Analysis of sine pump technology's ability to add value and reduce energy costs in high viscosity applications

Minimising costs, boosting profits

Contents

Key conclusions

There are a number of key benefits associated with using sine™ pump technology with respect to added value and process cost reductions, particularly regarding energy consumption.

Sine pump technology requires less power than lobe or circumferential piston pumps, typically up to 50% less, especially in viscous applications.

The size of the savings increases in line with viscosity. The higher the viscosity, the more the savings.

Significant reductions can be made in electricity consumption and carbon footprint.

The net inlet pressure requirement (NIPR) for sine pumps is lower than that of lobe pumps. As a result, cavitation is far less likely to occur.

MasoSine energy efficiency (Mee) curves have been developed as an effective tool to prove the above points.

Executive summary

This white paper sets out to show that MasoSine energy efficiency (Mee) curves are a useful and proven way of demonstrating that sine pump technology can deliver significant user benefits. This is in comparison with competing technologies such as lobe pumps and circumferential piston pumps.

The function and use of Mee curves will be explained and supported by independent academic testimony as well as a growing number of case study examples worldwide.

MASOSINE ENERGY EFFICIENCY mee Sustainability curves

Introduction

Organisations are becoming increasingly aware of energy efficiency. They are being driven by environmental regulations and the need to reduce carbon footprint, or by the ever present requirement to cut production costs. After all, improving energy efficiency enables manufacturers to increase profitability and remain competitive in today's cost conscious marketplace. Energy efficiency is today a board level commitment, driven by top-down legislation from governments across the EU, including the UK.

According to the British Pump Manufacturers' Association (BPMA), pumps account for no less than 10% of the world's electricity consumption, and two-thirds of pumps use up to 60% more power than necessary.* The effective management of energy consumption in process equipment is therefore critical.

The challenge

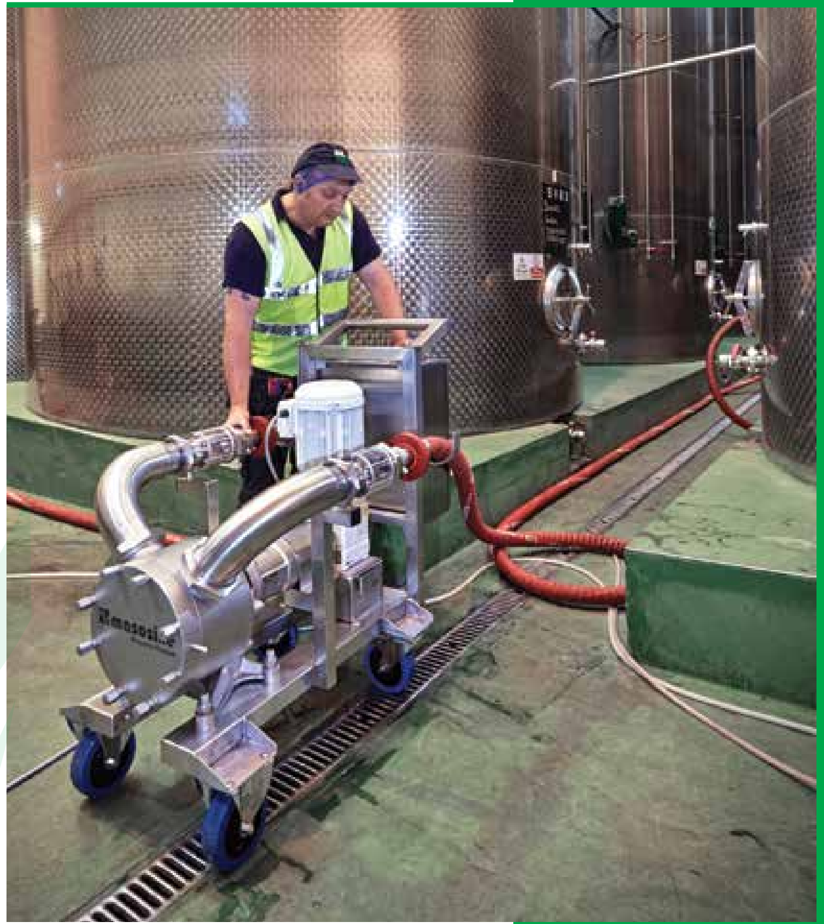
Many manufacturers face the requirement to pump a wide range of highly viscous products, from mayonnaise to meat, or from surfactants to silicone. This presents different challenges, and a range of viscosities that can sometimes register in the thousands or even millions of centipoise (cP).

Most pumping technologies are affected by high product viscosity. Typically, the torque and hence power required to drive the pump increases in line with viscosity, thus resulting in the need for electric motors. Larger motors draw more power, even when not operating at larger capacity.

According to the BPMA, on an industrial site, an average of two-thirds of the electricity cost will be spent on running electric motors.* Furthermore, energy represents 95% of a pump's life cycle cost, so the opportunities for savings are substantial.

"Energy represents 95% of a pump's life cycle cost."

"According to the BPMA, on an industrial site, an average of two-thirds of the electricity cost will be spent on running electric motors."



* Source: British Pump Manufacturers' Association (BPMA)

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> The benefits of MasoSine pumps increase in line with product viscosity.

The solutions

There are of course, many different ways of saving energy. For example, it is possible to use higher efficiency motors with existing pump technology, such as replacing an IE2 drive with a more efficient IE3. Alternatively, the process can be redesigned, reducing process steps or the need for product transfer. These are usually very expensive, but are often undertaken to achieve cost reductions.

Another option is to look at replacing existing pump technology with a more efficient principle, such as swapping a traditional lobe pump for an energy efficient sine pump. Sine pumps are not affected by viscosity in the same way as lobe pumps and require lower torque to drive them so can use smaller motors; a factor that has made them popular choices in the food, beverage and cosmetics industries, as well as in the chemical sector.

