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Operating

Applying NPSH to metering pumps

Net positive suction head calculations are routinely used to establish whether centrifugal pumps will operate satisfactorily in a given process. However, extending the NPSH concept to metering pumps presents a number of difficulties, as Patrick Deniau of Milton Roy Europe explains.

Net positive suction head (NPSH) quantifies the level of usable energy at the pump inlet. It is usually expressed in metres of liquid column (mlc). The objective of NPSH calculations is to verify that the pump will be operating outside the cavitation risk zone for a given process.

Centrifugal pumps

The NPSH concept is well understood in the centrifugal pump sector and the approach is fully standardized.

NPSHa

This is the available NPSH.

In the suction tank, we have a certain pressure – minus the liquid vapour pressure at the working temperature to prevent cavitation, this pressure represents the usable energy at the level of the storage tank.

The geometry of the installation defines the differential elevation between the liquid level in the suction tank and the pump itself. When positive, the pump is in the flooded suction configuration and can benefit from extra usable energy. When negative, the pump is in the suction lift configuration and benefits from less usable energy.

Along the suction pipe, we have friction losses that can be easily determined from tables or by calculation, based on suction equivalent length. Component manufacturers give the equivalent length of each of their products (elbow, valve, reduction nozzle, etc.) to facilitate this approach. Friction losses reduce the usable energy.

Combining these system parameters determines the available NPSH (NPSHa) at the pump inlet, the determination of which is the sole responsibility of the purchaser.

NPSHr

For their part, the pump manufacturer will qualify their pump, particularly by

Figure 1. The PRIMEROY®L, the most recent metering pump launched by Milton Roy, offers a minimum positive inlet pressure (MPIP) of more than 8 m suction lift.

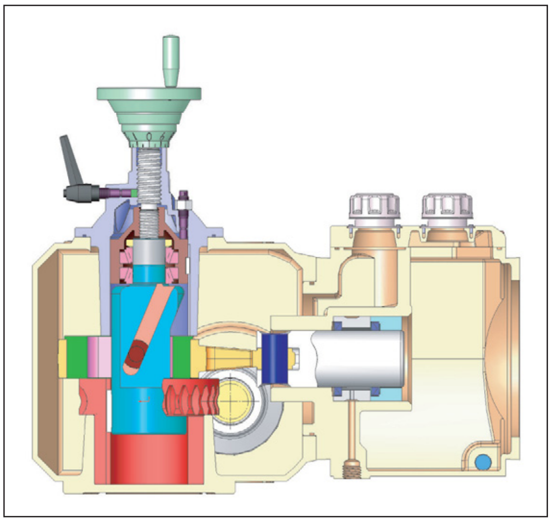

Figure 2. Cross section showing the variable eccentric design of the Primeroyal drive concept.

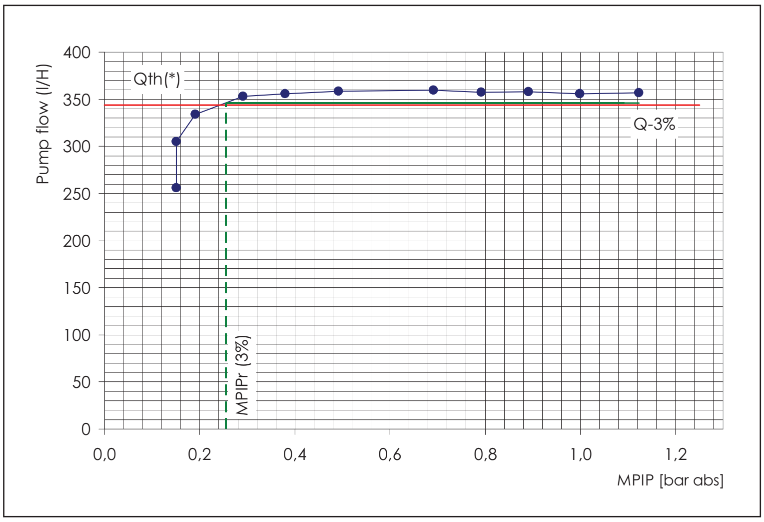

Figure 3. MPIP measurement on the newly developed PRIMEROY K pump range.

measuring the pump's required NPSH (NPSHr).

At a given working point, the pump will be installed with a starving device on its suction line so that the test loop can deliver an adjustable NPSHa. At the point where the NPSHa is low enough to affect the pump's volumetric efficiency (usually by 3%), the value is normalized as the pump's NPSHr. This data is the sole responsibility of the pump manufacturer.

NPSH criterion

It is the responsibility of the pump supplier to select a pump with an NPSHr below the NPSHa given on the customer datasheet, with a sufficient safety margin (usually 0.5 mlc), that is:

$$NPSHa > NPSHr + 0.5\ mlc$$

Metering pumps

Only one clear definition of a metering pump is given by the API675 standard: 'A reciprocating pump in which precise volume control is provided by varying its effective stroke length. Such pumps are also known as proportioning, chemical injection, dosing or metering pumps'.

