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Analysis and procedure for the energetic optimisation of pumps in water supply applications

„Pump check“

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Zusammenfassung

Das Energieeinsparpotenzial beim Pumpenersatz in den Wasserversorgungen wird aufgrund einer neuen Forschungsarbeit im Auftrage des Bundesamtes für Energie heute auf 10 – 20% geschätzt, was in der Schweiz Energieeinsparungen von 50 - 100 GWh/a bedeuten würde. Bisher wurden diese Potentiale noch nicht ausgeschöpft. Zum einen fehlten die Instrumente zu einer schnellen Abschätzung des Energieeinsparpotentials, zum andern ist das Wissen noch zu wenig verbreitet.

In diesem Forschungsprogramm ist ein Instrument zur Abschätzung des Energieeinsparpotentials einer Pumpe für Wasserversorgungen entwickelt und in der Praxis getestet worden. Das Vorgehen ist in zwei Schritte gegliedert.

Der erste Schritt ist der sogenannte Grobcheck. Den Grobcheck können Fachleute für eine Wasserversorgung für jede Pumpe rasch und einfach durchführen. Dazu müssen die Daten auf den Motoren- und Pumpendatenschildern abgelesen sowie Messungen zur manometrischen Förderhöhe, zur geförderten Wassermenge und zur Stromaufnahme des Motors durchgeführt werden. Daraus kann der Wirkungsgrad der bestehenden und der bestmöglichen Pumpe ermittelt und aus der Differenz das Energieeinsparpotential abgeschätzt werden. Wird ein bestimmter Grenzwert überschritten, wird ein Feincheck empfohlen. Es können auch andere Gründe zu einer Feincheckempfehlung führen, z.B. wenn eine Pumpe sanierungsbedürftig ist und sowieso ersetzt werden muss.

Der zweite Schritt ist der Feincheck, für dessen Durchführung vertieftes Fachwissen der Pumpen- und Motorentechnologie sowie des Betriebes einer Wasserversorgung (WV) notwendig ist. Im Feincheck wird eine detaillierte Analyse der Wasserversorgung durch Ingenieurbüros oder Pumpenhersteller durchgeführt, in der die Wirtschaftlichkeit eines Pumpenersatzes oder einer alternativen Energiesparmassnahme aufgezeigt wird.

Bei 6 Wasserversorgungen wurden in dieser Forschungsarbeit 18 Pumpen einem Grobcheck unterzogen. Das Energiesparpotenzial lag bei 0 bis 26 %, im Mittel bei 13%. Der anschliessende Feincheck wurde bei 5 Wasserversorgungen durchgeführt. Die Feinchecks zeigten gesamthaft Einsparungen von 59'600 kWh/a und jährlich CHF 14'664.- auf. Dies entspricht einem Durchschnitt von 10,8% weniger Stromverbrauch pro Pumpe. Beinahe die Hälfte des Einsparpotenzials wurde bereits innerhalb von einem Jahr umgesetzt.

Der Grob- und Feincheck sind öffentlich zugänglich. Siehe www.infrawatt.ch.

Résumé

Le potentiel d'économie d'énergie lors d'un remplacement de pompes dans les adductions d'eau en Suisse est estimé à 10 – 20 % ou 50 – 100 GWh/a. Malheureusement ce potentiel n'est pas exploité dû à un manque d'instruments d'analyses faciles à utiliser mais aussi dû à un manque d'information.

Le but de ce programme de recherche a été de développer un instrument qui permette une analyse rapide du potentiel d'optimisation énergétique d'une pompe. Cet instrument est divisé en deux parties.

La première partie est le « Grobcheck » : il estime le potentiel d'économie d'énergie d'une pompe en comparant la pompe installée à la meilleure pompe techniquement possible existante. Le service d'eau potable ne doit que mesurer le débit, la hauteur de refoulement ainsi que le courant consommé par le moteur. Selon le potentiel d'économie d'énergie, un

« Feincheck » est proposé. D’autres critères, comme la remise en état planifiée d’une pompe, peuvent aussi mener à une proposition de faire un « Feincheck »

La deuxième partie est le « Feincheck » qui nécessite un savoir approfondie en matière de pompes, moteurs et fonctionnement d’adductions d’eau. C’est un bureau d’ingénieur ou un fabricant de pompes qui mène l’analyse de rentabilité d’un échange de pompe ou d’une autre mesure d’économie d’énergie.

Le « Grobcheck » a été mené avec 18 pompes de 6 adductions d’eau. Le « Feincheck » a été conduit sur 5 pompes de 5 adductions d’eau. L’économie totale en énergie est de 59'600 kWh/a et l’économie financière de CHF 14'664.-/a dont 26'600 kWh/a et CHF 10’000.-/a ont été réalisés l’année passée. Ceci correspond à près de 11 % d’économie d’énergie par pompe.

Le « Grobcheck » et le « Feincheck » sont accessibles au public. Cf. www.infrawatt.ch.