Providing a highly reliable and economical solution, the sinusoidal rotor of a MasoSine pump overcomes the limitations of conventional pump technologies, producing powerful suction with low shear, low pulsation and gentle handling without the need for high power drives. In addition, the benefits increase in line with product viscosity – the rotor design enables handling of a very large range of viscosities (from 1cP to 8,000,000cP) without modification to the pump and with minimal effect on power requirements.

Sine pump design

A single sinusoidal rotor creates four evenly sized chambers as it rotates. Fluid is “pulled” through the inlet into each chamber in turn. As the chamber rotates, it closes, and then discharges fluid through the outlet port. At the same time, the opposite chamber opens to draw in more fluid, resulting in a smooth flow with virtually no pulsation. A gate functions as a seal between the inlet and outlet sides of the pump, thus preventing pressure equalisation and stopping fluid escaping from the higher pressure outlet to the low pressure inlet.

Notably, the chambers are moved as a whole, meaning their volume does not change during the pumping process and the product is not subject to any significant mechanical load. As a result, product is moved very gently from the inlet to the outlet.

Energy efficiency

The internal slip of sine pumps is determined by the gap widths between the rotor, the liners and the gate. These gaps can be kept very small due to the clear rotating motion (small surrounding gap), which means that the pump offers very good volumetric efficiency. Furthermore, the volume of the four chambers remains constant during the entire handling process and, in contrast to other operating principles, the sine pump rotor does not cut through the product being handled, minimising product damage.

The design principle of using only one rotor, one shaft and one seal, without the need for an additional timing gear, means that the torque required for continuous movement is reduced to a minimum. Energy consumption is not increased by diverting power to the gear.

Another factor governing good energy efficiency is that a sine pump transports products almost without pulsation and ensures a consistent flow rate. Continuous flow saves energy and is gentle on all system components. Typically, sine pumps offer up to 50% less energy usage for the same flow compared with other pump types.

Professor Eberhard Schlücker, Head of the Institute of Process Machinery and Systems Engineering at Friedrich-Alexander University, Erlangen-Nürnberg, Germany, is able to confirm the energy advantages of sine pumps after close examination of their operating principle.

“A sine pump has few sliding surfaces, which has a positive effect on energy consumption in comparison to competing operating principles” he states. “In the case of highly viscous products, the sine pump is particularly impressive because there is very little internal friction and minimal fluid deformation, making it more efficient than rotary pumps, for example.

As far as power density is concerned, a sine pump is one of the leading displacement pump types for the transport of viscous fluid.”

Size matters

Irrespective of the pumping technology used to achieve optimum efficiency and minimise energy costs and pump wear, the size of pump must be matched precisely to process requirements. From an energy perspective, there are always problems if too small or too large a pump is chosen, as they will usually have to be operated with increased energy consumption.

The importance of size not only applies to the pump but to the choice of motor; while a pump with a motor that is too small cannot do its job properly, an oversized drive needlessly wastes energy and requires additional investment.

> Typically, sine pumps offer up to 50% less energy usage for the same flow compared with other pump types.

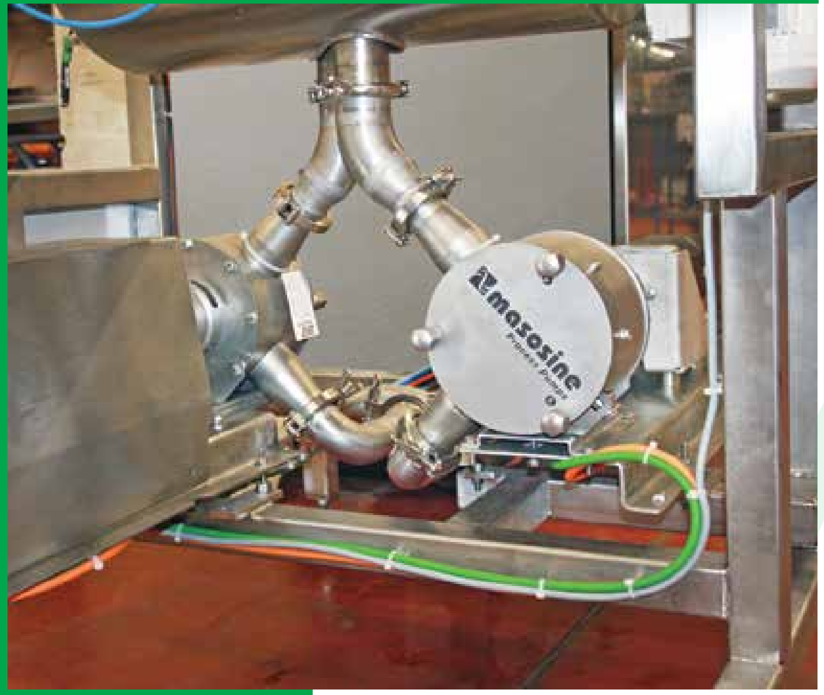
Sustainability curves

Mee curves

It is the energy efficiency characteristics of sinusoidal technology that led MasoSine to launch the concept of Mee curves. In basic terms, Mee curves enable MasoSine to prove to customers (via a set of performance curves and calculations) the energy saving benefits of sine pumps. It is also possible to show how energy savings rise as viscosity increases.

Mee curves have been developed from extensive research as a tool to help identify the correct size of pump and drive, and thus save money for the customer. They show how many kilowatts of power are required for a motor to run a particular application (relative to varying viscosities), as well as the efficiency of the pump.

Before addressing the specific details of Mee curves, a number of factors require exploring to develop a better understanding of why the curves are so important. These include Net inlet pressure available/Net positive suction head available (NIPA/NPSHA), Net inlet pressure requirement/Net positive suction head requirement (NIPR/NPSHR), cavitation and power requirements.



NIPA/NPSHA and NIPR/NPSHR

Sine pumps not only offer low pulsation with high suction capability, but low NIPR/NPSHR, which reduces the risk of cavitation and helps increase flow rates. Put simply, the sine pump's single shaft and sinusoidal rotor design compares favourably with the dual rotor and complex timing gears associated with lobe pumps.

