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TECHNO DIGEST

A GUIDE TO CURRENT TECHNICAL DEVELOPMENTS

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Life Cycle Costs – A Factor in Selecting and Operating Pumping Systems

Over the last few years, plant owners and operators have begun to attach increasing importance to cross-cutting technical and financial analyses of system components and evaluation of the total cost of ownership or life cycle cost (LCC).

Dr. Sönke Brodersen

LIFE CYCLE COSTING TAKES INTO ACCOUNT

- Initial investment costs
- Installation costs
- Operating costs
- Maintenance costs
- Energy costs
- Downtime costs
- Decommissioning / disposal costs

In the early 80s, the first English-language publications on this issue began to appear. Rising environmental awareness and a greater focus on "green" issues resulted in a series of agreements at international level. Most prominent among these were the Rio Treaty (1992) and the Kyoto Protocol (1997), which called for a reduction of global greenhouse gas emissions. The European Union is currently in the process of translating these agreements into directives and regulations. The EU countries agreed to reduce CO_2 emissions by an average of 8% below 1990 levels by the year 2010. Germany alone targets a 21% reduction. This year has seen the start of the EU's "Motor Challenge" programme designed to improve the energy efficiency of motor-driven systems.

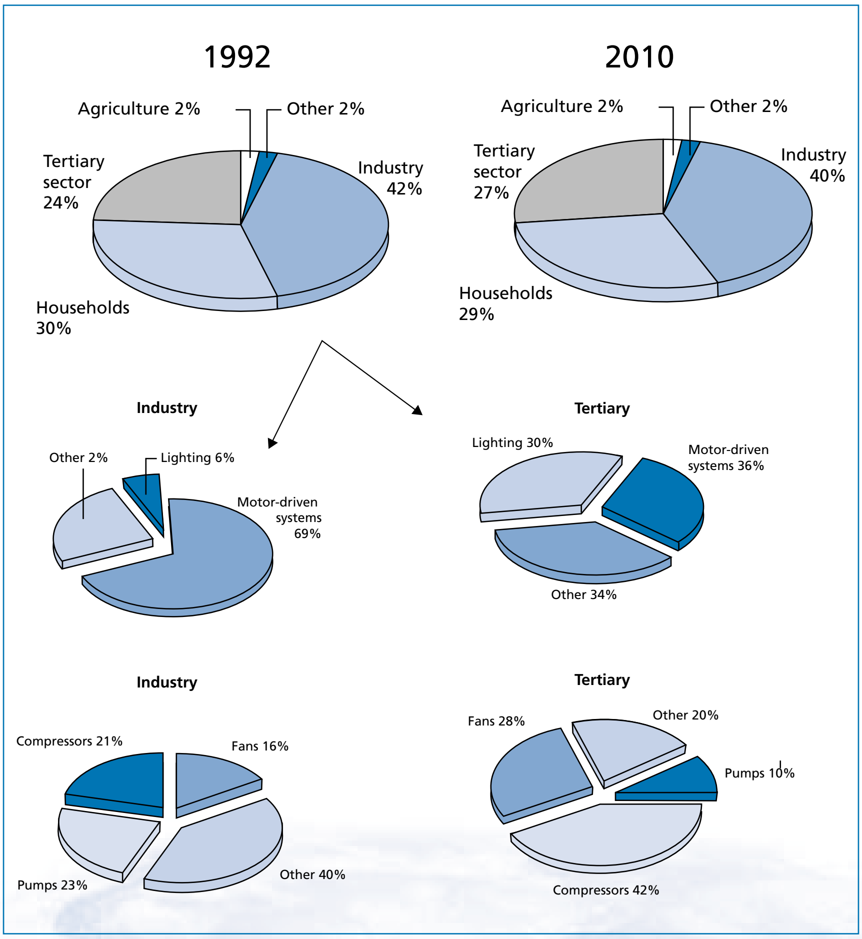


Fig. 1: Electrical energy consumption in the EU

POTENTIAL PUMP INPUT POWER SAVINGS

As electric motor applications account for a large share of electricity use, they are likely to offer the greatest potential for saving energy (Figs. 1 and 2). If just 35% of all pumps used in German industry were equipped with speed control systems, the resulting increase in efficiency would reduce energy consumption by 16,000,000,000 kWh per year. This means that, based on current industrial electricity prices, billions of euros could be saved each year. In the U.K., tax relief schemes to encourage investment in energy-saving technology are already in place. Even though environmental issues are a key factor, of course, the European Union is also aiming to safeguard energy supplies and enhance its industries' competitiveness by improving energy efficiency. Against this political background, organizations like EUROPUMP and the US Hydraulic Institute (HI) have published a guide which is intended to help pumping system owners and operators identify opportunities for cutting energy expenses

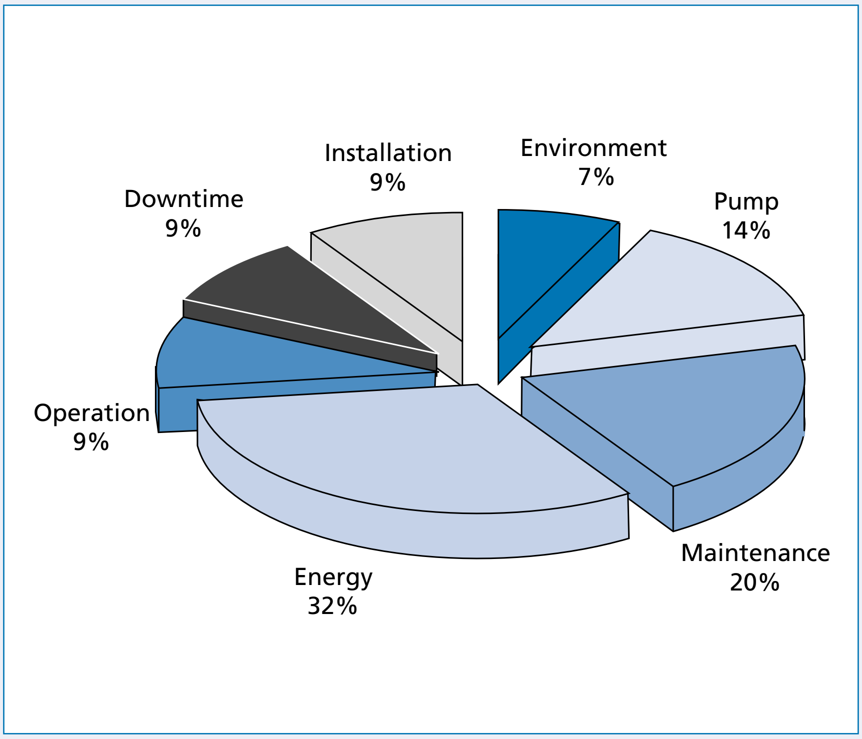


Fig. 2: Typical cost breakdown for a medium-size industrial pump

and other costs. These activities reflect a general awareness of the savings potential involved in view of the fact that pumps and pumping systems account for about 20% of the world’s electrical energy demand.

It‘s Profitability That Counts !

Decisions on investments are typically made with a strong focus on profitability. Projects and measures taken must amortize over a given period of time.

An overall LCC analysis of pump operation within a system will help identify and quantify potential cost reductions, both in terms of energy saved and other benefits, which can be realized by selecting suitable products:

- **Improved system availability and productivity increases**
- **Reduced maintenance and lower repair costs**
- **Improved capacity utilization**
- **Lower decommissioning / disposal costs**

Comprehensive as LCC analysis may be, there are still challenges that offer considerable scope for action by pump manufacturers. Life cycle costing was top on the agenda of the Pump Users’ International Forum 2000 in Karlsruhe (Germany) and also a key topic of the 2nd Pump Manufacturers’ Forum held in Frankfurt in September 2002. At the latter event, major results of the Karlsruhe conference were reviewed to pinpoint additional prerequisites and activities. One of the workshop groups at the Karlsruhe forum explored why and in which cases life cycle cost considerations tend to be neglected. The following three challenges for pump manufacturers and plant managers were identified:

- **Plant engineering issues**
- **Verification of relevant LCC data**
- **Compatibility with adopted budgets**

Conflict of Interests between Plant Designers and Plant Managers

Plant designers and plant managers usually have fundamentally different interests and goals. Top priority for plant designers and engineering contractors is, naturally, the plant‘s selling price. Plant managers are much more interested in the overall cost incurred over the system’s lifetime. Seen in this context, production and installation costs are only part of the equation. The focus is on the cost of operating and maintaining the system. So, if plant designers are to put more emphasis on the overall cost of the plant to be built, plant managers need to make this point clear.

Using LCC-optimized products can also reduce planning and installation costs. For example, providing speed control systems may help compensate for planning uncertainties and expensive design errors. Changing business approaches in industry, such as outsourcing or *BOT (Build – Operate – Transfer)* models, add to the impact LCC considerations may have. If plant manufacturers take care of operating the equipment on behalf of end users for some period of time and put all their expert know-how into ensuring the plant’s optimum functioning, they will obviously be greatly interested in low maintenance, repair and energy costs. Investment decisions will thus be based on an extended set of criteria. For plant suppliers, other cost reduction opportunities may include lower planning and installation costs, as well as package offers and modular systems provided by pump and valve manufacturers.

Build – Operate – Transfer: A manufacturer builds a plant and operates it for some time before the end user takes over.

