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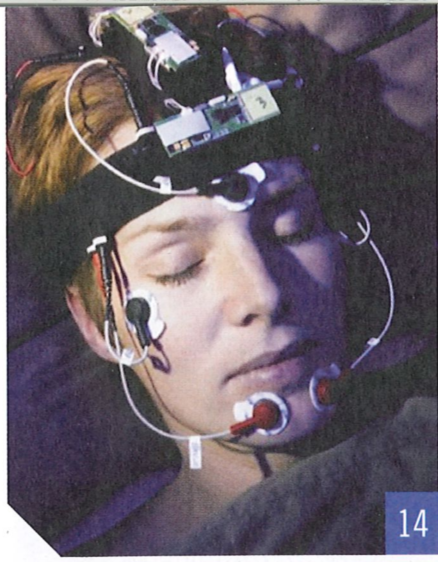
CONTENTS



14

32

FEATURES

COLUMN

REGULARS

MARKETPLACE

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Understanding the Critical Parameters of Selecting a Liquid Pump

An error in pump selection for a medical device can lead to manufacturing problems, device failures and reputation-damaging product returns. Here are some of the most important parameters to take into account when choosing a pump.

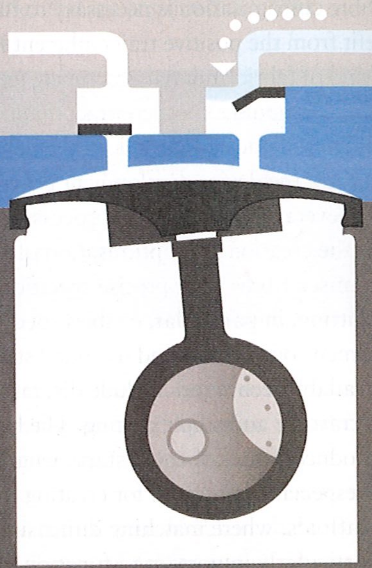

FIGURE 1: In a diaphragm pump, a diaphragm moves up and down in a chamber, and inlet and outlet valves are used to transfer liquids.

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Bad day at the office

It is a situation that engineers and medical device designers dread: you have completed development of a €20,000 analyser, 50 units of which have already been sold, and you've thrown yourself into your next project. Then comes the bad news. An inadequate pump in the system has caused virtually all of the new analysers to fail to function properly. Critical development time and money have been wasted, and the entire marketing plan for the new product is in jeopardy. The company is suffering a major setback.

This is not an imaginary scenario; it's not even that rare. In the past 10 years, important technological breakthroughs have been achieved in pump design, giving design engineers unprecedented flexibility, and yet many engineers are unaware of the advances. Additionally, there has been a serious lack of clear guidelines highlighting important criteria for pump selection. Add to this mix the medical device designer's traditional approach to purchasing a pump late in the design process from a catalogue of standard products, and you have a disaster in the making.

To prevent pump failure, it is extremely important that the designer be familiar with the latest pumping system technology and that the key parameters of the pumping system's needs have been clarified. It is essential that the designer communicates these parameters to the pump supplier early in the design process.

Pumping systems defined

A pump is a subsystem, not a commodity. It is a dynamic, interactive element of the medical device in which it functions. A pumping system will perform differently as conditions within the medical device change. For example, temperature or electrical power variations beyond a pump's defined tolerance limits could cause it to malfunction, thereby shutting down the entire medical system.

There are many types of pumping systems on the market, each with specific advantages and typical applications (Table 1). The most common are described below.

Diaphragm pumps: A diaphragm moves up and down in a chamber and inlet and outlet valves are used to transfer liquids (Figure 1). Diaphragm pumps are primarily used in blood analysers and life-support systems. As they do not have rotating or sliding seals, they are more tolerant of liquids or wet vapours than other pumps.

Peristaltic pumps: Flexed tubing induces liquid flow within a system. As the tubing can be sterilised, peristaltic pumps are often used to transfer sterile fluids such as those found in blood transfusion devices, automatic liquid feeding devices or in biological applications. They are also used for multi channel pumping, such as when one pump and a variety of tubes are used to transfer different fluids simultaneously.

Linear pumps: A form of linear displacement (by magnetic or pneumatic means, for example) moves the pump diaphragm as opposed to it being flexed by rotating elements. Linear pumps can operate very quietly, which is desirable for in-room patient-care equipment such as nebulisers and automatic drug-delivery systems.

Syringe pumps: A small infusion pump used to gradually administer small amounts of liquids to patients or for use in chemical or biomedical research. Syringe pumps are used, for instance, to inject solutions into high-performance liquid chromatography (HPLC) instruments in biochemistry and analytical chemistry.

Critical performance requirements

A pump's performance can vary dramatically depending on the device and the environment in which it operates. Therefore, it is vital to clarify the system's performance requirements early in the design process and to match them to the device design. Critical performance requirements that should be considered include:

- the type of fluid being pumped as well as its temperature
- the flow rate measured with a plus and minus tolerance
- the actual conditions at the pump's inlet and outlet, including load (vacuum and pressure)
- the ambient temperature at which the pump will operate
- motor type and electrical requirements measured with a plus and minus tolerance
- the pump's duty cycles (periods of operation and inactivity)
- the physical dimensions of the pump
- production quantity of the device (this may be necessary to justify a custom pump, if appropriate).

