Pumping System Parameters to Consider for Your Medical Instrument

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Selecting the wrong pump for a medical instrument can lead to costly manufacturing delays, dangerous device failures, or even reputation-damaging product recalls. Therefore, it is critical that designers have the minimum parameters they need to consider in mind when making their choice. This article helps to highlight several of the more important aspects that need to be factored into their selection.

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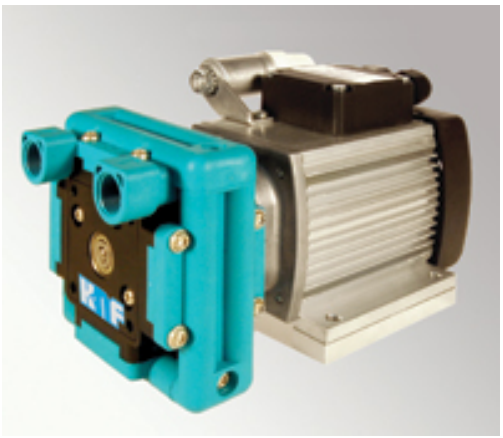
It's the kind of scenario that makes engineers and medical device designers cringe. The design of a $150,000 blood analyzer is completed and, with 50 units in the field, the next project is already underway.



Then, the news comes in. Because of an inappropriate pump in the system, virtually all of the new analyzers have failed to function properly. Critical development time and money as well as tightly knit plans for marketing the new product have suffered a major setback.

This is not an imaginary scenario, nor is it a rare one. While in the past 10 years, major technological breakthroughs have occurred in the design of pumping systems giving design engineers more flexibility than ever before many engineers are not aware of them. Additionally, clear guidelines highlighting important criteria for selecting the right pump have been seriously lacking. Add to this mix the medical device designer's traditional approach to purchasing a pump late in the design process and from a catalog of standard products and the makings for a disaster are in place.

To avoid a pump's failing, it is extremely important that the designer acquaint

himself with the latest pumping system technology and clarify the key parameters of his pumping system's needs. Then, and most important, the designer must communicate these parameters to his 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 the pump to malfunction and thus, the entire medical system to shut down.

Pump Types

There are many types of pumping systems on the market, each offering its own advantages for particular applications. Examples include:

•**Diaphragm pumps:** These use inlet and outlet valves to create pressure or a vacuum, as well as to transfer liquids under a vacuum. They primarily are used in blood analyzers and life-support systems because, by not having rotating or sliding seals, they are more tolerant than other pumps to liquids or wet vapors.

•**Peristaltic pumps:** These pumps flex a tube to induce liquid flow within a system. Because the tubing can be sterilized, peristaltic pumps are used most often to transfer sterile fluids, such as in blood transfusion devices or automatic liquid-feeding devices. They also are used for multi-channel pumping (i.e., using one pump and a variety of tubes to transfer many different fluids simultaneously).

•**Linear pumps:** These use a form of linear displacement (e.g., magnetic or pneumatic) to move the pump's diaphragm, as opposed to flexing the diaphragm through the use of rotating elements. They can operate very quietly, which is desirable for in-room patient-care equipment, such as nebulizers and automatic drug-delivery systems.

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 early in the design process the system's performance requirements and to match them with those of the device's design. Several critical performance requirements to consider are:

•The type of fluid being pumped and its temperature

•UL or other third-party approvals required for installation

•Physical dimensions of the pump

•Production quantity of the device (necessary to justify and amortize the cost of customization, if appropriate)

•Actual conditions at the pump's inlet and outlet, including load (vacuum and pressure) and flow rate measured with a plus and minus tolerance

•Motor type and electrical requirements measured with a plus and minus tolerance

•Ambient temperature at which the pump will operate

•The pump's duty cycles (periods of operation and inactivity)

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 115 V—is not enough. Rather, if the pump operates in a system that varies up to 10 V, specify 115 V with a tolerance of ±10 V. Similarly, when specifying vacuum rate and flow rate, the designer needs to specify a tolerance of flow rate over a tolerance of vacuum or pressure. This helps ensure that the pumping system will function in the particular system environment for which it was designed.