Being a reciprocating pump, a metering pump generates a highly pulsating flow. Instantaneous flow variation being fluid speed variation, this means that the pump will have to alternately accelerate and decelerate the liquid column. On the suction side of a metering pump this translates as:

- At the beginning of the suction stroke, the liquid column must be set in motion and accelerated, which is achieved by the pump creating a relative vacuum to pull the fluid.
- At the end of the suction stroke, the liquid column is in motion and, due to its inertia, the pump has to decelerate it by exerting an overpressure.
- Friction losses are greatest at the middle of the suction stroke when the speed is at a maximum. Except for high viscosities, friction losses do not interfere with acceleration, as they are out of phase with each other.

Impact on NPSH approach

The first problem is that acceleration is largely predominant when compared to friction losses (by a factor of more than 50 in most cases), and must be integrated into the NPSH calculations. As a consequence, pump buyers do not need to take account of friction losses in their NPSHa calculation.

A second problem is that acceleration is a function both of the installation (the responsibility of the buyer) and of the selected metering pump (the responsibility of the seller). Typically:

$$Acceleration = 0.016L.Q.N/d^2$$

This formula is not a standard across all metering pumps; each manufacturer has its own formula, but they are all basically equivalent. Here, L and d are respectively the actual length (in m) and the internal diameter (in mm) of the suction line; Q and N are respectively the pump's maximum output (in litres/h) and its stroke speed (strokes per min; spm). Note that, on the installation side, the pipe diameter d is squared and so has a significant influence and, on the pump side, stroke speed N may be a critical factor as well, since a low stroke speed may imply a larger pump, which is likely to be more expensive.

ISO 13710 standard

The ISO 13710 standard was published in December 2004 and addresses 'Reciprocating positive displacement pumps for use in the petroleum and natural gas industries'. In its NPSH section, it stipulates that NPSHa is the responsibility of the buyer, similar to the centrifugal pump NPSH approach, and, as the standard writers knew that there are acceleration issues in the case of reciprocating pumps, they simply add that NPSHa must include acceleration losses.

The third problem is that the buyer cannot determine the NPSHa as it is also a function of the selected pump.

ISO 13710 also defines an NPSHr for reciprocating pumps, to be provided by the manufacturer. This NPSHr is measured in exactly the same way as for centrifugal pumps.

This brings us to the fourth problem: though the NPSHr approach is meaningful in centrifugal pumps as it measures a working point where the volumetric efficiency starts to drop, therefore approaching the point where the risk of cavitation appears, it is not meaningful for reciprocating pumps. Reciprocating pumps are supposed to deliver the same volume at each stroke, and such a measurement simply measures the pump's ability to work under starved suction conditions, what we call the minimum positive inlet pressure (MPIP), which is the minimum static pressure on the suction side needed for the pump to deliver its volume per stroke (see Figure 3). It is not a sign of incipient cavitation, as cavitation is caused by acceleration, and applies to a very short period of time at the beginning of the suction stroke, independent of MPIP pump performances.

Illustration

Some years back, I had an intellectual 'fight' with a customer's witness inspector keen to apply the ISO 13710 NPSH approach. The application was for liquefied gas metering. As usual for these complex applications, the installation was quite simple: a suction tank pressurized at the vapour pressure level (to maintain the liquid phase), with a short, straight suction line providing a flooded suction configuration to the pump.

The pressure in the suction tank, minus the vapour pressure (equalling zero at this stage), plus the tank's relative elevation to the pump, minus the acceleration (not even considering friction losses) was leaving a very low NPSHa… which was below the pump's MPIP reported in the datasheet. According to the ISO 13710 NPSH interpretation:

NPSHa < NPSHr, and…

… not any metering pump can do the job!

By the way, today, this pump is working well. Why?

- First, the tank elevation was slightly larger than the calculated acceleration, leaving some usable energy at the pump inlet.
- Second, the static pressure under which the pump is working (the pressure in the suction tank plus the tank elevation) was larger – by far – than the MPIP required by the pump. Vapour pressure does not need to be considered here, as the pump does not differentiate if the pressure is coming from a liquid or a gas.

NPSH test

Another issue arises here. As for centrifugal pumps, metering pump customers increasingly want to confirm the pump selection by an NPSH test – again, another possible intellectual fight between the parties.

Do we want to measure the pump's MPIP? Easy, but, as illustrated above, it has nothing to do with an NPSH approach whose purpose is to prevent cavitation. Do we want to simulate acceleration? A bit more complex to do, but it is not a real test, as it is a simulation based on calculations. Do we want to really test what the seller says (that the pump will work under the specified conditions)? We would have to reproduce the entire installation (!), using a fluid with the same specific gravity, vapour pressure, etc. Everybody can understand that this is simply not feasible.

Conclusion

Trust is the answer! The customer has to provide the manufacturer with the best reliable information on the product and the installation (usually well defined in the datasheets). The manufacturer, for its part, has to make the best appropriate metering pump choice, including the NPSH criterion approach, and give advice, such as recommending enlargement of the suction pipe diameter or shortening the pipe, suggesting the use of a dampening device or a multiplex pump design, and so on.

The final, appropriate NPSH criterion for metering pumps, which covers more than 90% of metering pump application cases, is:

NPSHa (without friction losses) > Acceleration + 2mlc (the safety margin). ■

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