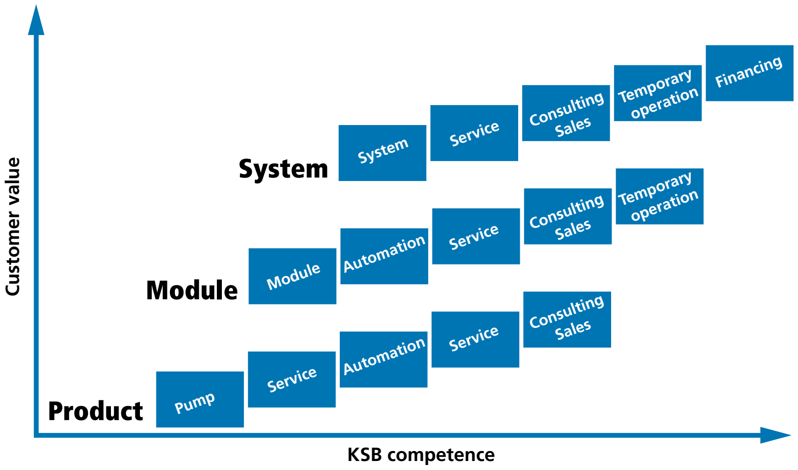


Fig. 3: Competence translates into customer value

COMPILING LCC DATA

A major challenge in putting life cycle cost analysis into practice is the quantitative assessment of productivity improvements. Any evaluation of the economic benefits of a particular technical solution compared with alternative systems requires reliable data on the individual cost elements. As far as energy costs are concerned, these might be relatively easy to obtain. The costs of operation, maintenance, repair and downtimes, as well as the intervals at which these will be incurred (MTBF, MTBR, etc.) are far more difficult to assess. Modern IT systems used by the plant owner / operator can be valuable tools for generating reliable, statistically sound data. These tools may be used to map cost profiles of individual items of equipment in a system, such as pumps, and evaluate the life cycle cost of potential improvements. To mention but one example, the KSB LCC Comparator uses average values compiled for various industries for the assessment of cost benefits offered by speed control systems and monitoring.

IDENTIFYING COST DRIVERS

If you can determine the cost incurred for a particular component in a system, you can frequently identify major potential for savings. Since pumping systems may have a life span of up to 20 years, designers and buyers need to consider the overall cost over the equipment's lifetime from the start. But it may also make economic sense to review existing systems. There are many reasons why installed systems are not optimized. For example, system requirements or maintenance and operating conditions may have changed over time. Upgrading installed systems with new technology may increase their efficiency. Separate budgeting for individual areas of a company often is a major obstacle to implementing suitable LCC measures. If maintenance and purchasing budgets, for example, are managed by different units without any coordination whatsoever, the company will not arrive at an optimum overall cost solution. If those in charge of maintenance have a say in selecting the quality of the products to be purchased, this will have a decidedly positive effect on future servicing and maintenance costs. There are, of course, also cases where the end user "does not have the money to save money" and as such is unable to invest in energy-saving and low-maintenance equipment for example. Here, financing models may be the solution. Specific starting points for making life cycle costing an established issue among pump and valve suppliers and buyers are (Fig. 3):

- **Optimum system design**
- **Optimum pumps for the application**
- **Technical support by the pump manufacturer**
- **Speed-controlled pumps**
- **Pumps / valves with additional functions (pump as a "system monitor", local intelligence, ...)**
- **Modules (pump + control system + valves+++)**
- **Active system integration**
- **Service activities, incl. teleservice etc.**
- **Financing services**

COST-EFFICIENT OPERATION OF SPEED-CONTROLLED SYSTEMS

A detailed analysis of the plant requirements is one prerequisite. Selecting the right pumps, valves, control system, piping and fittings is another. In pumping systems, the piping diameter plays a significant role, for instance. Installation and operating costs as well as the size of the components to be purchased are directly correlated with the pipe size. So what the end user needs is competent, LCC-focused advice by the pump and / or valve supplier.

Using speed control systems will help run pumping systems at or close to BEP. Resulting benefits are:

- **Energy savings**
- **Longer maintenance intervals thanks to reduced loads on the pump**
- **Fewer repairs and lower risk of failure**
- **Reduction in downtime costs**

Depending on the plant's overall configuration, speed control may also help reduce the number of different pump sizes required. One pump size might, for example, be used for different requirements or planned plant extensions. Integration of the control system in the pump / motor set (e.g. Hya-Drive) may greatly simplify installation and operation. There are, of course, physical limits to the cost benefits to be achieved by speed control, for example in systems with low piping losses or high static components.

CONDITION MONITORING INCREASES AVAILABILITY

Additional functions like pump monitoring and diagnosis also improve system availability. They facilitate low-cost, predictive maintenance and thus reduce operating costs. Obviously, evaluation of the signals and data obtained directly from the pump is not intended to compensate for shortcomings in pump design, but needs to be seen in the wider context of comprehensive system monitoring. Correlating actual data with the supplier's know-how regarding the typical response of pumps and systems to off-design conditions provides valuable information, which can be applied to reduce the above-mentioned cost elements. KSB's Pump Expert, for example, can serve as a "system sensor". It features standardized hardware equipped with the interfaces usual to process control systems. At the heart of the monitoring unit is a software replete with expert knowledge.

Energy expenses and longer maintenance or repair intervals frequently offer the greatest scope for minimizing LCC. But where critical or sensitive systems are concerned, the need to keep production processes going may have top priority because the cost of lost production would be unacceptably high. In these cases, additional investments in monitoring equipment may amortize very quickly.

MODULES, SYSTEMS AND SERVICES

The savings achieved with respect to individual components, such as pumps and drives, can be aggregated by incorporating these components in modules and systems and by optimizing their interaction (integral speed control, integrated local intelligence, valves, piping, monitoring and safety elements).

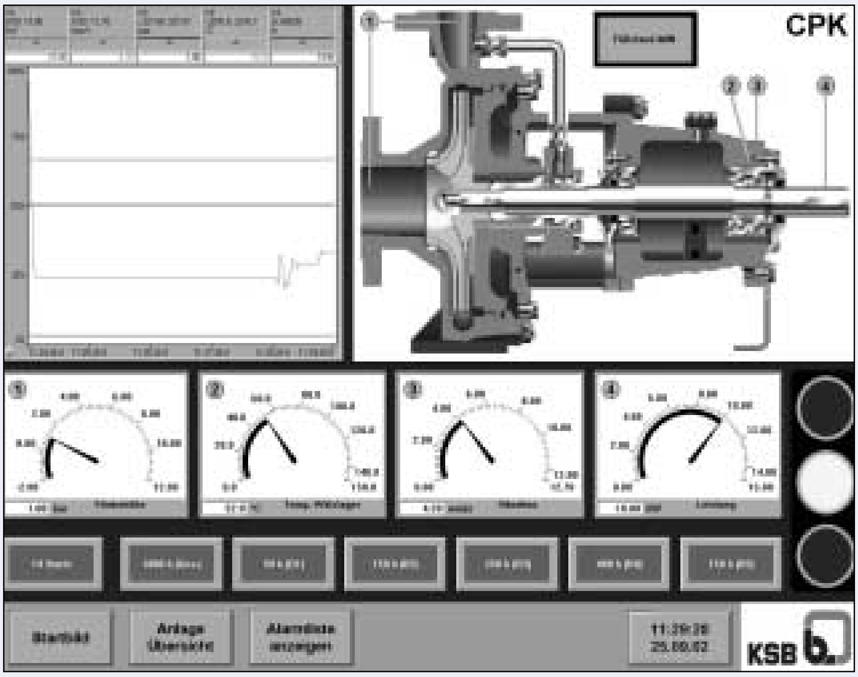
Major LCC reduction potential may also be found in activities offered within the scope of maintenance contracts or services packages. If these are performed by professional service providers at a lower (variable) cost, plant owners / operators may cut down on fixed costs. Integrating teleservice or remote monitoring (for example, by using SMS) in overall service management concepts are other options. Last but not least, a whole range of financing models for rehabilitation, retrofit and upgrade projects may be worth exploring.

CONCLUSION

End users increasingly consider the savings potential offered by LCC analysis and base their purchasing decision on relevant criteria. In the following areas in particular, KSB stands a good chance of gaining a competitive edge by emphasizing LCC aspects:

- **Technical consulting competence**
- **Speed control and automation**
- **Maintenance and other services**
- **Modules and systems**

The following articles highlight some of the approaches taken. If you are interested in additional information or practical examples, you can have a look at the so-called LCC Folder in the KSB Marketing Database.



Proper system design is a prerequisite for low life cycle costs. Pumps and system components must be perfectly matched. If these conditions are not met, any measures taken to reduce cost can only have limited effect. The system requirements and major parameters need to be analysed in detail.

How System Design Affects Life Cycle Costs

Norbert Gröning

Diameter as a Cost Factor

With respect to the cost elements material, installation and power input, the diameters selected for the system piping are of major importance. In pumping systems, therefore, the piping diameter plays a significant role. The material and installation costs are immediately dependent on those diameters and, hence, on the weight of the individual parts and components. Such attendant costs as thermal insulation for the components cannot be ignored, either. The chosen diameter directly defines the velocity of flow for the system's design capacity. Any increase in the size of a pipe reduces the velocity of flow and, accordingly, the dynamic pressure drop across the various wetted components. As the pressure loss decreases, so does the required system head. A pump with a lower output rating can be selected. The optimal size of pipe, however, can only be found, if the behaviour of all system components is duly considered. The system's pumping performance per se is assessed by first calculating the system curve for the given dynamic pressure losses and static head. Designing the system for optimal economy over its entire service life requires additional data, e.g., on the distribution of operating cycles at different volume flow rates. This "load profile" is decisive for, among other things, the selection of the pump.

In many cases, parallel operation of several pumps is a good choice ($Z \geq 2$). The given load profile determines how the pump control works and what the best controlled-operation curve is.

$H_P =$ Discharge head

$$C_e = \sum_{j=1}^{Z} \left\{ n \cdot \frac{E_0}{\left[1 + \frac{i-p}{100}\right]^n} \cdot \rho \cdot g \cdot \int_{t_0}^{t_1} \frac{Q_P(t) \cdot H_P(t)}{\eta_P \cdot \eta_M} \, dt \right\}$$

Fig. 1: Main energy cost factors

Energy-cost Parameters

The energy cost formula Ce (Fig. 1) of the pumping system shows the relevant parameters. Taking a closer look at the pump's energy input parameters (Fig. 1), one notices that:

The discharge head of the pump, $H_p(t)$, which factors proportionally into the power input, is a function both of the dynamic head losses of the piping and of the consumer requirements. The smaller the pipe diameter and the greater the rate of volume flow that has to pass through it, the greater the percentage of the pump's power that is expended on flow and friction losses.