For example, if a pump has the tolerance to create a vacuum greater than that required by the device and the device contains soft tubing, the pump's excessive vacuum could cause the soft tubing to collapse, resulting in a system shut-down or equipment damage. Likewise, a pumping system that can create pressure greater

than a medical instrument's tolerance can break connectors and other system parts when the pressure becomes excessive.

Electrical Requirement

Naturally, every system environment demands specific electrical power requirements. Will the pumping system operate on 115 V/60 Hz exclusively? Will the system operate in the United States as well as Europe, requiring that it operate with both 50- and 60-Hz current?

Perhaps voltage conditioning will be a factor—requiring a voltage transformer between the pump and power supply—so that the pump operates with 115 V in one environment and 220 V in another.

If a pump designated to operate at 115 V (±10 V) is located where voltage may vary as high as 130 V, that pump may shut down on over temperature, resulting in overall system failure. Many times, this can be solved by specifying a brushless DC motor to drive the pump. The addition of a universal AC to DC power supply, that handles a wide range of voltages and frequencies to produce a steady DC output, allows the use of one pump anywhere in the world.

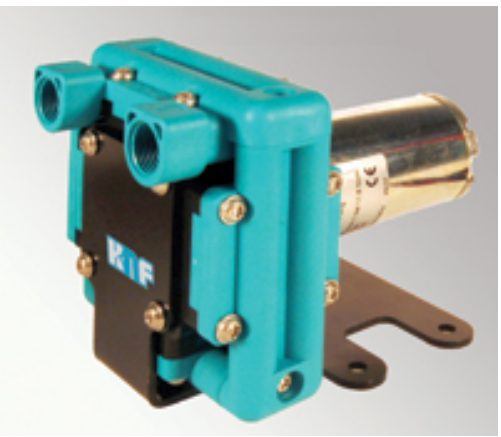
For worldwide use, and for portable, battery operated instruments, there are many parameters to consider when selecting the motor, including providing adequate power supply capacity to start and run the pump and battery capacity. Because of the short lifetime of brush-type DC motors, they have long been replaced by brushless DC motors, especially as the price of these devices becomes more competitive.

BLDC 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 control and logic on-off control. This allows the designer to match pump performance with an instrument's instantaneous demand, controlling pump speed using the motor's tach feedback output and instrument logic. Because the pump generally operates at lower speeds, lifetime is enhanced.

Ambient Temperature

The pump's location within an instrument is very important. If ventilation is inadequate, the ambient temperature could climb. If it climbs above the temperature tolerance of the pump, the system could shut down and the equipment fails. At the very least, high ambient temperature and improper ventilation can shorten the life span of a pumping system.

Duty Cycle



Some blood analyzers, for example, will at some point in their operation perform an analytical function, such as optically reading the contents of a vial. This function can take from 10 seconds to two minutes. During this time, fluid movement within the system stops; the vacuum pump is not needed and frequently turns off. How long the pumping system remains inactive, the demands on the pump when the analyzer performs its next function, and many other factors can be critical to selecting the right pump for the job.

For instance, will the pump need to restart against load? Most pumping systems must be at no-load conditions on inlet and outlet to restart properly. However, some pumps can be modified to start against vacuum. If a pumping system must restart against vacuum, the designer must communicate this to the pump supplier. Otherwise, a standard pump—one not designed to start against pressure—may be supplied.

Case Histories

The following case histories illustrate some common pitfalls designers encounter when selecting a pumping system.

Case 1

A designer selected a linear piston pump to perform a vacuum application in a blood analyzer 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. The solution: The piston pump was removed, the architecture of the vacuum system was modified, and three small diaphragm liquid vacuum pumps were incorporated.

Case 2

A sterilizer manufacturer had improperly defined the operating parameters of his 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 sterilizer to function. Therefore, when the pump's pressure dropped below 43 psi, the sterilizer did not function. 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.

Case 3

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

Conclusion

Pump failures, such as the ones illustrated in these cases, usually are not the fault of the pumping system, but rather, due to the designer not communicating complete system requirements to the pump supplier. Working closely together, designers and suppliers can select the right pump to match a system's requirements.

Online

For additional information on the technologies and products discussed in this article, see *MDT* online at www.mdtmag.com [2] or KNF Neuberger Inc. at www.knf.com [3].

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