Abstract

The potential for saving energy when exchanging pumps in water supplies in Switzerland is estimated at 10 – 20 % or about 50 – 100 GWh/a. Due to the lack of knowledge and/or lack of tools to make a fast analysis, these potentials are not exploited.

The aim of the research program was to develop a tool to help estimate the energy saving potential of a pump. The tool is divided into two parts.

The first part is called the “Grobcheck”. This tool assesses the energy saving potential between the existing pump and the technically best pump existing on the market. The only things the water supply needs to measure are the delivery height, the delivery volume and the motor current. According to the energy saving potential, expressed as a percentage of the efficiency of the best existing pump, a so-called “Feincheck” is recommended. Other criteria besides the energy saving potential, as for example the imminence of a pump exchange, can lead to a recommendation for a “Feincheck”.

The second part is the “Feincheck”. The cost effectiveness of a pump exchange and/or other energy saving measures is conducted by an engineering company or a pump manufacturer.

The “Grobcheck” has been conducted on 18 pumps in 6 water supplies. The “Feincheck” has been conducted in 5 water supplies resulting in overall energy savings of 59’600 kWh/a and financial savings of CHF 14’664.-/a of which nearly half have been implemented. This means an average of nearly 11 % of energy savings per pump.

The “Grobcheck” and “Feincheck” are accessible to the public.

For further information: www.infrawatt.ch.

Introduction

When replacing the pump, the full potential with regard to the power consumption is not used yet in water supply applications, as even today a precise dimensioning or optimization of the pumps, motors and the operation by means of advanced EDV tools is hardly done. The potential for energy savings when replacing the pump is estimated at 10 – 20 %. For Suisse this means savings of 50 - 100 GWh/a.

Aim of the project

Aim of the project is the development of a feasible pump check. For reasons of efficiency and costs the pump check is done in two steps:

At the first step professionals of the pump owner or external professionals can make a first rough analysis of the pumps including identifying the potential of optimization. This is the so called **rough check**. A rough check is made for each pump.

Depending on the result of the rough check the second step comprehends a detailed analysis of the water supply, where the economic efficiency of a pump replacement or another energy-saving measure is shown. This is the so called **fine check**. For conducting the fine check advanced knowledge is required, which for example consulting engineers or pump manufacturers have.

Carried out works and obtained results

Rough check

The rough check gives a recommendation on basis of the energy efficiency and the opportunities for action, if a fine check is profitable. Thereto the following questions are cleared:

1. Is there a potential for energy optimization being higher then 10 % compared to the best possible pump?
2. Does the flow rate or the pump head differ by more than 20 % from the data stated on the nameplate?
3. Are there qualitative data indicating a need for reconstruction of the motor, pump or total system that call for a fine check?
4. Is the pump so large (power more than 375 kW) so that a rough check looses its validity and a fine check is required in any case?

If one of these questions is answered with „Yes“, a fine check is recommended.

The first questions is answered by means of a pump and motor database by searching the best technical solution of the pump-motor unit for the today duty point and by comparing its efficiency with the efficiency of the existing solution.

For 18 pumps of 6 water supply applications a rough check has been done. The potential for optimization was between 0 and 26 %. The mean value was 13 %.

For details see the attached rough check and its operational sequence description in the appendix.

Fine check

The fine check has been made at one pump of the following water supply companies:

WV	Energetic savings potential fine check	Energy savings	Financial savings pump	Other saving measures	Replace-ment invest pump	Pay back pump replace-ment
	[%]	[kWh/a]	[CHF/a]	[CHF/a]	[CHF]	[years]
Uzwil	16	9,000	1,250	0	8,700	7
Buchs (AG)	13-19	19,000	2,900	0	14,000	5
Lausanne	10	20,000	3,000	0	0	0
Sils	5	6,600	1,000	6,000	14,500	15
SWG Worben	7	5,000	514	0	29,800	58
Summe *Mittel*	*10.8*	*59,600* *11,920*	*8,664* *1,733*	*6,000* *1,200*	*67,000* *13,400*	*17*

- At the water supply company Uzwil und Buchs AG no pumps have been replaced until the end of the research project. Studies are still running.
- At the water supply company Lausanne one energy-saving measure has been implemented. One pump could be switched off and the amount of water pumped by this pump could be pumped more efficient by other pumps. The savings add to appr. 20,000 kWh/a or CHF 3,000.-/a, without making any investments.
- The water supply company Sils i.E. has replaced their pumps mid-May. Two optimizations have been made: first of all a smaller pump with a higher efficiency at the selected duty point has been installed (energy saving of 6,600 kWh/a). As a second optimization the operating time has been changed, so that the pumps run in times of cheaper night current (monetary savings of CHF 6,000.-/a). Early June the company Grundfos will make control measurements. The monetary potential for savings is estimated at CHF 7,000.- and the energy savings at 6,600 kWh/a.
- At the SWG Worben energetically optimal pumps are already used today. An economic potential for energy savings could not been found.
- In total 59,600 kWh/a can be saved at the five water supply companies. In the first year approximate half of the savings or 26,600 kWh/a could be realised already.

The results of the fine check have been presented personally to the different operators.