Pipe "Efficiency"

This unusual approach (Fig. 2) assesses the efficiency of a pipe or piping system in its handling of fluids. Dynamic friction losses are responsible for the head loss H_L. The head loss, in turn, is the difference between the initial head H_1 at the beginning of the pipe and the residual head H_2 at the end of the pipe:

$$H_L = H_1 - H_2$$

since: $H_L = H_1 - H_2$

then: $\eta = 1 - \frac{H_L}{H_1}$

The maximum efficiency is reached when the dynamic head loss H_L has been minimized.

The above example (Fig. 3) describes the situation in a cooling water supply system for injection moulding machines in a hypothetical factory. After injection, the mould has to be cooled down to a specific temperature, and that calls for a certain amount of cooling water for each machine. In the given situation, a flow pressure of P = 2.0 bar assures proper cooling. The spent (= warm) cooling water flows off under atmospheric pressure for recooling. In this plain and simple open system, the consumer is situated at the same elevation as the water level in the inlet tank. In other words, no water can flow to the consumer without the aid of a pump. A volume flow rate of Q = 18 m³/h and an effective pressure of P_2 = 2.0 bar (corresponding to $H_2 \approx 20$ m of water) are needed for the consumer.

DN 50
IN FULL-LOAD OPERATION

The system, consisting of a pipe, a check valve and two other valves, is initially assumed to have a nominal size of 50 mm. The piping was calculated with the aid of a computing module from the KSB Offert selection program (Fig. 4). The piping was postulated as being made of thin-walled, welded steel. The total head loss obtained for a perfectly ordinary flow velocity of v = 2.26 m/sec amounted to:

$$H_L = 34 \text{ m}$$

The following diagram (Fig. 5) illustrates the situation for a DN 50 pipe. The pump characteristic curve intersects the system curve at 54 m. Due to the high velocity of flow (v~2.3 m/sec), the flow losses add up to some 34 m (~1340") of water. Hence, only 37 % of the pump's discharge head reaches the consumer as effective head, while 63 % is devoured by impediments to flow!

Since the "effective head" available to the consumer is known to amount to H_2 = 20 m, it is easy to calculate the hydraulic "conveying efficiency" of the entire piping system, including valves. In this case, η_{pipe} = 0.37, i.e., is quite low, and the requisite pump input power is 3.95 kW.

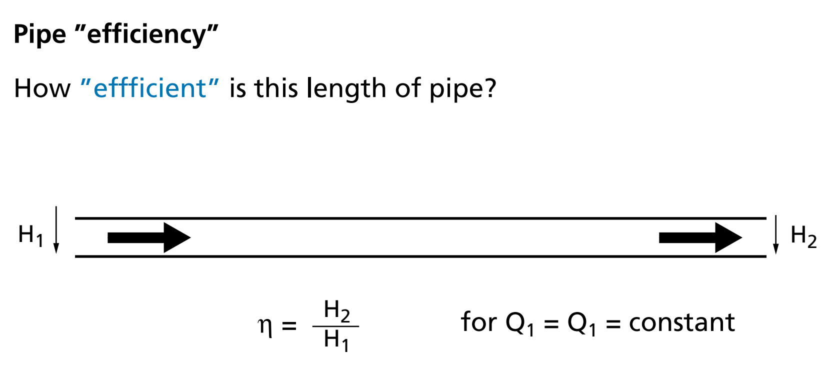


Fig. 2: Pipe "efficiency"

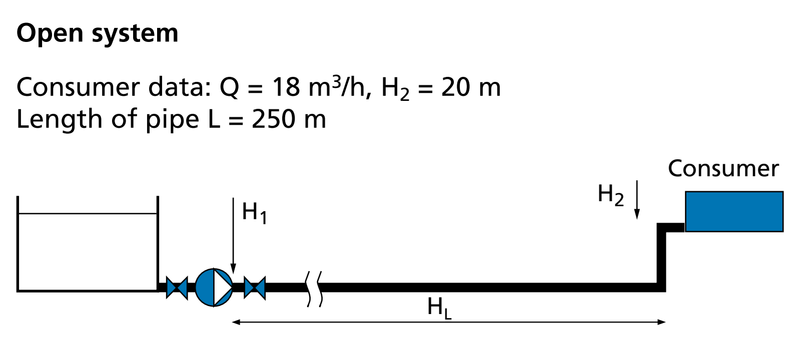
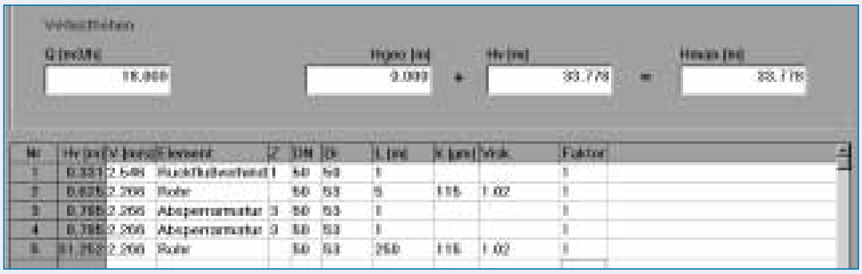


Fig. 3: Open system



Q [m³/h]	Hgeo [m]		Hv [m]		Hman [m]
18.000	0.000	+	33.778	=	33.778

Nr	Hv [m]	V [m/s]	Element	Z	DN	Di	L [m]	k [µm]	[illegible]	Faktor
1	0.331	2.548	[illegible]	1	50	50	1			1
2	[illegible]	2.266	Rohr		50	53	5	115	1.02	1
3	0.785	2.266	Absperrarmatur	3	50	53	1			1
4	0.785	2.266	Absperrarmatur	3	50	53	1			1
5	[illegible]	2.266	Rohr		50	53	250	115	1.02	1

Fig. 4: Losses for a DN 50 pipe, calculated using KSB Offert

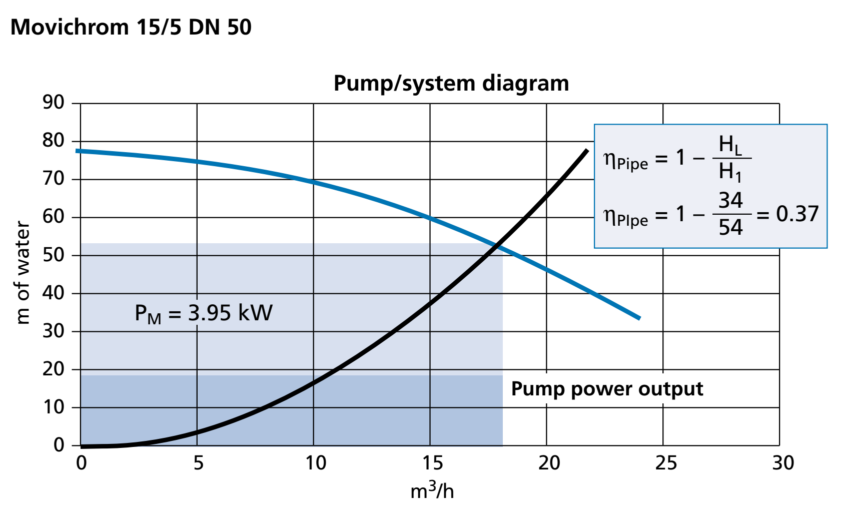


Fig. 5: Situation for a DN 50 pipe

DN 80 IN FULL-LOAD OPERATION

This selection program allows quick calculation of head losses for other nominal diameters as well. All that needs to be done is to change the entries in the DN column from 50 to 80 (in our example).

The mean velocity of flow decreases to about v = 1m/sec. Since the dynamic head losses are approximately quadratic functions of the velocity of flow, the total head loss drops to:

$$H_L = 4\ \text{m}$$

A glance at the situation depicted in Fig. 7 shows a plainly altered situation. Increasing the nominal diameter of that pipe to 80 mm decreases the dynamic losses decidedly.

The flow resistances drop to about 4 m of water, the theoretical “conveying efficiency” of the DN 80 pipe increases to η_{pipe} = 0.83, and the pump input power is a mere 1.76 kW.

COST COMPARISON OF THE TWO SYSTEMS

Comparing the two systems in terms of cost (Fig. 8), we obtain the following results:

While the DN 80 system initially costs somewhat more than the DN 50 system (€ 475, or 24 %), the first year of full-load operation totalling some 4800 operating hours will yield energy savings to the amount of € 1568.-!

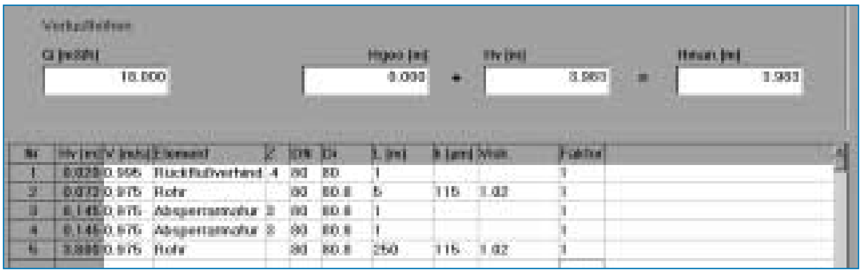


Fig. 6: Losses for a DN 80 pipe, calculated using KSB Offert

Movichrom 15/2 DN 80

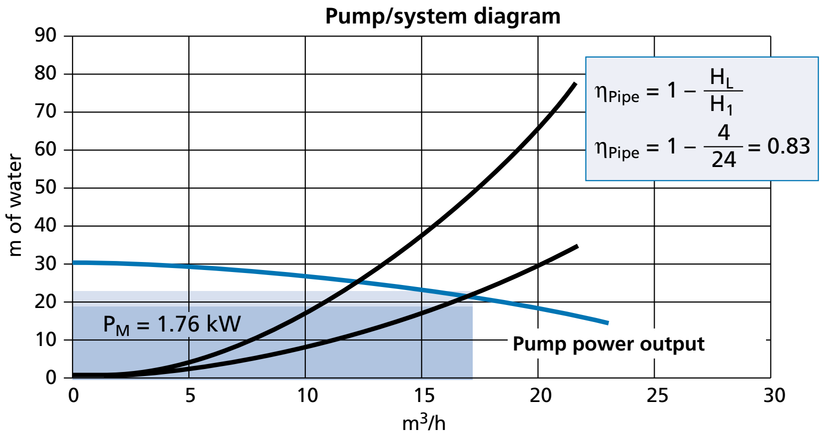


Fig. 7: Situation for a DN 80 pipe

Movichrom 15/5 DN 50, throttled

Plant 1: (DN 50)

Component	Type	Price
1 Pump	N15/05	884.–
2 Valves	BOA-C	244.–
250 m pipe	DN 50 St	875.–
	Total	**2003.–**

PLant 2: (DN 80)

Component	Type	Price
1 Pump	N15/02	552.–
2 Valves	BOA-C	430.–
250 m pipe	DN 80 St	1496.–
	Total	**2478.–**
	Difference	**475.–**

Fig. 8: Cost comparison: DN 50 vs. DN 80

Similar comparative approaches can be taken to closed systems, although the fact must be considered that they rarely involve velocities of flow exceeding v = 1 m/sec (with the exception of district heating systems), so the savings are likely to be less spectacular. One positive side effect of a low-loss design is that the system can be expected to have better hydraulics, with a flat pressure loss profile. Thanks to the lower differential pressures prevailing in the piping, hydraulic balancing is accordingly easy, and the pressure losses in the balancing valves needn’t be nearly as high, either. Consequently, the consumer control valves gain added authority, which improves the control action.