NIPA/NPSHA is the absolute pressure at the inlet port of the pump provided by the system. Similarly, NIPR/NPSHR is the minimum pressure required at the inlet port of the pump to avoid cavitation. In simple terms, NIPA/NPSHA is a function of the system, and NIPR/NPSHR is a function of the pump. The NIPA/NPSHA must be greater than the NIPR/NPSHR to avoid cavitation.

In a typical pumping system, on the suction (low pressure) side of a pump, there will usually be a tank at atmospheric pressure. Emerging from the tank there will be an elbow and some piping, followed by a number of valves, and then the pump.

There will always be an amount of pressure loss from the inlet piping, as well as associated losses caused by gate valves, butterfly valves, product viscosity and so on. For this reason, even pumps with great suction capabilities like the sinusoidal pumps from MasoSine should always be as close to the tank as possible. This ensures that the system provides as much product as the pump wants to draw.

Cavitation

Cavitation occurs when the pump wants to draw more product through the suction line than the system can provide. As a result, the pressure in the pump inlet drops below the vapour pressure of the liquid, creating vapour 'bubbles' that get moved to the discharge side of the pump and collapse due to the higher pressure. The implosion of the vapour bubbles generate a noisy and intensive shockwave and vibration which can cause damage to the pump and the entire system.

Further issues caused by cavitation include loss of capacity as vapour bubbles consume space where liquid should be.

Power requirement

The power requirement of a pump is affected directly by flow, pressure and viscosity. The components of this power requirement are as follows:

Water horsepower (WHP) – the power required due to external system conditions. Sometimes known as fluid horsepower or hydraulic horsepower, WHP is a calculated value that remains the same for all pump types: the flow rate multiplied by the discharge pressure divided by a constant.

Additional horsepower (AHP) – the power required due to internal conditions in the pump, which includes pressure losses and mechanical friction. This is a measured value specific to the pump type.

Viscous horsepower (VHP) – the power required due to viscosity within the pump. Again, this is a measured value specific to pump type. It should be noted that viscosity only has a minor influence on sine pumps as the rotor simply moves the product through the pump. Conversely, other pump types are affected significantly by viscosity as they have to cut through the product.

The effects of viscosity

The VHP and NIPR/NPSHR curves are particularly revealing when it comes to noticing the effects of viscosity. For instance, the VHP will be seen to go up dramatically for lobe or circumferential piston type pumps. Using a lobe pump will typically show that a 20,000cP increase in viscosity (say, for pumping something like orange juice concentrate as opposed to water), will demand far greater power to the tune of 50-60%.

A similar effect of viscosity relates to NIPR/NPSHR. When viscosity increases, the maximum running speed of a lobe or circumferential piston pump needs to be reduced considerably to avoid running the pump under cavitation. This reduces also the achievable flow rate of the pump. So users might need to specify a pump which is bigger than the theoretical necessary flow rate just to avoid cavitation. Costs for spares and equipment, such as frequency inverters rise accordingly. For instance, in a typical situation, when product viscosity approaches anything near 100,000cP, a 2.5” (63.5mm) lobe or circumferential piston pump will struggle to run much beyond 100rpm.

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So, what happens to a sine pump at high viscosity? Well, something very different. When viscosity increases, VHP only goes up a tiny amount of that compared with a lobe or circumferential piston pump; just 3% in fact. Furthermore, even at fairly high speeds of 400 or 500rpm, sufficient NIPR/NPSHR exists to perform the task in hand. For instance, at 400rpm speed pumping a 100,000cP product, only 7.3 psi is required at the pump inlet, thus proving that sine technology can pump thick products faster. This, coupled with greater suction capabilities and the need for less power, is what Mee curves are able to prove.

A circumferential piston pump of the same size (same volume per revolution) wouldn’t be able to run this application at the same speed without running under cavitation. Using a circumferential piston pump would require a pump approximately twice the size in terms of volume per revolution just to get the same flow rate without inducing cavitation. The larger size of pump and other equipment like motor, frequency inverter and spares, means a bigger price tag.

For correct sizing, the following three variables must be known: product viscosity, flow rate and pressure. All are important to determine the correct pump speed, while pressure also helps to calculate the necessary motor power.

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What do Mee curves look like?

To help explain the structure of Mee curves, the slip correction curve at the top is always the first step in correctly sizing a pump. This is needed in order to calculate the internal loss caused by the pressure in the pump. The higher the viscosity of the pumped product the less effect has the pressure on the internal loss.

Beneath this will be a Gallons per minute/Litres per minute (GPM/LPM) curve, as well as the horsepower curves already mentioned: WHP, AHP and VHP. The final curve at the bottom is for NIPR/NPSHR.

How to use Mee curves

For those who are familiar with Mee curves or have seen a presentation on their application, using Mee performance curves is a simple, five step process.

The first step involves determining the internal slip of the pump. In essence, this is the quantity of fluid that slips back from the discharge side to the suction side due to internal clearances, especially with low viscosity products like water.

Steps two to four focus on the required power.

The final step examines NIPR/NPSHR.

So, consider a typical application of 100cP product viscosity, 10,000 litre/hr flow and 7bar pressure. The first step is to look at the viscosity correction curve slip correction curve parallel to the other lines.

In this example, the flow is 10,000 litre/hr. So, upon finding the 10,000 point on the Y-axis, draw a horizontal line across to the calculated operation line that was previously extended to the X-axis base. Where it meets, draw a line vertically down to the X-axis. This will show a speed of circa 165rpm. So, it can be determined that for pumping a 100cP viscosity product at 7bar pressure, this particular pump needs to run at 165rpm.

The next stage concerns how much pressure is required. Using the same Mee curve, continue the vertical line downwards to the WHP curve until it hits the 7bar pressure line. Draw a line horizontally across to the Y-axis and it will show that around 2.4kW is required.