The fine check instruction has been formulated in general on basis of the worked out fine checks. See the instruction and specifications in the appendix.

Comparison of the results of the energy saving on basis of the rough and fine check

At three water supply companies the conformity between the results of the rough check and the fine check is good. The mean value of the potential for savings is 14 % at these three pumps.

At the other two water supply companies the fine check shows a much lower potential for optimization than the rough check. The reasons are known:

- At the water supply company Sils the pumps are running at different duty points. This could not be seen within the rough check. Therefore a much too high potential for optimization has been determined.
- SWG Worben: The data determined within the fine check vary a lot from the data determined within the rough check. The pump selected within the fine check has not such a high potential for optimization as calculated initially.

National cooperation / realization

Cooperation with the national market leader among the pump manufacturers in the water supply sector: the Häny AG.

The national cooperation with the francophone Suisse has been ensured by the company Planair SA.

Collegiate knowledge has been involved by means of the university Luzern.

The Semafor AG provides their programme „OPAL“ for calculating the possible energy savings of pump systems. Furthermore, the data of the motor database are used within the pump check.

The EnergieSchweiz für Infrastrukturanlagen or InfraWatt takes over the broad distribution of the gained knowledge. By means of the campaign "Pump check for water supply applications", conducted by InfraWatt within the context of the federal programme „Wettbewerbliche Ausschreibungen“, the developed tools are directly used for the implementation of energy-saving measures.

At the beginning the procedure and results of the pump check have been interchanged with topmotors in 2009.

Within the Swiss „Brunnenmeistertagung“ in 2010 the pump check has been presented more than 1,000 professionals from the water supply sector.

In the fall of 2010 the pump check has been presented to the international experts at the „Motorsummit“.

The works in regard to the pump check have also been published in different professional journals (obtainable via www.infrawatt.ch):

- DVGW Jahresrevue 12/2010
- GWA 06/2009 and 6/2011

International cooperation

International cooperation with the Danish pump manufacturer Grundfos. The company Grundfos will ensure an Europe-wide, if not global distribution of the results including the translation into English.

Until now the pump check has been presented to a Luxembourgish delegation and at an event of the DWA.

Evaluation

Success:

- First realization measures have been done: the water supply company Lausanne has obtained an energetic saving of 20,000 kWh/a or CHF 3,000.-/a.
- The Sils i.E. has implemented an energy-saving measure mid-May. The savings are 6,600 kWh/a and thanks to tariff adjustments CHF 7'000.- per year. Control measurements will be made early June.
- The tools developed within the research work will be used in the campaign "Pump check for water supply applications" from the association InfraWatt within the federal programme „Wettbewerbliche Ausschreibungen“. As a result considerable energy savings are expected at national level.

General findings:

- Large-scaled operators of water supply applications have often competent professionals.
- For a fast implementation of energy-saving measures the decision makers and the operating manager should attend during the presentation of the fine check.
- For a correct conduct of the fine check access to all relevant data of the water supply company is required. The water supply company should be involved in the process and be an active part.
- The conduct of the rough and fine check was the initial point or basis for some water supply companies to search for redevelopment measures or energy optimization in other areas.
- Suisse-wide efforts are in progress to define a minimum value for the efficiency of pumps and motors. Then lower efficiencies were not allowed anymore. It might be that in future today existing pumps/motors are allowed no longer.

Findings from the conduct of rough checks:

- A reliable determination of data and measurement parameters is vital for a convincing rough check. For this purpose corresponding professionals are needed.
- For advertising the rough/fine check and the implementation of the energy-saving measures widely, directed trainings are necessary (amongst others seminar from 15. June 2011, see www.infrawatt.ch)
- Pumps with high operating hours and high motor power show the best chances for a larger potential for energy savings.
- The determination of reliable data about the manometric pump head seems to be difficult.

Findings from the conduct of fine checks:

- For conducting a fine check it must be possible to change the duty point. This has to be clarified with the water supply company beforehand.
- Before evaluating the data of the fine check the operator of the water supply application has to be contacted to verify the stated data.
- The hydraulic scheme of the water supply application is needed for a fine check by all means.
- For the cost-benefit analysis the costs for a replacement of a pump being necessary anyway and the work for replacing the pump have to be listed separately and have to be allocated to the budget item conservation of value/maintenance.
- A fine check has to be made product neutral; otherwise it lost the objectivity (use no sales brochure!).
- When replacing pumps and motors, it can be possible that there is a difference between the technically and economically optimum solution and the offers on the market. Therefore, an optimum replacement is not possible in any case.
- When the pumps are controlled by a frequency converter, it must be possible that the frequency can be set to 50 Hz.