The two alternatives dealt with above were calculated on the assumption that the pump's entire output is needed by the injection moulding machines.

DN 50 IN PART-LOAD OPERATION (THROTTLED)

Under part-load conditions, with only 50 percent of the cooling water needed, the situation would be as follows. In the case of a fixed-speed pump, the flow of water has to be throttled with a valve. The water pressure downstream of the central throttle valve is accordingly lower, and the volume flow through each cooler is reduced by one half.

The diagram in Fig. 9 reflects the situation for a DN 50 pipe. The pump characteristic curve (shown in blue) is intersected by the throttled and unthrottled system curves (of which the latter is only included for purposes of comparison with full-load operation). Due to high throttle losses across the central throttle valve, the conveying efficiency drops to 7 %. In that respect, allowance is made for the fact that the effective head of H_2 = 20 m at Q = 18 m^3/h decreases by three quarters, i.e., H = 5 m, if the flow is reduced by 50 percent (Q = 9 m^3/h). The shaft power in the throttled mode is roughly 1 kW lower than in the full-load mode.

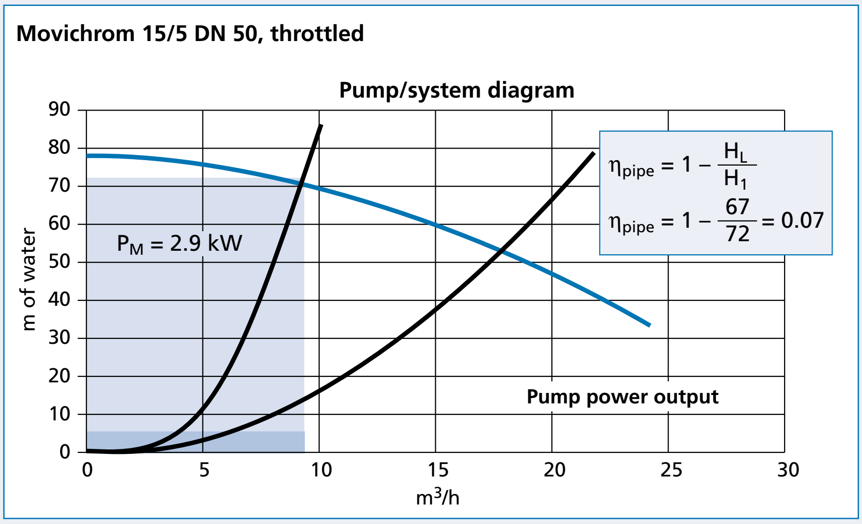


Fig. 9: Situation for a throttled DN 50 pipe

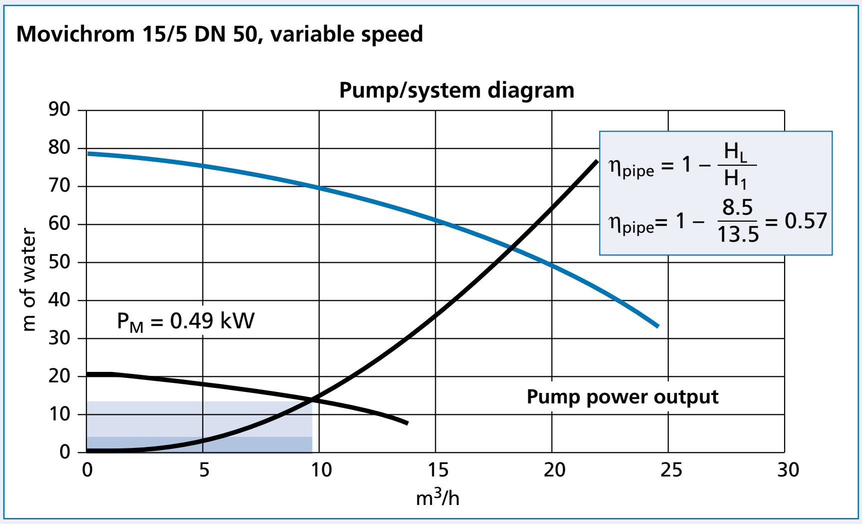


Fig. 10: Situation in a system with a variable-speed pump and a DN 50 pipe

DN 50 IN PART-LOAD OPERATION (VARIABLE SPEED)

The use of a variable-speed pump yields significantly better results. The central throttle valve is no longer necessary, because the pump itself reduces the flow rate.

In the above case, the desired delivery rate is achieved - without need of a throttle - by continuously variable speed adjustment of the pump. Since there is no throttle valve to impede the flow, the operating point is now situated at a flow rate of Q = 9 m^3/h on the unthrottled system curve. The "conveying efficiency" is accordingly high (57 %), and the shaft power requirement amounts to a mere 0.49 kW, or roughly 17 % of the 2.9 kW needed for the throttled mode with a fixed-speed pump.

CONCLUSION

High energy costs are not an inescapable evil. Often, they are a consequence of misguided thriftiness. Anyone who, in planning and designing a system, concentrates solely on the initial investment costs of the components, will be amazed at how much energy the finished system consumes. Conversely, the additional cost of a low-loss system will be retrieved within a very short time.

The LCC Comparator and Its Potential

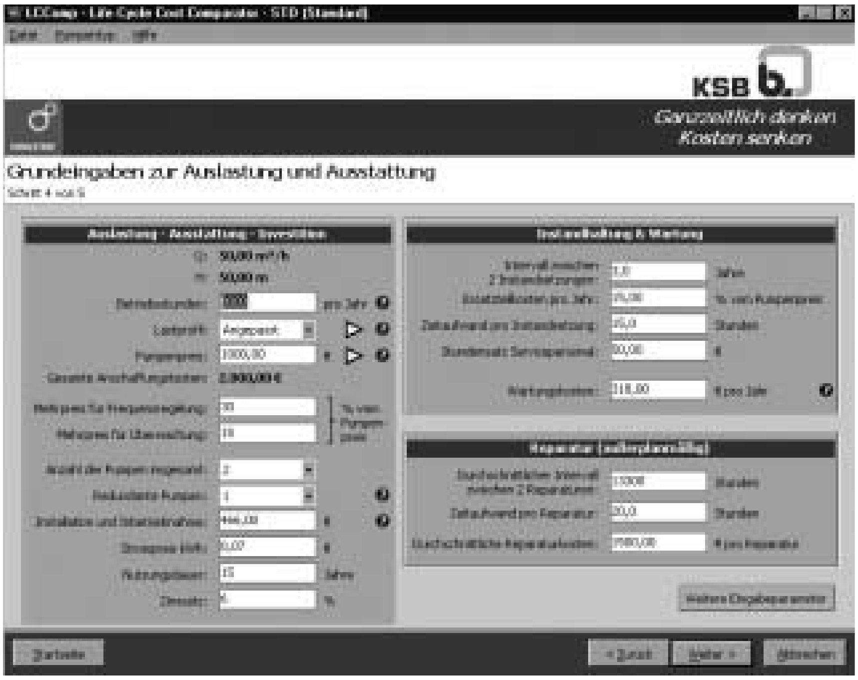
Saskia Graf

The new LCC-Comp software is a valuable tool that helps sales staff generate quantitative information on the costs incurred for a pump over its entire life span. LCC-Comp is based upon empirically established data from various KSB divisions, statistical data collected by the VDMA (German Machinery and Plant Manufacturers' Association) on equipment failure frequency in correlation with redundancy and monitoring, as well as physical properties. The calculation of potential savings through frequency control is facilitated through the integration of a program developed at Kaiserslautern University. Alternative technical solutions can be easily compared.

AN EFFECTIVE TOOL

From among different pump systems, sales staff can determine the model most economical in the long term. As well as providing an overall cost breakdown by cost type, the program can calculate the payback period and potential savings by investment in higher-quality equipment.

The long-term effects of different solutions can be computed by changing the input variables; the results can then be compared. Additional capital expenditure can often be more easily justified by highlighting its long-term savings potential. The program also illustrates the possible impact of influential factors which at first glance may seem irrelevant but, over the course of a machine's life cycle, can cause notable costs. This assists the decision-making process involved in a considered evaluation of the system as a whole.



LCComp - Life Cycle Cost Comparator - STD [Standard]

Ganzheitlich denken
Kosten senken

Grundeingaben zur Auslastung und Ausstattung

50,00 m³/h
50,00 m

Fig. 1: Screenshot of the main entry screen. More detailed data can be input by accessing additional parameters.

JUST 5 MOUSE CLICKS FOR A RESULT

A simple and clear user interface backed up by extensive databases presents easily comprehensible results in tables, charts and graphs. All parameters have been defined in the form of average user profiles and can be adjusted individually. If certain values are unknown or of little importance from the user's point of view, he or she may leave the suggested values unaltered – the results are then based on average, representative empirical values. The additional "help function" gives detailed information on the default / user input values.