Continue the vertical line downwards to the AHP curve until it hits the 7bar pressure line. At the point of intersection draw a horizontal line across to the Y-axis to discover that around 0.7AHP (0.6kW) is needed to overcome the internal conditions of the pump.

As before, continue the vertical line downwards to the VHP curve until it hits the 100cP line. Drawing a horizontal line across to the Y-axis shows that around 0.05 VHP (0.035kW) is necessary to overcome product viscosity.

Finally, continue the vertical line downwards to the bottom curve (NIPR) until it meets with the 100cP line. Again, drawing a horizontal line to the Y-axis shows that a minimum of 0.14bar is needed at the inlet of the pump to allow it to operate without cavitation.

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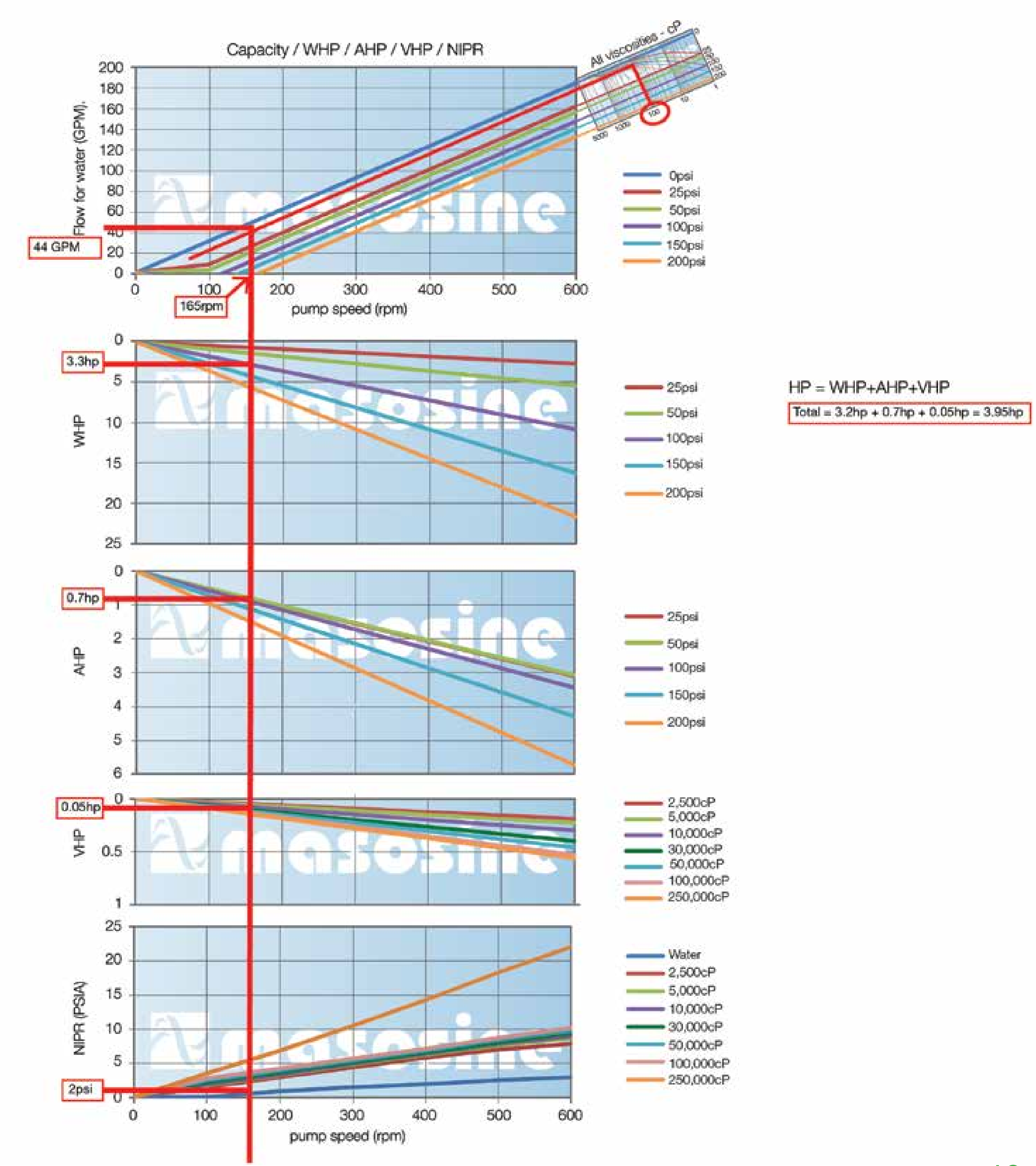
SPS 400



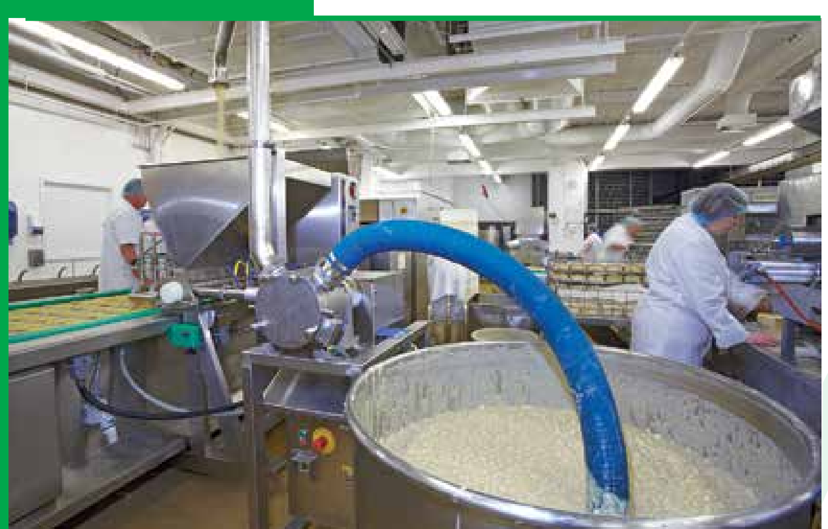
Sine pumps versus lobe pumps

Using comparable sine pumps and lobe pumps in terms of port size and litres/rev capability, consider an application involving 10,000 litre/hr flow, 14bar pressure and 20,000cP product viscosity.