References

www.infrastrukturanlagen.ch
www.infrawatt.ch
www.topmotors.ch
www.energieschweiz.ch/

Appendix

- Rough check – Calculation tool explained by means of a fictional example
- Rough check – Method of calculation?
- Fine check – Instruction
- Fine check – Data to be collected

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Analysis and procedure for the energetic optimisation of pumps in water supply applications

"Pump check"

Rough check -
Calculation tool explained by means of a fictional example

energieschweiz
InfraWatt
Lucerne University of Applied Sciences and Arts HOCHSCHULE LUZERN Engineering & Architecture
GRUNDFOS
HÄNY Pumpen, Turbinen und Systeme
SEMAFOR
PLANAIR Ingénieurs conseils en énergies et environnement
Ryser Ingenieure AG

Pump rough check - disclaimer

This product has been developed for supporting the decision making process of energy-saving measures at pumps in water supply applications. A warranty for the correctness and completeness of the obtained results and information can not be given. Principally, any liabilities are excluded that are referred to material or more imaginary damages caused by the use or disuse of the presented information or the use of incorrect and incomplete data.

Pump rough check: Summary of the results

Data of the exemplary water supply application		
Pump		
Manufactur	Exemplary pump	
Nominal flo	20	[l/s]
Nominal pu	30	[m]
Motor		
Manufactur	Examplary motor	
P_{mech}	7.5	[kW]
Rated volta	400	[V]
Rated curre	16	[A]
Measurements at the duty point		
Flow rate	18	[l/s]
Pump heac	25	[m]
Current (m	14	[A]
Pump unit		
Total efficie	53%	

Results of the rough check			
Total efficien	#WERT!		
Energy efficie	#WERT!	How close is the actual condition to the technical optimum?	
			#WERT!
Potential for	#WERT!		#WERT!
Potential for	#WERT!	[kWh/a]	
Savings of er	#WERT!	[CHF/a]	
	#WERT!	CHF over a lifetime of 15 years	
Validation of sizing parameters Q & H			
Difference of	17%	[-]	ok
Difference of	10%	[-]	ok

Recommendation for further procedure: Is a fine check recommended'		
Fine check due to the	#WERT!	#WERT!
Fine check due to the	NO	The actual pump head differs less than 20 % compared to the sizing pump head.
Fine check due to the	NO	The actual flow rate differs more than 20 % compared to the sizing flow rate.
Fine check due to the qualitative	YES	Based on the qualitative statement to motor, pump and total system a fine check is necessary.
Fine check due to the	NO	The framesize of the pump alone calls not for a fine check.
For reasons **#WERT!**		

What is a fine check?

The fine check is a detailed energetic analysis of the water supply, where the profitability of a pump replacement or another energy-saving measure is shown.

Pump rough check - help file

Please print this sheet
and keep it at hand for the rough check.

Inputs from nameplate: Read out the data!
Measurements: MEASURE only, do NOT CALCULATE!
Calculation: Will be done automatically!
General questions

Prioritisation of the pumps (the higher the number, … =(lifetime * power)/year of manufacture
... the rather a rough check should be done) or: a system change has been made

Important:
- for pumps controlled by frequency converter**:** Set frequency converter to 100 % (50 Hz).
- **Switch off the blind current compensation or measure the current between the blind current compensation and the motor terminals (best directly at the motor terminals)**.

Measurements
Three measurements are made:
- **manometric pump head in metre:** Therefore a pressure gauge is needed. Mostly one is installed on the discharge side of the pump. Furthermore, the pressure on the suction side of the pump has to be estimated, if no pressure measurement is installed on the suction side. Help to this offers the table sheet "Pump head calculation" with three sketches of the most widespread cases.
- **flow rate in litre per second [l/s]**: Mostly a magnetic flow meter is already installed and has only to read out. If no magnetic flow meter exists, a mobile measurement of the flow has to be made.
- **current in ampere [A] of the three phases of the electric motor**: This measurement is done by means of an amps clamp.

Example of an amps clamp:

Constants

Accelaration of gravity	g=	9.81	[m/s^2]
Density of water	ρ=	1'000	[kg/m^3]
Maximum current difference between the phases (motor)		5%	limit for fault alarm
Lifetime of the pump		15	years

Input: Information about the water supply system

Water supply company		Please state the address, contact person, phone number, etc. What pump type is installed?
Contact person		
Position of contact person		
Address		
Cip code		
City		
Phone number		
E-mail		
Location of the pump station		
What pump type is installed?		

Input: Annual data

Operating hours per year		h/a	How many hours does the pump run per year?
Electricity consumption per year, motor		kWh/a	Current this motor uses per year in kWh/a.
Pumped water amount per year, pump		m^3/a	Water amount pumped per year in m³/a
Energy price		CHF/kWh	What is the average price for a kWh incl. tariff loading at peak periods and low/high tariff?