COMPETENT ADVICE FOR THE USER

LCC-Comp calculates the life cycle costs of a pump system in accordance with the recognized guide to LCC analysis developed by Europump and the Hydraulic Institute. At the end of the calculation process all results appear in the form of graphs and tables. Standard solutions are automatically contrasted with those incorporating frequency control or monitoring. The most economical solution depends on the conditions of each individual installation. Additionally, components facilitating cost savings are identified. The aim is not merely the determination of the life cycle costs of the pump, but rather the recognition and implementation of potential cost savings through consideration of frequency control or monitoring systems. Competent technical assistance regarding the use of seal-less pumps and the selection of suitable impeller geometries is also supported by the program. A cost comparison function helps select the optimum solution from KSB's diverse portfolio of products.

The following inputs are required in order to individually calculate the various cost elements

C_{IC}: INITIAL INVESTMENT COSTS

As well as the purchase price, the acquisition of a pump involves other costs such as those incurred for planning, tendering, ordering, documentation, testing, freight and purchase order administration.

C_{IN}: INSTALLATION AND COMMISSIONING COSTS

Default values for all costs for the connection of the piping and electrical equipment, the installation of auxiliary systems and the alignment of the pump are available in the system. Additional expenses must be specified by the user.

C_E: ENERGY COSTS

In order to calculate energy costs, the program simply requires the input of energy costs per kW/h, flow rate Q and head H at the operating point, static head and density of the fluid pumped, as well as specification of the load profile. Data on wear-induced losses, varying efficiencies for individual pump types and impeller geometries, as well as individual load profiles are also included.

C_O: OPERATION COSTS

All expenses incurred per year during operation for monitoring and general performance supervision count under operating costs.

C_M: MAINTENANCE AND REPAIR COSTS

These expenses comprise on the one hand the average annual cost for replacement parts and maintenance, on the other all unplanned repair expenses including the hourly rates for servicing staff.

C_S: DOWNTIME COSTS

This cost element takes into account the expenses incurred for production downtime resulting from pump failure.

C_{ENV}: ENVIRONMENTAL COSTS

Here an average annual value is indicated, which covers the expenses incurred for the disposal of contaminants, as well as for contamination by the fluid pumped and by auxiliary systems.

C_D: DECOMMISSIONING / DISPOSAL COSTS

This encompasses the total cost of dismantling pump and auxiliary systems and the restoration of the local environment.

TOTAL COST MUCH HIGHER THAN INITIAL INVESTMENT COST!

LCC-Comp helps the process of decision-making by offering cost-saving solutions. The user recognizes at once that, after some years, investment costs only account for a small proportion of the total cost, and that investment in higher quality products and precise pump selection does pay for itself. Yet the benefits the customer can expect from LCC-Comp go much further, as the LCC methodology is not just applied to pumps alone but rather used within the scope of a holistic approach to facilitate comparable, quantified analyses of entire pump systems.

CONTROL BY THROTTLING

Fixed-speed centrifugal pumps possess hydraulic characteristic curves plotting the head H as a function of the flow rate Q. By throttling valves on the pump's discharge side, the flow rate can be adjusted. This means the flow resistance rises and the flow volume changes, dependent as it is upon Q and H. With increasing flow resistance, the system curve becomes steeper and the intersection between pump and system curve shifts towards lower pump flow rates. Flow control by throttling always results in lower efficiency. Energy is wasted, since the surplus head generated by the pump is not used by the system but eliminated in the throttle valve. This type of control is only acceptable when operation under off-design conditions is limited to short periods or when the pump does not run very far off its design point. Systems with high static head portions, such as for example high-level tanks, also tolerate this kind of control.

SPEED CONTROL

From an economic point of view, it often makes sense to use variable speed drives to adjust the flow rate as required. If the pump curve is steep, i.e. if the dynamic head share predominates over the static head, then speed control has advantages. When using continuously variable speed control, energy input is matched to the actual requirements, hence no energy is wasted. In this case, the point of intersection between system and pump curves moves down the system curve. The wear on pump, throttle and installation is reduced since the system has been aligned with the actual operating conditions. The motor load is markedly reduced, smooth start-up of the pump is facilitated, and unfavourable hydraulic reactions are avoided. The energy costs for systems involving throttling or speed control are computed using a calculation program developed by the Department of Turbomachinery and Positive Displacement Machinery of the Mechanical and Process Engineering Faculty of Kaiserslautern University (Germany). This program contains extensive databases on motors, frequency inverters, evaluated curve interaction data and physical properties for centrifugal pumps. Regardless of the system, the general form of the flow-dependent energy balance of a process – and accordingly the system curve – is determined using this formula:

$$H_A = (p_2 - p_1) / \rho g + (z_2 - z_1)$$
$$+$$
$$[(1- A_2^2 / A_1^2) + \zeta]\ Q_2 / 2gA_2^2$$

Any desired system curve can be processed by entering an operating point and a static head. Prerequisite is that the pressure loss in the system corresponds to that of a turbulent flow where ζ = constant. The total efficiency is then determined using the pump specific speed n_q which is in turn calculated using speed, flow rate and head. Using the software data, individual losses can be calculated relative to each other or as a part of the total power input. In this way, the pump curves required for comparative calculation can be plotted. As far as speed control is concerned, values obtained for particular definite speeds can, on the basis of the affinity laws, be recalculated for different speeds.

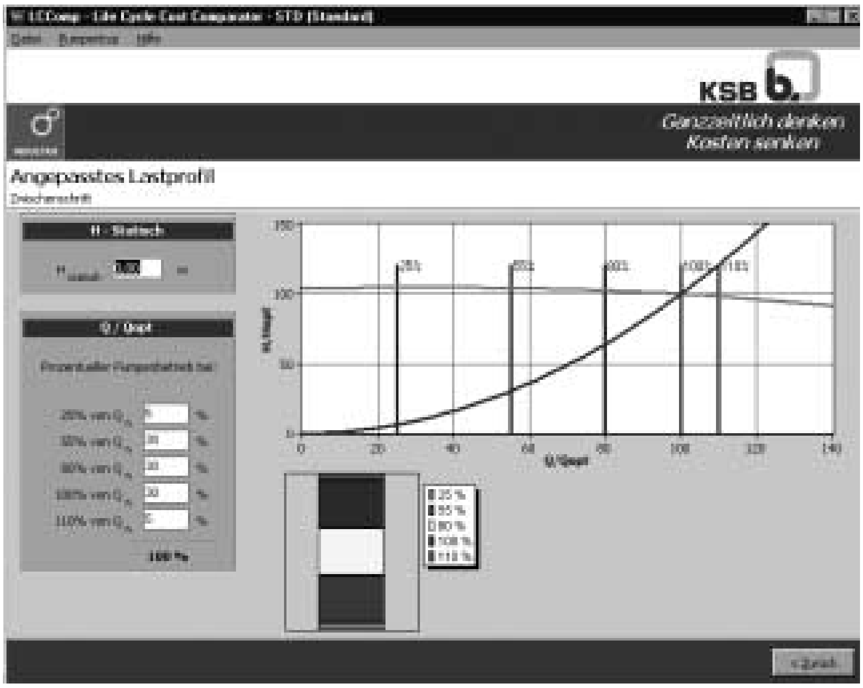


Fig. 2: Load profile (percentage distribution of operating hours over 5 duty points)

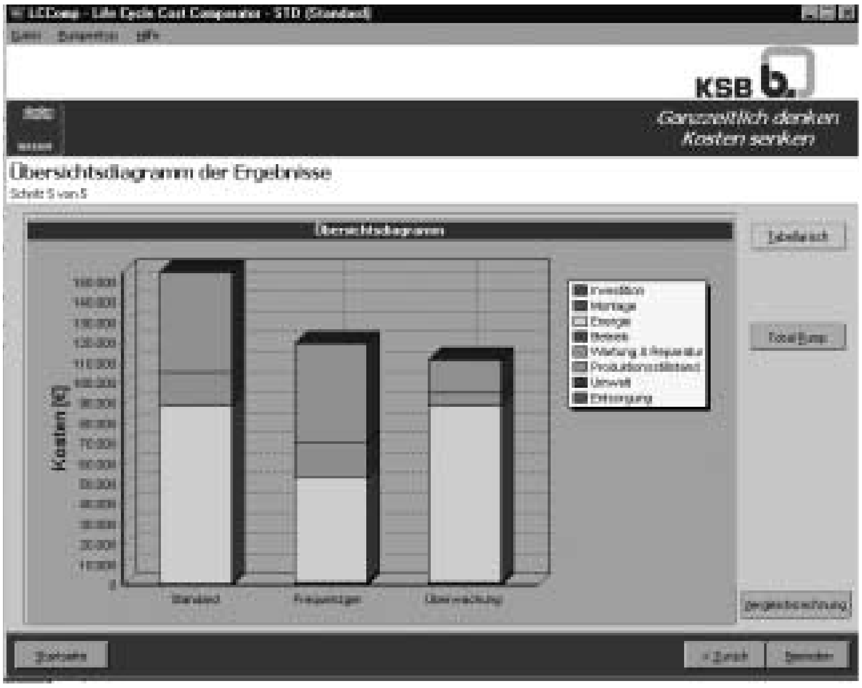


Fig. 3: Stacked-bar chart showing the results of pump control through throttling, speed control and monitoring.

COST COMPARISONS

In order to carry out individual cost comparisons, the following data must be entered:

- **Additional costs for speed control**
- **Operating hours per year**
- **Pump system’s total operational life**
- **Static head**
- **Load profile (percentage distribution of operating hours over 5 duty points)**

PUMP MONITORING

With the assistance of a pump monitor such as Pump Expert anticipated unacceptable operating conditions and potential pump failure can be avoided. Since pumps respond to changes in processes, information can also be obtained on the condition of the entire system. This intelligent method of condition monitoring for various types of centrifugal pump helps prolong the operational life of pump and plant and increases system availability.

The savings that could be achieved by using a pump monitor are automatically computed by LCC-Comp – the single required input is the additional cost of the monitoring system. The remaining values are calculated depending on the total number of installed and redundant pumps and all data connected with maintenance and repair which need to be input in any case. A graphic and tabular comparison between monitored and unmonitored pumps (Fig. 3 + 4) is provided at the end of the program run.