The first thing to note is that the slip correction shows there is no internal slip due to the high viscosity of the product.

Using the Mee curve process reveals that the sine pump requires around 330rpm speed, while the total WHP (3.9kW) + AHP (1.2kW) + VHP (0.1) is equal to 7hp (5.2kW). This compares extremely favourably against the lobe pump, where the corresponding values are 5.2WHP + a combined VHP/AHP of 5.8, thus totalling 11hp (8.2kW), some 58% more power than the sine pump.

Assuming the application is a food plant running 4,000 hours a year, the electricity savings will be in the region of €2,160 per annum, while CO_2 emissions savings will be around 7,260kg (in comparison to an equivalent sized lobe pump based on €0.19kWh electricity cost and 0.605 kg/kWh CO_2 factor). As a point of note, that's for just one pump. For a large food plant running 100 lobe pumps, which is not uncommon, the potential energy savings are vast (100 pumps with a saving of €2,160 per annum and 7,260kg CO_2 per annum equals savings of €216,000 and 732,250kg CO_2). The NIPR/NPSHR is also higher for the lobe pump, which increases the risk of running the pump under cavitation.



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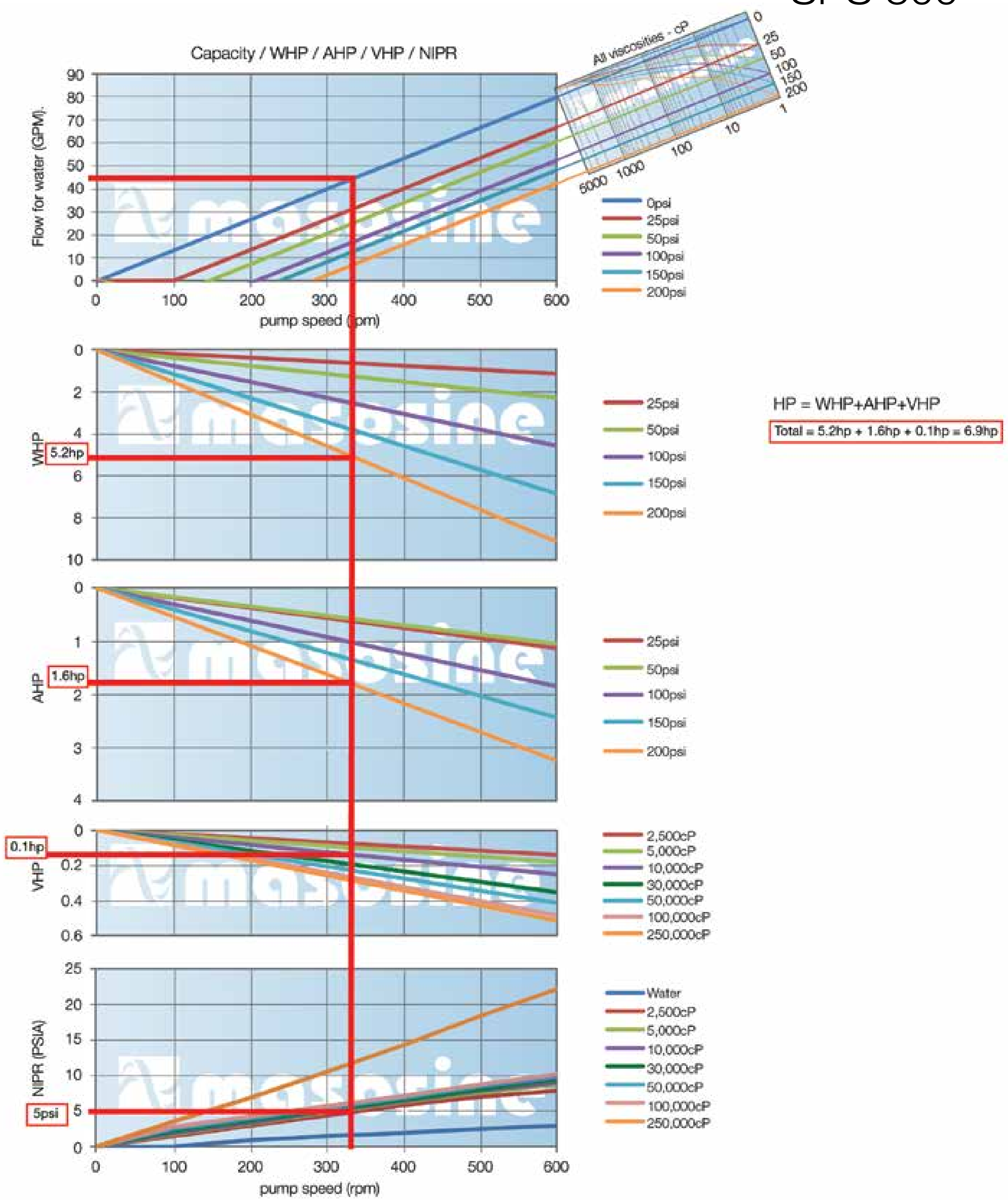
SPS 300



What if a higher viscosity product is introduced?

Put simply, if a production or process plant changes to a higher viscosity product, the impact on a sine pump is minimal is not negligible. For instance, using the same application parameters as before, but switching from a 20,000cP product to a 200,000cP product, the VHP of a sine pump increases by around 0.1, to 0.3VHP (0.22kW).

Such a shift is actually possible at beverage plants handling concentrates, for example. Here, there can be a marked difference in viscosity between product at ambient temperature, and product at cold temperature. This is especially true if the temperature drops below 0˚C, at which point viscosity will make a step increase. In certain applications this could even happen across a single batch or shift.