Pump rough check - help file

Input: Sizing data of pump (read from nameplate)

Make / manufacturer				see pump nameplate
Serial number				see pump nameplate
Kind of pump / design				see pump nameplate
Dry installed			*(yes/no)*	Submersible pump?
Submersible pump			*(yes/no)*	Dry installed pump?
Number of stages (in case of high pressure pumps)				
Single stage low pressure pump			*(yes/no)*	In the two green fields on the left "yes" or "no" have to be entered!
Multistage high pressure pump			*(yes/no)*	
Number of stages			[-]	In case of mutistage high pressure pumps the number of stages has to be entered here. Default
Flow rate of the pump, sizing data	Q		[l/s]	see pump nameplate
Pump head, sizing data	H		[m]	see pump nameplate

Input: Sizing data of motor (read from nameplate)

Make / manufacturer				see motor nameplate
Serial number				see motor nameplate
Motor type / design				see motor nameplate
(Mechanical) rated motor power	P_n=P_{mech}		[kW]	see motor nameplate - in kW!
Rated motor speed	n_n		[1/min]	see motor nameplate
Motor efficiency at nominal load	η_n		[-]	see motor nameplate
Rated motor current	I_n		A	see motor nameplate
cos φ at nominal load	cos φ_n		[-]	see motor nameplate
Rated motor voltage	U_n		[V]	see motor nameplate

easurement: Measurement at duty point (when pump is running!!!)

Effective flow rate	Q_{eff}		[l/s]	How many litres per second are pumped at the duty point?
Measured pump head	ΔH_{dyn}		[m]	What is the pump head of the pump at the duty point? See also table sheet "Pump head calculation". Thereto click on the blue link.
Does the pump head vary?			*(much / little / don't know)*	State, if possible.
Current measurement				
Does a blind current compensation exist?			*(yes / no / don't know)*	Switch off the blind current compensation or measure the current between the blind current compensation and the motor terminals (best directly at the motor terminals).
Is a frequency converter switched on?			*(yes / no / don't know)*	State, if a frequency converter exists, otherwise leave field empty.
If yes, on which frequency is it set?			[Hz]	
Current, phase 1	I_{phase1}		[A]	Please measure each phase separately. Caution: The frequency converter has to be set to 50 Hz and the measurement has to be done at the motor terminals. In case of a submersible pump measure the current at the cables coming out of the control cabinet.
Current, phase 2	I_{phase2}		[A]	
Current, phase 3	I_{phase3}		[A]	

. questions: General status recording for pump & motor

Can it be seen that renewal, optimization and/or reconstruction is needed actually?

Motor		*(yes / medium-term / no / don't know)*
Pump		*(yes / medium-term / no / don't know)*
Total system		*(yes / medium-term / no / don't know)*
If yes, please describe		

Estimation of the repair/maintenance costs

Motor		*(high / normal / low / don't know)*
Pump		*(high / normal / low / don't know)*
Total system		*(high / normal / low / don't know)*

Changes

Have changes regarding the operation or piping (new pipes, ...) been made since the commissioning of the pump?		*(yes / no / don't know)*
If yes, what has been changed?		

Pump rough check - calculations

Color key:
Inputs from nameplate: Read out the data!
Measurements: MEASURE only, do NOT CALCULATE!
Calculation: Will be done automatically!
General questions

Prioritisation of the pumps (the higher the number, …	=(lifetime * power)/year of manufacture
... the rather a rough check should be done) or:	a system change has been made

Important:
- for pumps controlled by frequency converter: Set frequency converter to 100 % (50 Hz).
- Switch off the **blind current compensation** or measure the current between the blind current compensation and the motor terminals (best directly at the motor terminals).

Constants

Accelaration of gravity	g=	9.81	[m/s^2]
Density of water	ρ=	1'000	[kg/m^3]
Maximum current difference between the phases (motor)		5%	limit for fault alarm
Lifetime of the pump		15	years

Input: Information about the water supply system

Water supply system	Exemplary watersupply system
Contact person	
Position of contact person	
Address	
Zip code	
City	
Phone number	
E-mail	
Location of the pump station	
What pump type is installed?	

Input: Annual data

Operating hours per year	4'000	h/a
Electricity consumption per year, motor		kWh/a
Pumped water amount per year, pump		m^3/a
Energy price	0.15	CHF/kWh

Input: Sizing data of pump (read from nameplate)

Make / manufacturer		Exemplary pump			
Serial number		74.115.1996			
Kind of pump / design					
Dry installed pump		yes	*(yes/no)*	ok	
Submersible pump		no	*(yes/no)*		
Number of stages (in case of high pressure pumps)					
Single stage low pressure pump		yes	*(yes/no)*	ok	
Multistage high pressure pump		no	*(yes/no)*		
Number of stages		1	[-]		
Flow rate of the pump, sizing data	Q	20	[l/s]	0.02	m^3/s
Pump head, sizing data	H	30	[m]		

Input: Sizing data of motor (read from nameplate)

Pump rough check - calculations

Make / manufacturer		Examplary motor			
Serial number		12.345.1997			
Motor type / design					
(Mechanical) rated motor power	$P_n=P_{mech}$	7.5	[kW]	7'500	[W]
Rated motor speed	n_n	1'455	[1/min]		
Motor efficiency at nominal load	η_n	0.82	[-]		
Rated motor current	I_n	16	A		
cos φ at nominal load	$\cos \varphi_n$	0.9	[-]		
Rated motor voltage	U_n	400	[V]		

easurement: Measurement at duty point (when pump is running!!!)