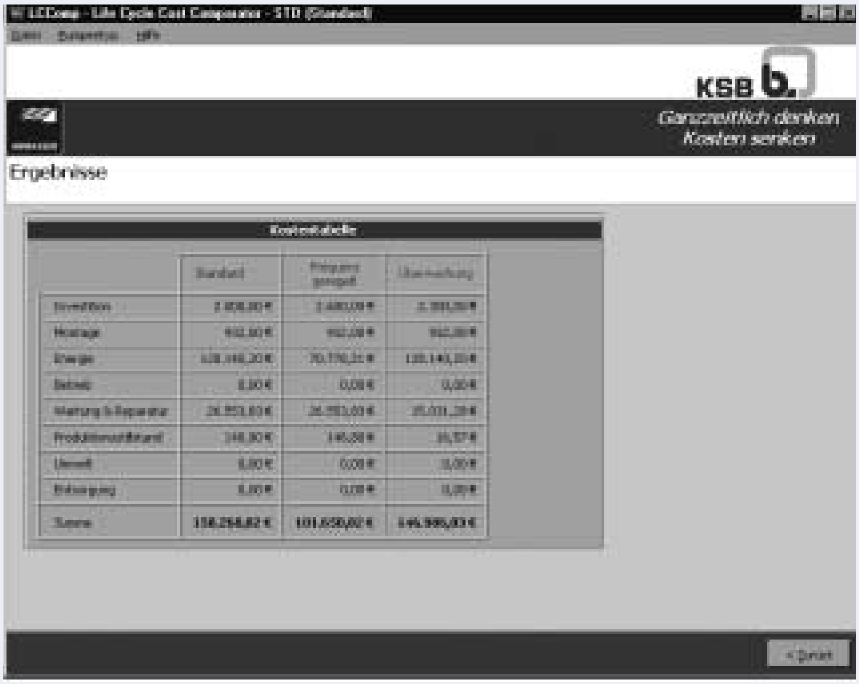


Fig. 4: The results from Fig. 3 in tabular form.

SEAL-LESS PUMPS AND IMPELLER GEOMETRIES

In the industry segment, the use of seal-less pumps may be of interest, for example in locations where hazardous liquids require pumping but also wherever maintenance, repairs and production downtime expenses can be reduced. In higher performance ranges, however, double-acting mechanical seals are more economical as here the increasing eddy current losses can no longer be compensated by saving costs in other areas. Parallel comparative calculations can also be carried out.

In the waste water sector, different impeller designs potentially suitable for the application can be compared. Here, the major criterion for identifying scope for savings will be efficiency.

CONCLUSION

Using the new LCC-Comp software, sales staff will now be able to offer end users on-site comparative information on diverse pumping systems. The potential savings to be achieved by supposedly more expensive technical solutions can be demonstrated quickly and reliably.

Innovative Design Lowers Cost of Pumping Station Operation

Low lift pumping stations are mainly used in drainage systems for flood control or groundwater-lowering as well as in agricultural irrigation setups. They supply the water required for industrial, water treatment and power plants or are used for municipal applications. The rising cost of energy and maintenance, in combination with the need for high plant availability, has led to criteria for new fluid transport systems that are much stricter than they were just a few years ago. The economic efficiency of a given facility depends primarily on its life cycle costs. Conventional low lift pumping stations are usually equipped with tubular casing pumps or submersible motor pumps.

Patrik Wagner

BASIC DESIGN OF A LOW LIFT PUMPING STATION

All conventional low lift pumping stations have what is referred to as an “intake structure” and are able to draw water from one or several channels. Each channel is fitted with a grate for intercepting pieces of solid material that could block or damage the machinery. Stop logs or gate valves are provided for shutting off the individual channels in order to drain and dry the pumps’ intake area. A tubular casing pump in a conventional arrangement with a dry-installed motor pumps the medium through a 90° elbow leading toward the siphon. The outlet channel can also be closed off with a stop log or gate valve to allow maintenance. If an ordinary type of submersible pump is used, the elbow, the horizontal pipe section and the discharge valve can be dispensed with – but instead, accordingly higher weir heads and backflow safety margins are required.

PLAIN-TO-SEE IMPROVEMENT THANKS TO HOLISTIC APPROACH

In the scope of the technical advancement, conspicuous improvements in the areas of initial investment and energy expenditures as well as maintenance and repair outlays were aimed at. This could not be fully achieved by way of conventional approaches. Hence, the job was to perform a holistic review of the entire system, from the intake structure to the point of discharge of the upper chamber water. All components were supposed to optimally interact - hydraulically, mechanically, electrically and also in terms of the control functions. All this led to a new design incorporating many new ideas and offering both the engineering contractors and the operators a number of advantages over the existing systems (Fig. 2 and 3).

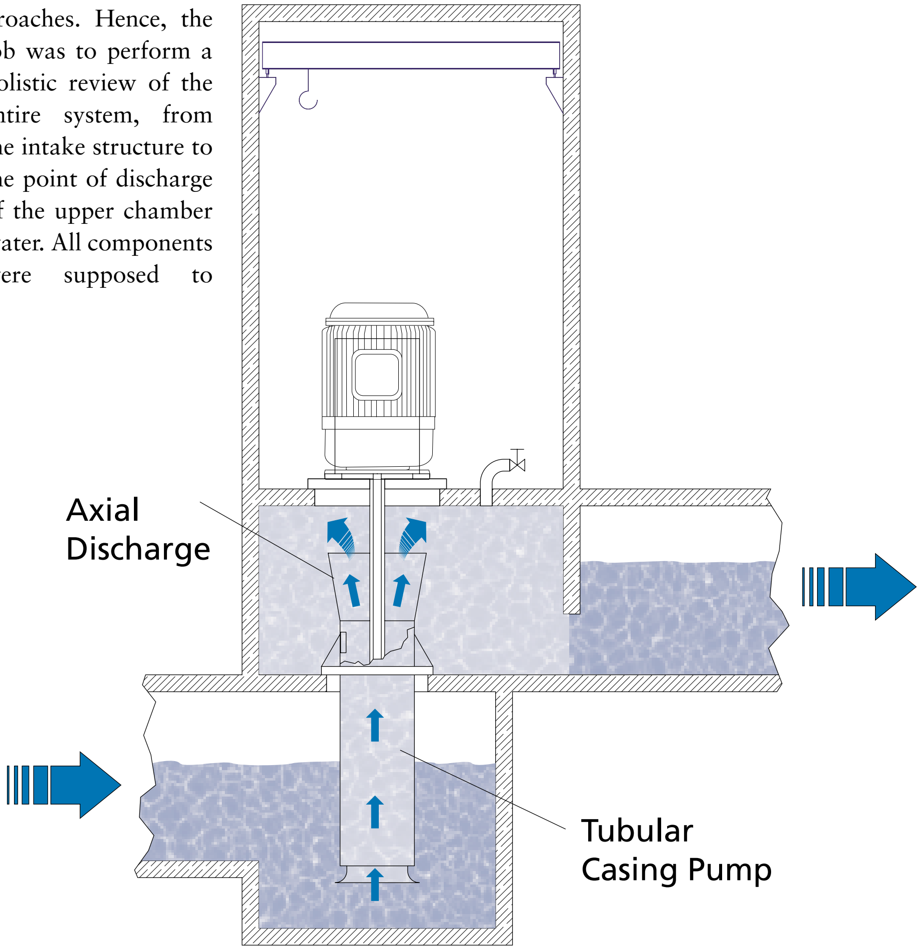


Fig. 1: New design with tubular casing pump

Function and Benefits of the New Pumping System

The water passes through a crate on its way to the suction side of the pumps in a hydraulically optimized inlet channel designed to minimize the inlet losses. The pump feeds into a vacuum chamber (isolated from the ambient pressure) and from there into the outlet channel. The subatmospheric pressure causes a siphoning effect between the lower chamber and the upper chamber as long as the pumping process continues. Consequently, stations with tubular casing pumps need no elbow with a penetration for the drive shaft, which accounts for a large share of the flow losses.

Since the crest of the riser is situated above the maximum water level in the outlet channel, there is no need for a mechanical swing check valve and its associated opening and damping equipment. Nor are any dismantling joints or wall penetrations necessary. In case of a power failure and during periods of downtime, the siphoning effect is interrupted by an automatic safety vent system that lets atmospheric pressure into the structure.

Lower Investment Costs

Such stations are conspicuously more compact, hence reducing the outlays for concreting and equipment components. Less earth has to be moved, and the construction period is significantly shorter. All things considered, the construction costs can be lower than those of a conventional station by as much as 35 %. Moreover, the compact type of construction enables land-area-conserving integration into the surrounding landscape.

Lower Energy Costs

System efficiency profits from the fact that there is neither an elbow to force an abrupt change of direction on the medium nor a penetration for the drive shaft. Less head is needed, so smaller pumps can be used. Additionally, the new version with a submersible motor pump avoids all losses caused by water gushing from the discharge tube outlet. In the case of a falling water level in the discharge channel the conventional design is even less efficient, because the locally defined maximum water level makes for a constant discharge head. By contrast, the new system compensates for fluctuating water levels in the outlet channel and for losses caused by spillage by keeping the vacuum chamber full of water at all times, hence preventing interruption of the siphoning effect.

Higher Availability

In flood control and other safety-related applications, the elimination of such trouble-prone, maintenance-intensive components as discharge valves, pipe elbows / fittings and dismantling joints increases system availability.

Maintenance Outlays

Both the operator and the plant engineer profit from the compact design and simplified technical configuration of the new system. Fewer, less intricate components reduce the installation, maintenance and repair costs for both the mechanical and the electric components, and smaller versions of the latter can be employed thanks to lower power requirements.

Conclusion

The new pumping system meets the operators' demands for lower investment and maintenance costs thanks to the compact and simple design of the system and the reduced number of components. Owing to the complete system's optimized hydraulic and construction combined with highly efficient individual components, the new design boasts lower specific energy consumption and is therefore both easy and inexpensive to operate. The reduction of the number and complexity of components increases operating reliability and system availability. The technical and commercial benefits are most apparent when the task is to lift large volumes of water to a low altitude. The system head should be in the single-digit range or only slightly higher, and the flow rate should be as high as possible.