By contrast, when using a lobe pump, VHP more than doubles to 12hp (9kW). Furthermore, while the NIPR/NPSHR for a sine pump increases to around 0.7bar, for the lobe pump the NIPR/NPSHR escalates to a staggering 7bar, around 10 times more to avoid cavitation. In short, to continue using lobe pump technology would require going up several pump sizes to a 6" (150mm) port size model with all the additional energy consumption costs that entails, as well as the higher cost of the pump itself.

In conclusion, the more viscous the product, the more savings can be accrued using sine pump technology.

Food and beverage industry case studies

In a recent survey by the Food and Drink Federation of 100 decision makers at UK food and beverage plants, three-quarters said that coping with rising energy bills has affected their decision to expand. It's plain to see that the need to save energy has never been greater.

It's also fair to say that the food and beverage sector is among the industries that suffer most because of varying viscosities. Here, many have the need to pump a large range of products, from orange juice and orange juice concentrate, to custard and cream. However, a growing contingent of food manufacturing plants have been benefiting from Mee curve data to justify changes to a MasoSine solution. These plants are enjoying a range of operational benefits that include: lower energy consumption, higher quality and faster processing, with low shear, high suction, low pulsation, and gentle handling of whole foods or highly viscous products.

Milk concentrates

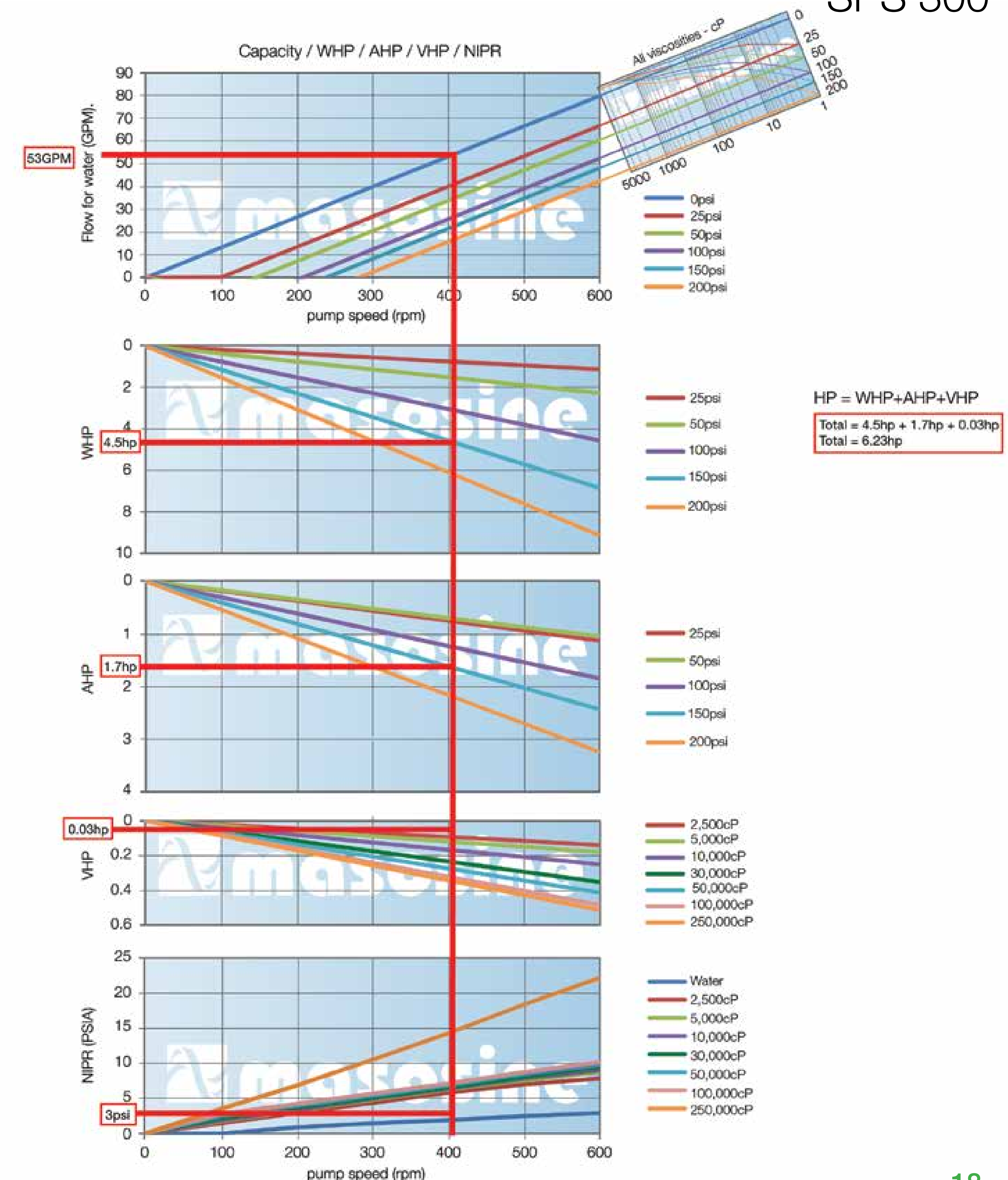
At a dairy product manufacturer, one application involved pumping (transporting or feeding) different kinds of concentrates from milk (1,200cP) at flow rates up to 12,000 litre/hr and pressure up to 10bar. Here, two MasoSine SPS 300 process pumps were acquired as they showed a power requirement of just 4.6kW, whereas the competitor pump needed 11kW.

With the pumps running 24 hours a day, five or six days a week, the energy saving was considerable.