Effective flow rate	Q_{eff}	18	[l/s]	0.018	m^3/s
Measured pump head	ΔH_{dyn}	25	[m]	Hint pump head calc. (click here)	
Does the pump head/flow rate vary?	(> +/-10 %)		*(yes / no / don't know)*		

Current measurement

Does a blind current compensation exist?			*(yes / no / don't know)*	
Is a frequency converter switched on?			*(yes / no / don't know)*	
If yes, on which frequency is it set?			[Hz]	
				Phase check:
Current, phase 1	I_{phase1}	14	[A]	ok
Current, phase 2	I_{phase2}	14	[A]	ok
Current, phase 3	I_{phase3}	14	[A]	ok

. questions: General qualitative statements to pump, motor and total system

Can it be seen that renewal, optimization and/or reconstruction is needed actually?

Motor	medium-term	*(yes / medium-term / no / don't know)*
Pump		*(yes / medium-term / no / don't know)*
Total system		*(yes / medium-term / no / don't know)*
If yes, please describe.		

Estimation of the repair/maintenance costs

Motor		*(high / normal / low / don't know)*
Pump		*(high / normal / low / don't know)*
Total system		*(high / normal / low / don't know)*

Changes

Have changes regarding the operation or piping (new pipes, ...) been made since the commissioning of the pump? | yes | *(yes / no / don't know)*

If yes, please describe.

Calculation: Total efficiency - ACTUAL value (processing of input values (actual status))

Calculation of hydraulic power (duty point)	P_{hyd} =	4'415	[W]	4.4	[kW]	
Calculation of electrical power						alternatively:
Electrical power at nominal load	$P_{electr, n}$=	9'977	[W]	10.0	[kW]	9'146
Approximation: current measurement						
Approximate coefficient (R. Tanner)	p_o	-0.342				
Approximate coefficient (R. Tanner)	p_x	1.345				
Load ratio	$P_{electr}/P_{electr,n}$=	0.83		ok		
Electrical power at duty point	P_{electr}=	8327	[W]	8.3	[kW]	
Total efficiency, ACTUAL value	$\eta_{tot, measured}$=	**0.53**	**[-]**			

Calculation: Total efficiency - OPTIMAL value

Pump rough check - calculations

Number of pole pairs	ppz	2	[-]	
Specific speed	n_q =	17.5		with n_n [1/min] (approximation) Qeff [m^3/s] H [m] = ΔP_{dyn}/number of stages, if multistage
Weighting according to impeller type: Table, which shows the maximal reachable hydraulic efficiency as a function of nq.	$\eta_{hydr, max.}$=	0.70		
Weighting according to frame size (Q): Smaller pumps have due to their construction a lower efficiency than larger pumps with the same speed (nq).	Corr. factor=	0.95		
Reduction in case of large number of stages with empiric coefficient f_r	Corr. Factor=	1		
Best possible pump efficiency	$\eta_{pump, opt}$=	0.67		
Best possible mechanical power	$P_{mech,opt}$=	6'638	[W]	6.6 [kW]
Best possible motor efficiency	$\eta_{motor,opt}$=	Wrong data!	Interpolation in table sheet "Best motors"	
Electrical power in optimum	$P_{el,opt}$=	#WERT!	[W]	#WERT! [kW]
Total efficiency, OPTIMAL value	**$\eta_{total,opt}$=**	**#WERT!**	**[-]**	

Result: Comparison of ACTUAL and OPTIMAL value

Energy efficiency (E coefficient) (must be <1!)	E=	#WERT!	How close is the ACTUAL condition to the technical optimum?	
			#WERT!	
Potential for energy savings				
ACTUAL energy	E_{act}=	33'308	kWh/a	
OPTIMAL energy	E_{opt}=	#WERT!	kWh/a	
	Potential for energy savings	**#WERT!**	**kWh/a**	
	in % related to the ACTUAL status	**#WERT!**	#WERT!	
Potential savings of energy costs (EK)		Energy price		
Actual energy costs per year	EK_{act}=	4'996	[CHF/a]	
Optimal energy costs per year	EK_{opt}=	#WERT!	[CHF/a]	
	Annual savings of energy costs	**#WERT!**	**[CHF/a]**	
	Savings of energy costs over an operating time of 15 years	**#WERT!**	**CHF**	
Comparison sizing – measurements				
Difference of pump head	$(H-\Delta H_{dyn})/H$	0.17	[-]	ok
Difference of flow rate	$(Q-Q_{eff})/Q$	0.10	[-]	ok

Motors with efficiency category IE3 (dry installation)