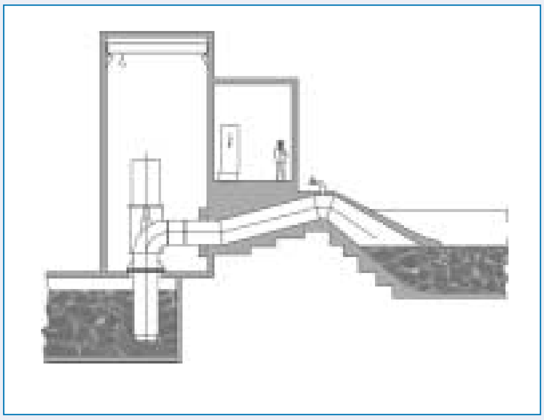
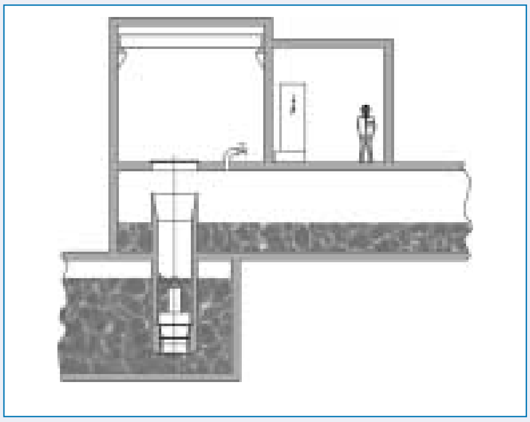


Fig. 2: Conventional design with tubular casing pump and siphon

Fig. 3: Conventional design with a submersible pump in discharge tube.



Service – Offerings and Opportunities

Stefan Reutter

For a majority of facilities, the lifetime maintenance costs take up a major portion of the total life cycle costs (LCC). Traditionally, the term "service" covers installation of a new plant, commissioning, repairs, inspections and maintenance, but it is in the process of expanding. All-in service packages, which include things like teleservice, financing and BOT models, are gaining increasing importance.

NEW DEVELOPMENTS

In LCC analysis, the maintenance and repair costs of an industrial pump account for approximately 20% of the total lifetime cost. The possibilities of minimizing these cost items and positively influencing the remaining LCC costs in the process, will be demonstrated in the following. But before we look at costs, we should take a look at the definitions of the terms inspection, maintenance and repair:

DEFINITIONS TO DIN 31 051

- **Inspection:**
  Establishing and assessing the actual condition and working order of the technical elements of a system.
- **Maintenance:**
  Keeping the technical elements of a system in good condition or working order.
- **Repair:**
  Re-establishing the required condition or working order of the technical elements of a system.

In the our case, the technical elements are pumps. What all three definitions aim at or mean by implication is that the required condition and working order of pumps have to be maintained and that any deviation from that condition has to be detected. If such a deviation is detected, then the required condition is to be re-established by means of re-conditioning or repair. Today, it is common practice to repair a malfunction and return a pump to its original condition. However, hardly ever is an effort made to analyse the cause of failure and to realize the insights gained through such analysis in order to ultimately prolong the *MTBF*. The question, whether this practice is still acceptable today, and whether it really is in the plant owner/operator's best interest, has no single answer which is valid for every application. In view of the high demands made on plant availability and process reliability, the high downtime costs and the steep service charges for problem installations, the mere elimination of a failure is no longer good enough. The causes of failure therefore have to be analysed and studied in perspective of the system as a whole.

FOUR TYPES OF MAINTENANCE

1. **Preventive maintenance (routine inspections and maintenance)**
2. **Predictive maintenance**
3. **Risk-based maintenance**
4. **Failure-based maintenance**

Which service strategy is the right one depends on the type of plant and the objectives pursued. If the objective is to increase the availability of the plant in the medium or long term, preventive or predicitve maintenance is the answer. If plant management is a question of meeting the budget only, maintenance is likely to be risk-based. However, doing nothing at all until a plant breaks down, is the worst policy because of the immense risks involved. The way a plant is serviced and maintained has an enormous impact on the LCC costs. A risk- or failure-based approach will push up the downtime costs in the medium term. The action required to bring down the cost of individual cost elements should never be analysed in an isolated manner.

TRADITIONAL SERVICE SCOPE NOT FULLY UTILIZED

One example to show that the possibilities of the traditional service scope are not exhausted is the field of "installation and commissioning of new plants". Many pump users are not aware of the risks they take by having a new installation installed and commissioned by their own or other inexperienced staff. Fig. 1 shows that most failures occur during the first phase of a system's life cycle. As a result, commissioning of an entire plant has to be put on hold and there are high downtime costs incurred.

MTBF: Mean Time Between Failures

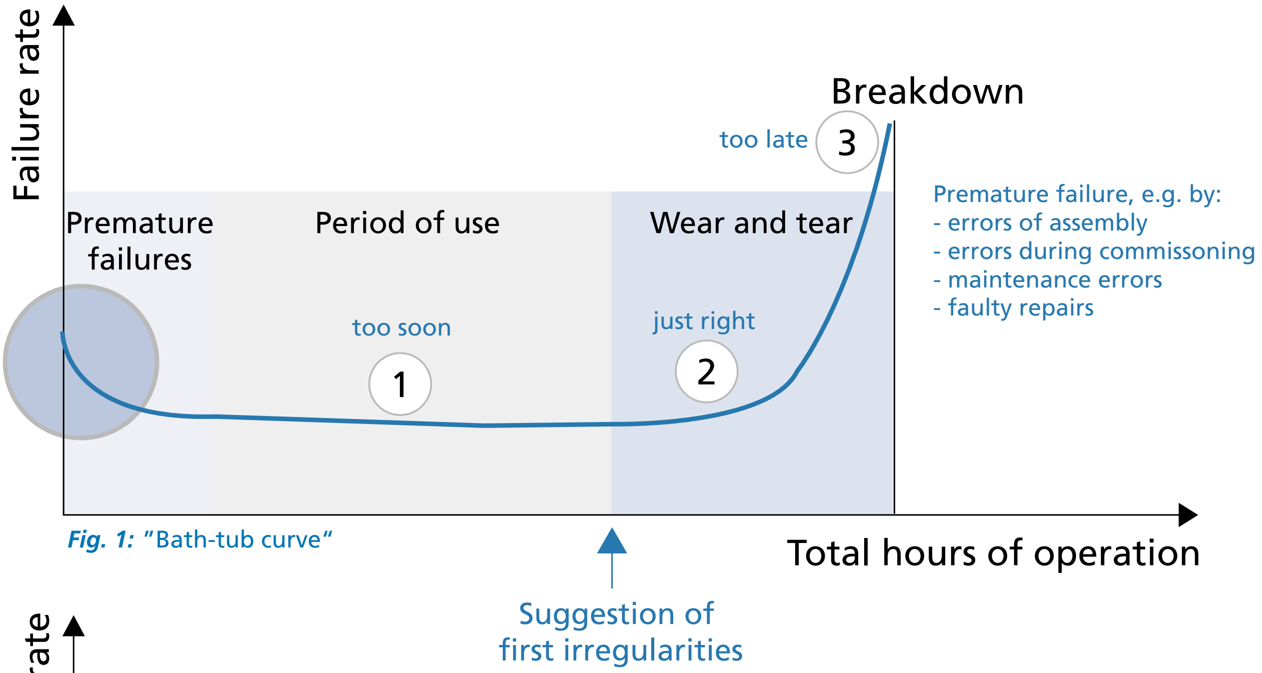


Fig. 1: "Bath-tub curve"

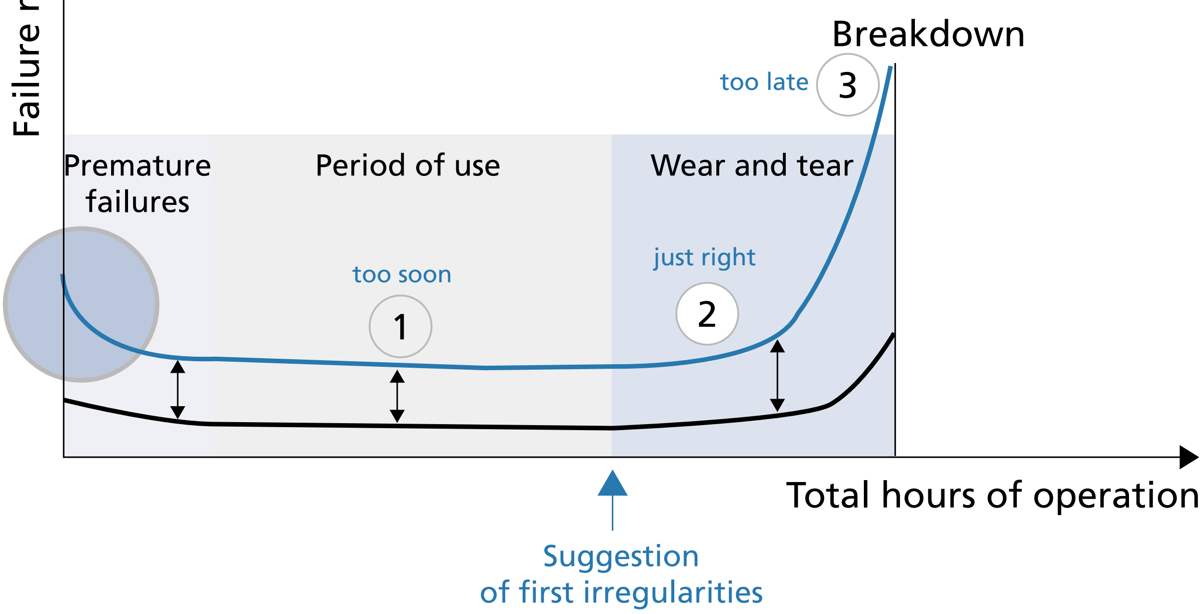


Fig. 4: Positive impact of an all-inclusive service approach on the "bath-tub curve"

For this reason, installation and commissioning by the manufacturer, in particular of high-quality systems and components, should be included in the scope of supply.