Milk concentrate

	MasoSine SPS 300	Competition
Pump volume per revolution [litres]	0.50	0.58
Flow [litre/hr]	12,000	12,000
Pressure [bar]	10	10
Viscosity [cP]	1,200	1,200
Running time per year [h]	7,400	7,400
Costs electricity [€/kWh]	0.19	0.19
CO_2 factor [kg/kWh]	0.18	0.18
Required motor power [kW]	4.6	11.0
Annual costs for electricity [€]	6,468	15,466
Annual CO_2 emission [kg]	20,594	49,247
Annual savings of electricity [€]	**8,998**	**0**
Annual CO_2 emission savings [kg]	**28,653**	**0**

SPS 300



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Fruit juice concentrates

At a fruit juice manufacturer in the USA, the use of Mee curves proved that it was possible to purchase a small MasoSine pump in preference to a larger lobe pump to transfer fruit juice concentrate in varying degrees of frozen state – ranging from slushy to solid. However, using the Mee curves it could be demonstrated that just a single MasoSine SPS 500 would manage all of the different frozen concentrates.

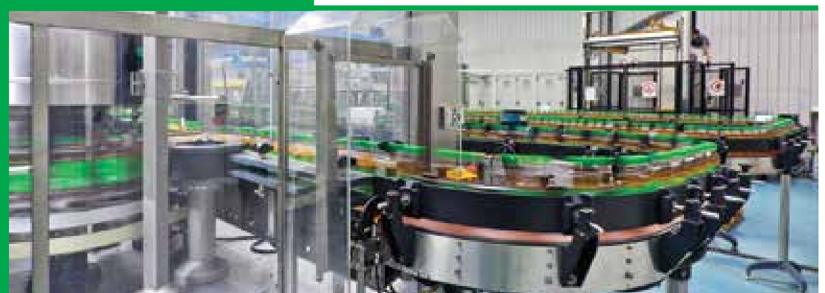
The application runs at 40,000 litre/hr flow rate and 14 bar pressure. The Mee curves showed that a MasoSine pump requiring just 27.8kW could be used in preference to a competitor lobe pump requiring 41.8kW.

This equals a cost difference for purchasing the motor of approx. €3,000 and additionally the higher price for a frequency inverter with more power.

For the running costs the larger drive requires approx. 14kWh more for each hour running. (4,000 running hours per year with a price of €0.19/kWh equals savings with the MasoSine technology of approx. €10,640 each year.)

Juice concentrate

	MasoSine SPS 500	Competition
Pump volume per revolution [litres]	1.92	1.90
Flow [litre/hr]	40,000	40,000
Pressure [bar]	14	14
Viscosity [cP]	40,000	40,000
Running time per year [h]	4,000	4,000
Costs electricity [€/kWh]	0.19	0.19
CO_2 factor [kg/kWh]	0.605	0.605
Required motor power [kW]	27.8	41.8
Annual costs for electricity [€]	21,128	31,768
Annual CO_2 emission [kg]	67,276	101,156
Annual savings of electricity [€]	**10,640**	**0**
Annual CO_2 emission savings [kg]	**33,880**	**0**



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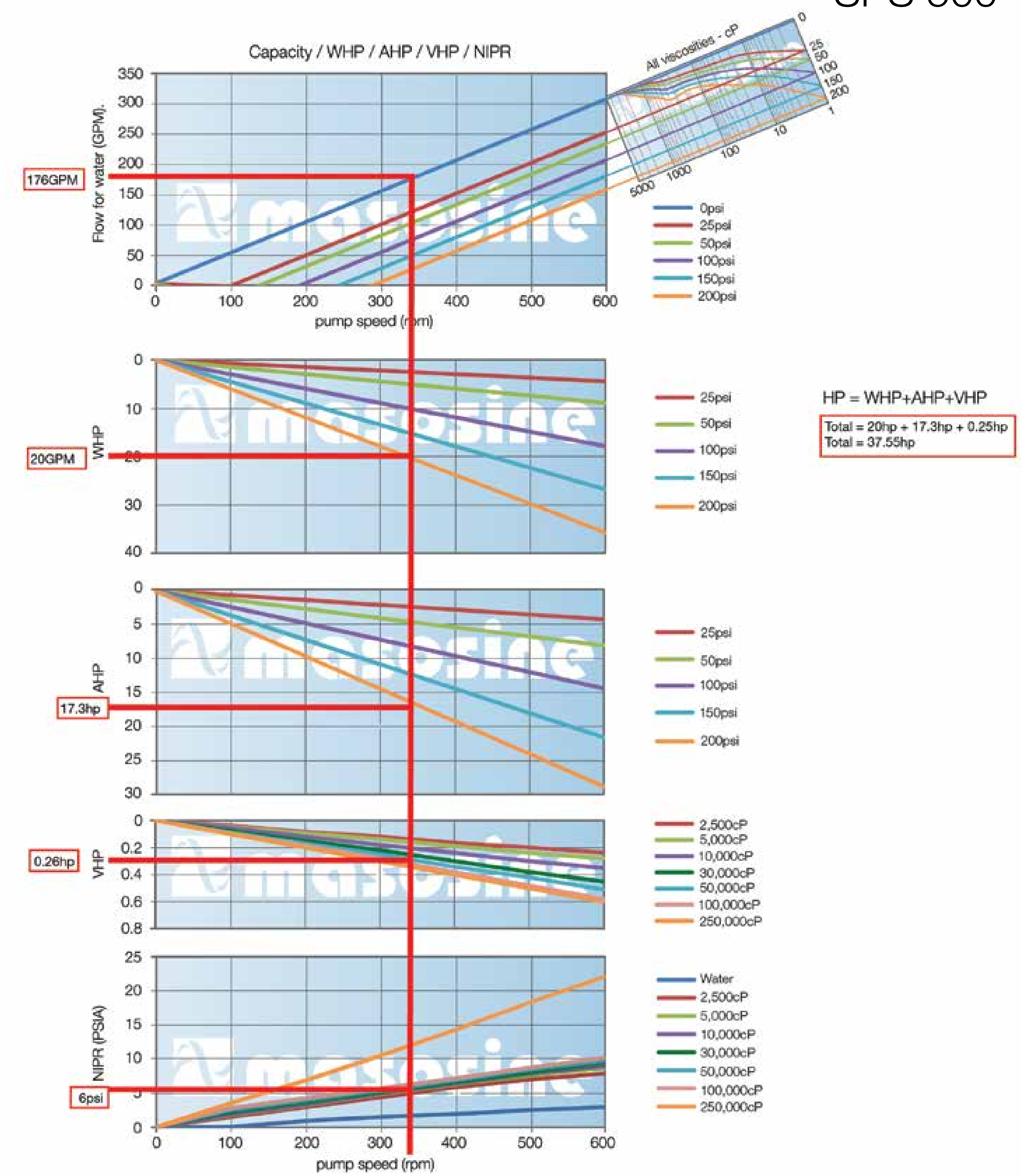
SPS 500