Source http://www.motorsystems.org/downloads
From Ronald Tanner

kW	Efficiencies in % 2-pole	4-pole	6-pole	Auxiliary values	
0.8	80.7	**82.5**	78.9	1.1	Validity of approximation method by R. Tanner
1.1	82.7	**84.1**	81	1.5	
1.5	84.2	**85.3**	82.5	2.2	
2.2	85.9	**86.7**	84.3	3.0	
3.0	87.1	**87.7**	85.6	4.0	
4.0	88.1	**88.6**	86.8	5.5	
5.5	89.2	**89.6**	88	7.5	
7.5	90.1	**90.4**	89.1	11.0	
11.0	91.2	**91.4**	90.3	15.0	
15.0	91.9	**92.1**	91.2	18.5	
18.5	92.4	**92.6**	91.7	22.0	
22.0	92.7	**93**	92.2	30.0	
30.0	93.3	**93.6**	92.9	37.0	
37.0	93.7	**93.9**	93.3	45.0	
45.0	94	**94.2**	93.7	55.0	
55.0	94.3	**94.6**	94.1	75.0	
75.0	94.7	**95**	94.6	90.0	
90.0	95	**95.2**	94.9	110.0	extended by R. Tanner
110.0	95.2	**95.4**	95.1	132.0	
132.0	95.4	**95.6**	95.4	160.0	
160.0	95.6	**95.8**	95.6	200.0	
200.0	95.8	**96**	95.8	220.0	
220.0	95.8	**96**	95.8	250.0	
250.0	95.8	**96**	95.8	300.0	
300.0	95.8	**96**	95.8	330.0	
330.0	95.8	**96**	95.8	375.0	
375.0	95.8	**96**	95.8		
		highest			

Mech. power [kW]	**Motor power, interpolation** X		**Efficiencies** 2-pole	4-pole	6-pole
6.6	5.5	lower limit	89.2	89.6	88
	7.5	upper limit	90.1	90.4	89.1

	Extrapolated efficiencies		
	2-pole	4-pole	6-pole
Number of pole pairs	1	2	3
Efficiency	**89.7**	**90.1**	**88.6**

