocouple. Using the appropriate devices, an alarm can then be triggered, or the pump can be shut down. Secondary damage can be prevented by shutting down the pump promptly. At the same time, this prevents the surface temperature of the pump from rising in an uncontrolled manner, in particular on the containment shell, which can develop into a potential combustion source in zones where there is a risk of explosion.

Flow measurement, supported by the operator on location

In the example described here, the operator decided in favor of a Coriolis flow measuring system. The determining factors were its ability to achieve the highest possible temperatures and to contend with the full range of viscosities that occur during the production process. Flow measurement can be beneficial in three ways on the mobile unit:

- It gives the operator on location the ability to pump volume-based batches around because the operator retains visual control on site at all times and is able to operate and shut down the pump via the control panel.
- The operator on site has a display screen that indicates if the pump is running against a closed valve.

Example of a pump

Operating point 1	Throttled	Frequency-controlled	Cost saving
	Speed = 2,930 rpm	Speed = 2,230 rpm	Run time: 8,064 hrs/year
	Q = 10 m³/hr	Q = 10 m³/hr	P_E = 24,514.56 kW
	H = 27 m	H = 15 m	P_F = 12,257.28 kW
	P_2 = 3.04 kW/hr	P_2 = 1.52 kW/hr	Cost saving, approx. 50%
Operating point 2	Bypass	Frequency-controlled	Cost saving
	Speed = 2,930 rpm	Speed = 2,170 pm	Run time: 403,2 hrs/year
	Q = 1.5 m³/hr	Q = 1.5 m³/hr	P_B = 1.044,29 kW
	H = 27.5 m	H = 15.2 m	P_F = 475,78 kW
	P_2 = 2.59 kW/hr	P_2 = 1.18 kW/hr	Cost saving approx. 55%

Fig. 4: Example of a manually operated control device with a mobile pump (configuration-dependent)

- Operation within the characteristics curve takes place in the normal manner. This visual check enables the operator on site to ensure that the pump always operates within its permitted characteristics ranges at different frequencies.

Frequency converters operate efficiently and save energy

By setting the actually required operating point, less strain is placed on the pump and energy is also conserved at the same time.

With their infinitely variable feedback control capability, frequency converters start and stop the motors very gently. The advantage compared to mains-operated motors is no torque or load impact. This reduces material wear in the system, components such as valves can be used longer, and repair and maintenance costs are reduced.

A comparison of the different types of feedback control confirms the efficiency of frequency converters. The affinity laws demonstrate this.

$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$ Flow rate Q is proportional to shaft speed.

$$\frac{H_2}{H_1} = \left(\frac{n_2}{n_1}\right)^2$$ Displacement head H is proportional to the square of shaft speed.

$$\frac{P_2}{P_1} = \left(\frac{n_2}{n_1}\right)^3$$ Power P is proportional to the cube of shaft speed.

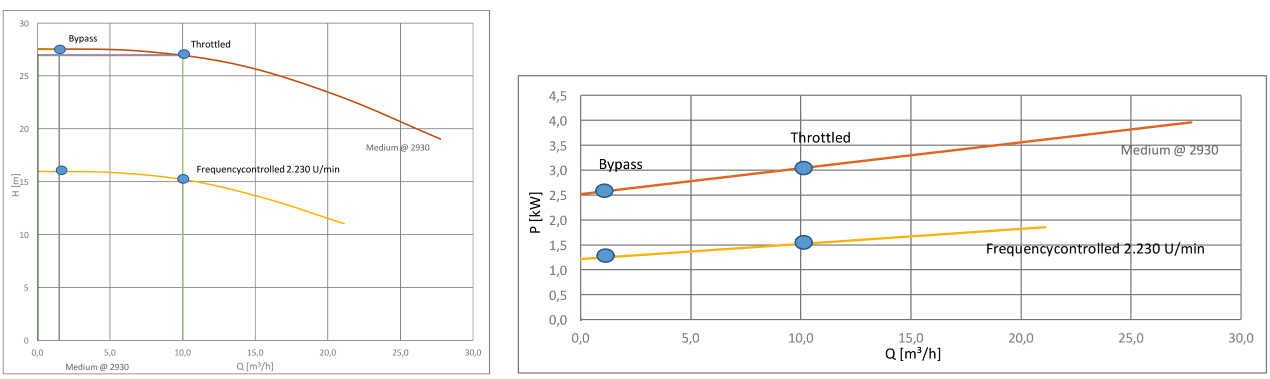


Fig. 5: The characteristics curve shows an installed pump that covers two uncontrolled operating points in the course of daily operation.

Mobile pumps offer numerous advantages

Modern drive technology raises the question whether the many different sizes of standard chemical pumps are actually required, and whether it may be possible to cover several of the currently existing characteristic ranges using just a few sizes of pump, and pumps which employ frequency control in the future.

Frequency control provides the operators of retrofit projects and mobile process pumps in explosion-protected zones with many advantages.

When planning a new system, frequency control can be integrated in the planning from the beginning, and appropriate pumps can then be sourced. In existing facilities, it is often very expensive to retrofit switch cabinets, particularly where space is limited. It is, however, possible to retrofit frequency converters to pumps with power ratings of 30 kW or 11 kW (EX zone). A range of different connections (field bus etc.) can be used to integrate these pumps into a higher-order control system, based in a control room, from which feedback control operations can be directed. In future, this could provide cost savings with regards to materials and inventory management, as well as in terms of energy consumption and CO_2 emissions. This would enable manufacturing businesses to actively contribute to protecting the environment.

According to the Federal Environment Agency, trade and industry and commerce and services account for approximately 70% of all electricity consumed in Germany. The industrial sector alone accounts for almost 45% of the electricity consumed. This results in potential cost savings for electrical drives, as they consume almost 40% of all electricity consumed in Germany, with approximately 80% of that figure being consumed by trade and industry. By using energy-efficient pumps, up to 5 billion kWh of energy could be saved annually in Germany alone.

Author:
René Grywnow, MBA
Managing Director / Sales Director
CP Pumpen GmbH, Mannheim, Germany