It is critical that designers specify the pumping system's tolerance to various performance requirements, including electrical power, temperature, flow rate, vacuum and pressure. Specifying a pump's power requirement, for example, without tolerance at 220 V is not enough. Rather, if the pump operates in a system that varies by up to 20 V, specify 220 V with a tolerance of ±10%. Similarly, when specifying flow rate and back pressure, the designer needs to specify a tolerance of flow rate over pressure to guarantee that the desired flow rate is delivered if pressure changes. This helps ensure that the pump will function in the particular system environment for which it is designed.

For example, if a pumping system creates a pressure greater than a medical instrument's tolerance, the soft tubing might collapse, connectors might break and other system parts might be affected when the pressure becomes excessive.

On the other hand, if the pump has to start pumping against an existing back pressure in the system, then the motor should have enough power to get the pump started.

Three Common Pump Pitfalls, and How to Avoid Them

Problem: A designer selected a linear piston pump for a blood analyser that handled wet gases (an inappropriate application for this type of pump). Of the 50 units in the field, virtually all were failing. The linear pumps were not producing the necessary vacuum. Moisture was corroding the piston and cylinder, rendering the pumps inoperable.
Solution: The piston pump was removed, the architecture of the vacuum system was modified and three small diaphragm liquid vacuum pumps were incorporated.

Problem: A steriliser manufacturer had improperly defined the operating parameters of a unit for maximum/minimum pressure. The manufacturer selected a pump with a maximum pressure of 43 psi. While this was the pump's maximum pressure, it was also the minimum pressure needed for the steriliser to function. Therefore, when the pump's pressure dropped below 43 psi, the steriliser no longer worked. This was the case with units operating in cities where absolute pressure is lower because of the altitude.
Solution: The operating parameters for pressure were properly defined and the pump was modified.

Problem: The designer of a blood analyser specified a pump with a specific motor power requirement. However, he did not specify a voltage power tolerance. The analysers were operated in countries where voltage output was higher, beyond the motor's capability. The consequences were thermal overload and pump shut-off.
Solution: A different motor with a specially wound, wider tolerance coil was incorporated into the pumping system.

TABLE I: Types of pumps and their typical applications.

Type of pump	Typical applications
Diaphragm pump	Blood analyser Life support systems Medical laboratory chemistry
Peristaltic	Transfer of sterile liquids Biology
Linear pumps	Automatic drug delivery Nebulisers
Syringe pumps	Analytical chemistry – HPLC

Electrical requirements

Naturally, every system environment demands specific electrical power requirements. Will the pumping system operate on 220 V / 50 Hz exclusively? Will the system work in Europe as well as in Japan, thereby requiring that it function at both 115 and 220 V and 50 and 60 Hz current?

If a pump designated to operate at 220 V (±10 V) is used in a location where the voltage can dip down to 180 V, pump performance might diminish to the point of causing overall system failure. This often can be solved by specifying a brushless dc motor to drive the pump. The addition of a universal ac to dc power supply, which handles a wide range of voltages and frequencies to produce a steady dc output, allows the use of a pump anywhere in the world.

When a motor is intended for global use or for portable, battery-operated instruments, there are many parameters to consider during the selection process, including adequate power supply capacity to start and run the pump and battery capacity. Because of their short lifetime, brush-type dc motors are being replaced by brushless dc (BLDC) motors, especially as their price has become more competitive.

BLDC motors offer many advantages over ac and brush-dc types, including low heat generation, high efficiency and low EMI/RFI. There is no brush wear or commutator sparking to shorten motor life. Advanced BLDC motors feature logic speed and on-off control as well as thermal, overload and reverse-polarity protection. This allows the designer to match pump performance with an instrument's instantaneous demand, controlling pump speed using the motor's feedback output and instrument logic. Because the pump generally operates at lower speeds, its lifetime is enhanced.

Ambient temperature

The pump's location within an instrument is very important. If ventilation is inadequate, the ambient temperature could soar. If it climbs above the temperature tolerance of the pump, the thermal fuse of the motor might switch off the motor (or, worse, on and off) and the system could be either seriously disrupted or shut down. At the very least, high ambient temperature and improper ventilation can shorten the life span of a pumping system.

Duty cycles

The pump's lifetime is directly correlated to the duty cycle, i.e. the number of hours the pump operates. Therefore, it is important to know if the pump will be running nonstop or only intermittently for a few minutes. This parameter should be taken into account when selecting a motor because different motors have different life spans.

Physical dimensions

There is an overall trend in the medical device industry towards size reduction, particularly in the case of portable devices. The pump's physical dimensions are also a factor to be taken into account.

Conclusion

Pump failures such as the ones illustrated in the accompanying article, Three Common Pump Pitfalls and How to Avoid Them, usually are not the fault of the pumping system. Rather, they are caused by the designer not communicating complete system requirements to the pump supplier. Working closely together, designers and suppliers can select the right pump to match system requirements.

> High ambient temperature and improper ventilation **can shorten the life span** of a pumping system

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