Further case examples

Further examples of the energy savings on offer from the adoption of MasoSine technology can also be seen in other industries. In one example based on a 6,800 litre/hr flow, 7bar pressure application pumping a 10,000cP viscosity product, the proposed lobe pump required a power of 3.9kW (according to the lobe pump sizing sheet). However, the subsequently selected MasoSine pump (using Mee curve data) only required 1.8kW of power, 54% less. Similarly, for an application involving the same flow and pressure, but for a 3,000cP viscosity product, the MasoSine pump showed a 28% reduction in power requirement over a lobe pump.

In another customer application, the specific drive size could be reduced from 45 to 31kW. Here, using MasoSine technology for 1,000 operating hours a year (four hours a day, five days a week, 50 weeks a year) equated to a saving of 14,000kWh and reduced CO_2 emissions by more than 8,000 kg for each pump used.

Competing against a circumferential piston pump, MasoSine again scored favourably. For a 20,000cP product, with 10,000 litre/hr flow rate and 14bar pressure, a MasoSine SPS 300 rated at 5.2kW power could be deployed in preference to the circumferential piston pump at 8.2kW. Based on an annual operational time of 2,000 hours, the yearly electricity costs for the MasoSine pump could be shown as €2,000 compared with €3,100 for the circumferential piston pump. In addition, annual CO_2 emissions were calculated as 6,292kg versus 9,922kg. Furthermore the smaller motor is approximately €500 less expensive than the competitor's motor just because of the smaller size. Additionally a smaller frequency inverter can be used which saves also money for the customer.

Further case study examples

	MasoSine SPS 300	MasoSine SPS 300	MasoSine SPS 300	MasoSine SPS 500	MasoSine SPS 300
Pump volume per revolution [litres]	0.50	0.50	0.50	1.92	0.50
Flow [litres/hr]	10,000	6,800	6,000	44,000	10,000
Pressure [bar]	14	7	7	14	14
Viscosity [cP]	20,000	10,000	3,000	40,000	20,000
Running time per year [h]	4,000	3,500	3,500	1,000	2,000
Costs electricity [€/kWh]	0.19	0.19	0.19	0.19	0.19
CO_2 factor [kg/kWh]	0.605	0.605	0.605	0.605	0.605
Required motor power [kW]	5.2	1.8	1.8	31.0	5.2
Annual costs for electricity [€]	3,952	1,197	1,197	5,890	1,976
Annual CO_2 emission [kg]	12,584	3,812	3,812	18,755	6,292
Annual savings of electricity [€]	**2,280**	**1,397**	**466**	**2,660**	**1,140**
Annual CO_2 emission savings [kg]	**7,260**	**4,447**	**1,482**	**8,470**	**3,630**

Greening the supply chain

> **Fans and pumps accounts for 12% of food and drink sector emissions.**

The ability to lower carbon footprint is clearly significant, with big initiatives to ensure 'green' credentials are promoted at both company and supply chain level. The challenges, however, remain vast. According to a recent UK government report on industrial decarbonisation and energy efficiency, the UK food and drink processing industry remains the fourth highest industrial energy user in the country. Furthermore, the main sources of greenhouse gas emissions from food and drink manufacturing sites relate to the use of energy, with fans and pumps accounting for 12% of food and drink sector emissions.

According to the Carbon Trust's Food and Drink Processing Guide, a fully loaded motor consumes its own purchase cost in electricity in 30 to 40 days of continuous running.* With this in mind, initiatives such the Carbon Reduction Commitment ensure there are incentives to perform on an environmental level.

There's also the Energy savings opportunities scheme (ESOS) to consider, a new piece of EU legislation intended to aid the UK in meeting its emissions target. It is a compulsory government initiative for larger businesses (those with more than 250 members of staff or turnover in excess of €52 million (£40 million), requiring them to undertake audits every four years of their energy consumption and potential energy saving opportunities. Manufacturers that failed to conduct their ESOS assessment by December 2015 risk financial penalties ranging from €6,500 up to €65,000 (£5,000 to £50,000).**

*Source: Carbon trust

**Based on an exchange rate of 1 GBP = 1.3 EUROS

Keeping in mind that the energy costs for pumps and their motors are quite high compared with the purchasing cost of a new pump, it is worth comparing not just the purchase price, but also on the running costs. At the end of the day a pump with more efficient technology will reduce costs in the long term.

MasoSine technology can help to reduce electrical power consumption and reduce CO_2 emissions. Furthermore, the company's sales team can help customers find the optimum solution for the application. All sales staff are equipped with calculation tools that allows them to input the required power of the MasoSine pump technology and the current motor power of the competitor pump. Together with the application data they get a simple result that delivers clarity for the customer.

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Conclusion

Essentially, the inherent design of MasoSine technology is based on the premise that improving energy efficiency enables manufacturers to reduce costs and remain profitable in today's fiercely competitive marketplace.

The use of Mee curves shows scientifically that sine pump technology demands around 50% less power than lobe or circumferential piston pumps. The savings for users, therefore, arrive in the form of significant electricity consumption reductions, as well as smaller carbon footprint. What's more, the higher the product viscosity, the more impressive the savings.

"The use of Mee curves shows scientifically that sine pump technology demands around 50% less power than lobe or circumferential piston pumps."

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