TIMING IS OF THE ESSENCE

Moreover, the curve depicted in Fig. 1 clearly shows that costs of maintenance vary according to the service concept. Frequent inspections are the most reliable means of failure prevention. But frequent inspections are costly, and the expenditure often is a misrepresentation of the actual condition of system and pump. If the inspection intervals are scheduled too far apart, the costs of product failures and downtimes can easily run up to several 10,000 €.

Operation monitoring and teleservice comprising early failure detection are very effective means of discovering basic errors of operation as well as detecting the first signs of a trend that will eventually lead to failure. Having know-how in this field means knowing

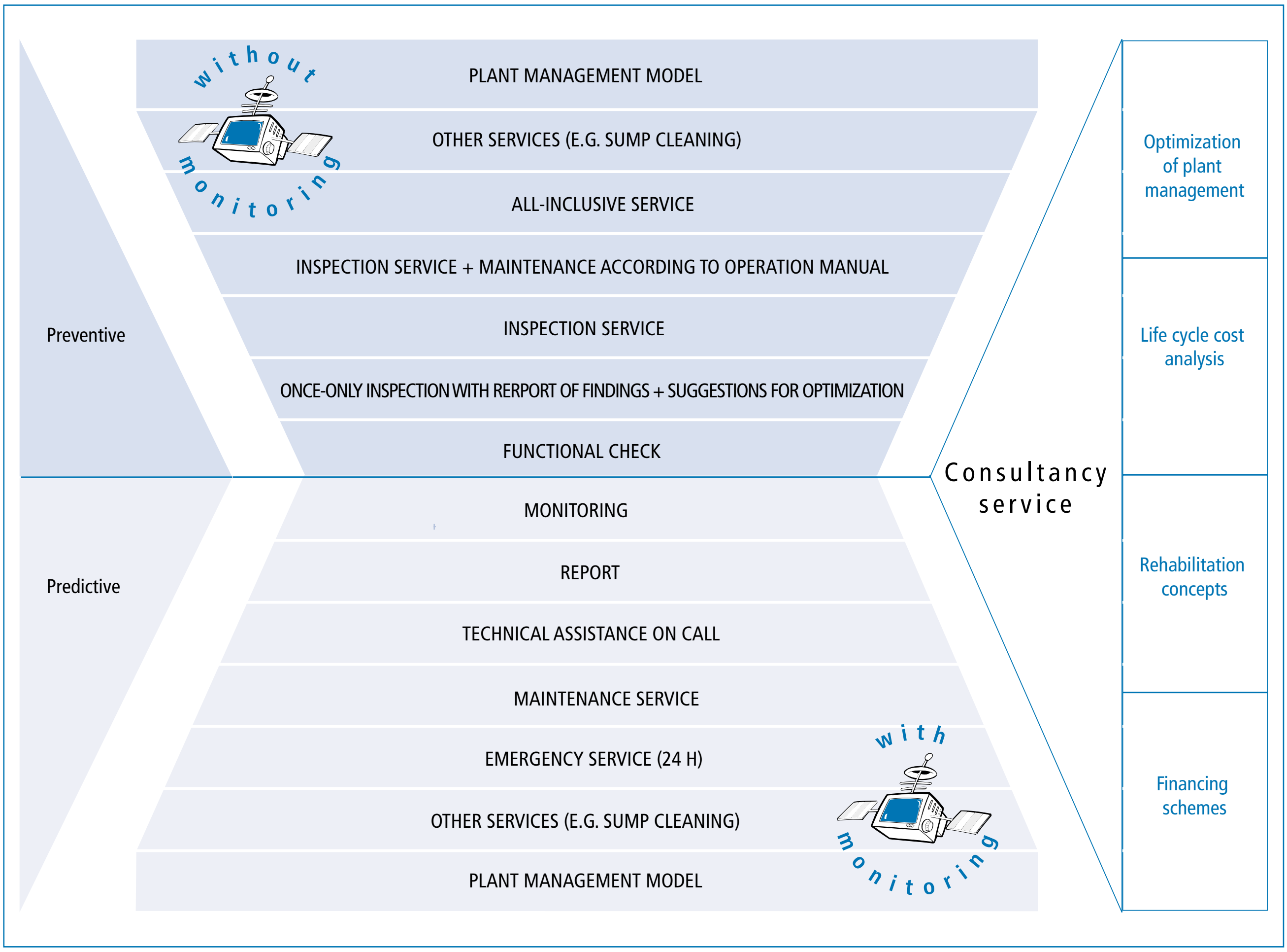


Fig. 2: Modular service concept for pumping stations, including telemonitoring

how to record which data, interpreting the data and compiling them in an easily understood format. The information compiled can then be placed at the disposal of the customer himself, the service provider or both. It is an essential tool for avoiding operation mistakes and planning the service intervals better. This in turn substantially increases the reliability and availability of the plant and at the same time brings down the costs of repair. To gain the most from teleservice, telemonitoring must be followed up by the necessary services. After concluding a so-called dynamic inspection contract, the plant operator no longer needs to keep his own personnel ready to deal with a problem. Only when the system detects the first signs of a technical problem are these signalled and is it time to take action. The necessary service can be provided by an external service company. If a particular trend, indicating, say, worn or damaged parts, persists, the cause(s) can be analysed by KSB’s pump experts, who will then recommend and carry out the proper remedial action. Which services in connection with the teleservice concept should be integrated in a service contract is for the customer and the pump manufacturer to jointly decide (Fig. 2).

Practical Application of the Concept

The data of a pump unit are evaluated and transmitted. In response to a fault message, the staff of either the service provider or the plant operator is alerted depending on the contract particulars. The message is transmitted by SMS, e-mail or telephone. At the same time, the service engineer concerned is supplied with the relevant product details and informed about the suspected failure. This allows him to collect the necessary replacement parts and tools. Teleservice with an early failure detection system is recommended in those cases where the efficiency of a plant has to be improved, if a plant has a history of defects or if the plant requires a high level of safety. An all-in service concept should be included whenever the objective is to secure the availability of a plant in the medium or long term. In other words, the amount of service can be tailored to precisely match the needs of the pump user according to customer’s specification or as demanded by the application.

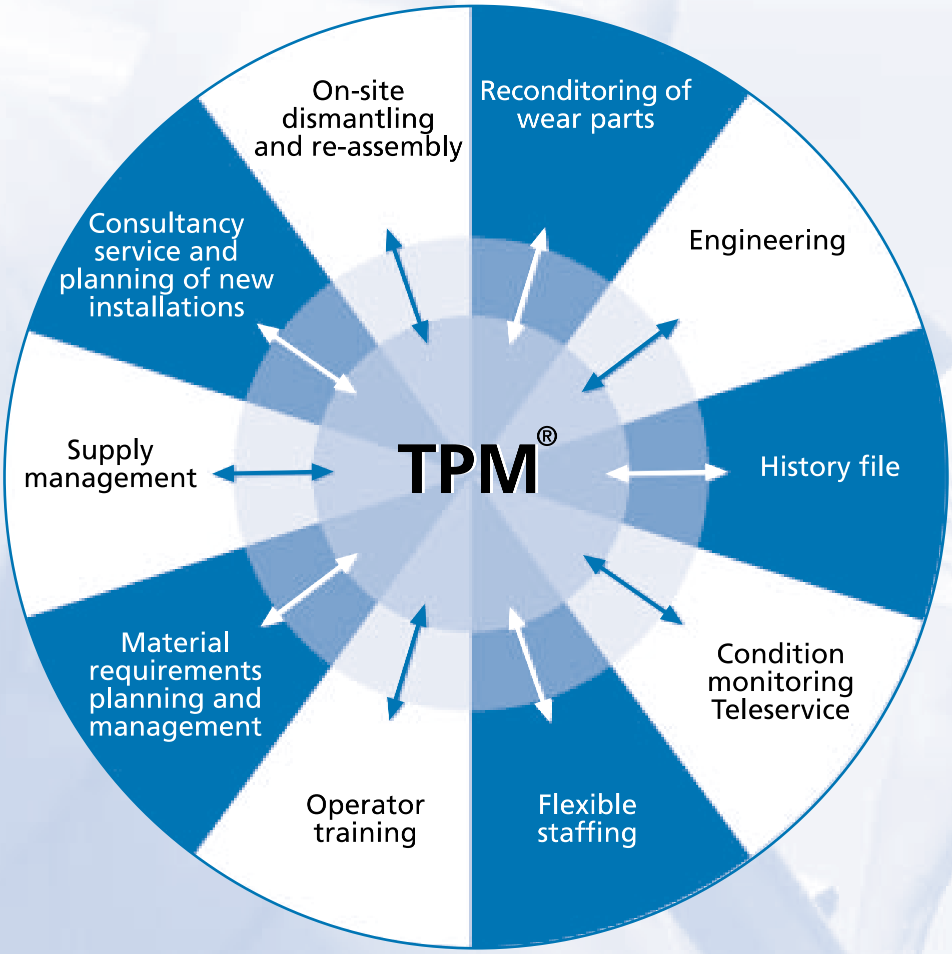


Fig. 3: TPM® Total Pump Management

MODULAR SERVICE CONCEPT

Having recognized the need for an all-in approach, KSB developed TPM® (Fig. 3) in 1999. All product and plant details, spare parts requirements and causes of failure of pump units are recorded and analysed. The results are recorded in a so-called history file and serve as basic data for life cycle cost analysis. They serve as a basis for technical adjustments to the operating conditions and for defining the maintenance intervals and the stock of spare parts. The modular structure of the system allows the users to choose a service package for their pumps, valves and related systems - regardless of make or supplier- that is precisely tailored to their needs. The modules making up the package range from the once-only servicing of a single component to a Total Pump Care package, with the service provider even taking care of operating the pump. Operator training and thereby increasing staff awareness of the inner workings of a plant is another module that is sure to bring the desired improvements. First experiences gained at a number of pumping stations have shown that the faithful application of this service concept will reduce the total maintenance volume by 20 to 30 percent. To date, a total of fifty TPM® framework agreements have been concluded in Europe. The effects of this service approach become clear if we take another look at Fig. 4.

CONCLUSION

An all-inclusive service approach, including teleservice, is an effective means of significantly reducing failure rates and the entailed total costs expected during the life cycle of a product.

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