Motors of submersible pumps

Source empiric

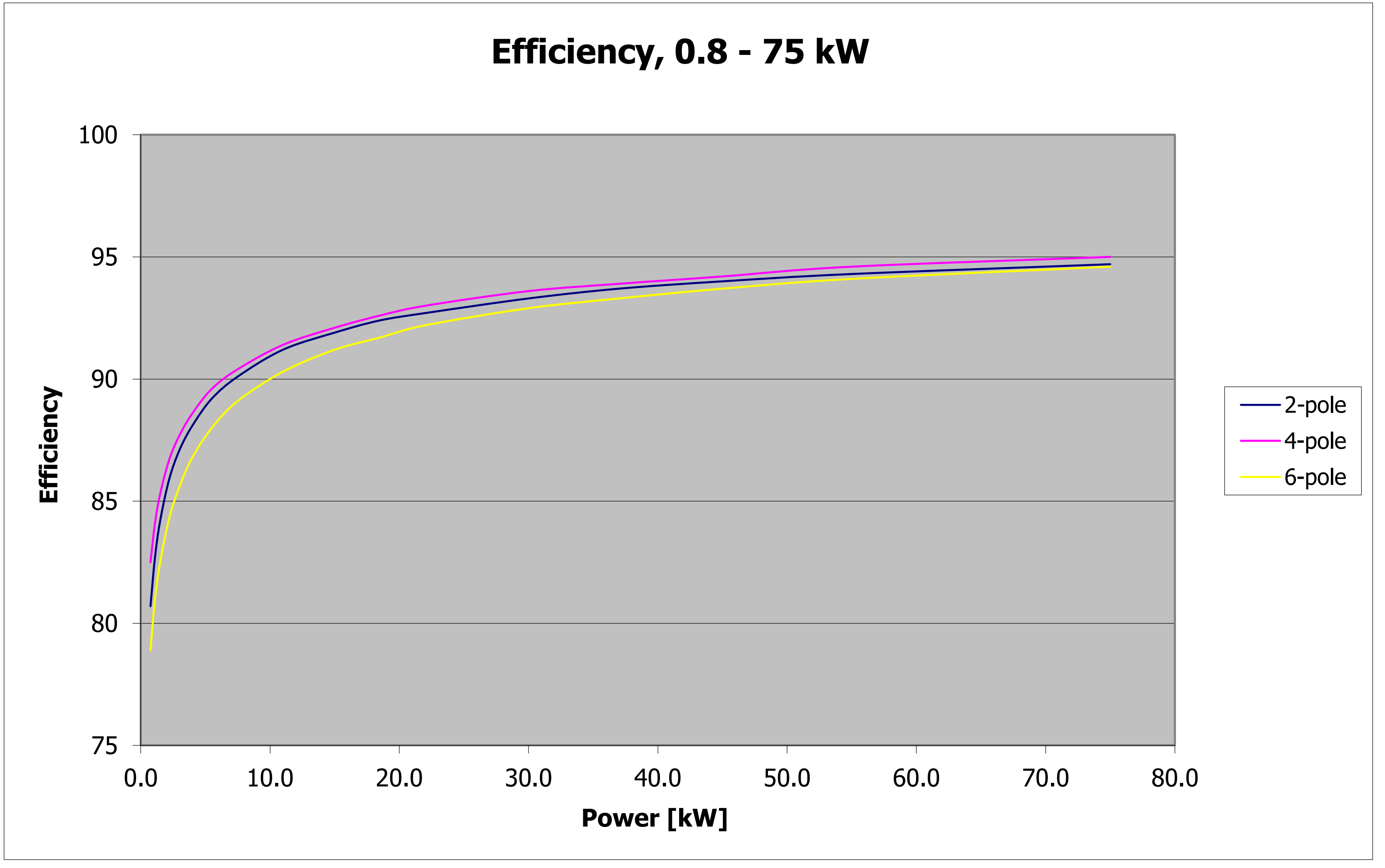
From Reto Baumann
Date 04.06.2009

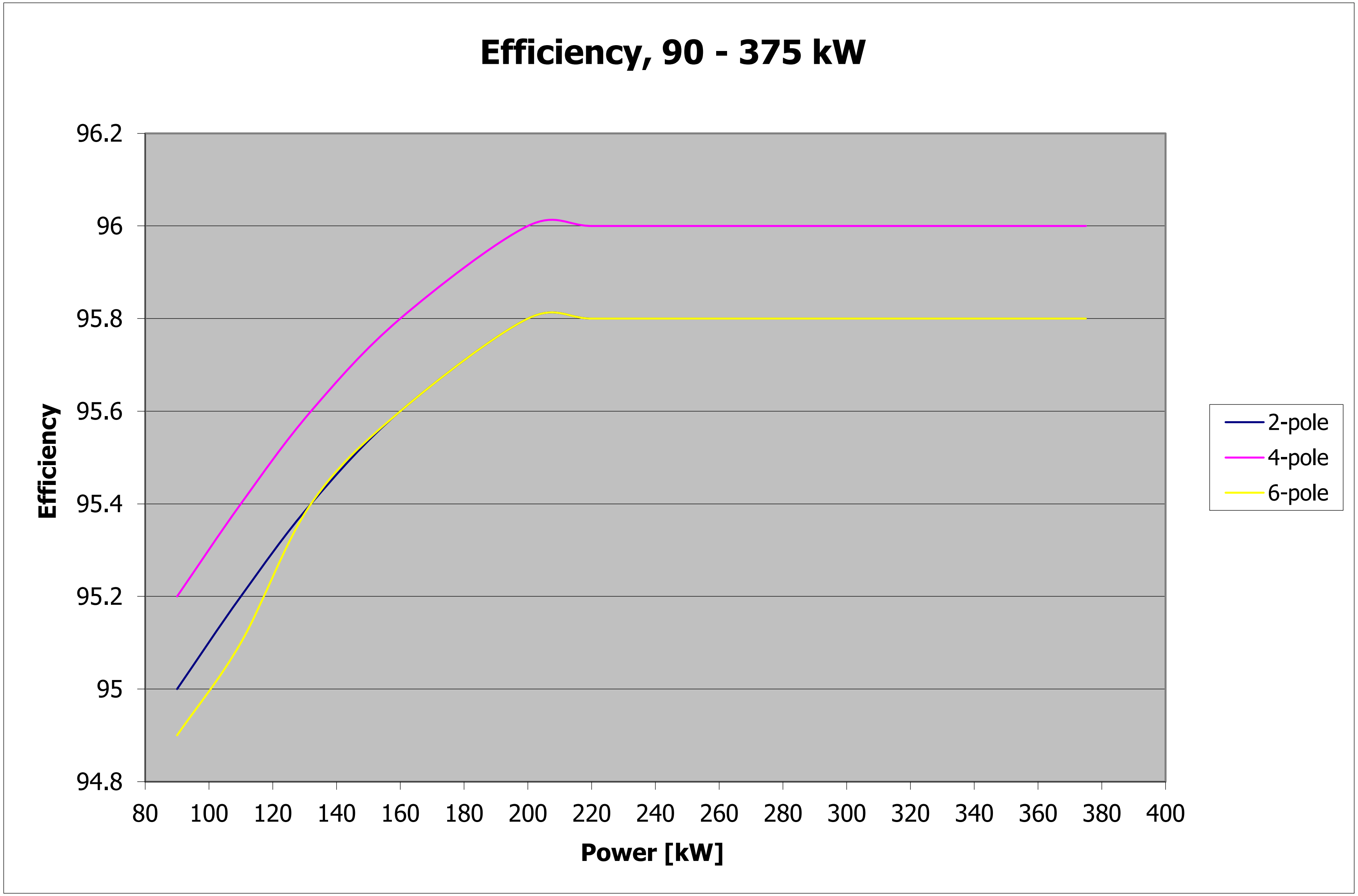
kW (P2M)	Efficiencies 2-pole	Efficiencies 4-pole	Auxiliary values
0.8	82.0	82.5	1.1
1.1	83.0	83.5	1.5
1.5	84.0	84.5	2.2
2.2	85.0	85.5	3.0
3.0	86.0	86.5	4.0
4.0	87.0	87.5	5.5
5.5	88.0	88.5	7.5
7.5	88.0	88.5	11.0
11.0	88.0	88.5	15.0
15.0	88.5	89.0	18.5
18.5	88.5	89.0	22.0
22.0	88.5	89.0	30.0
30.0	88.5	89.0	37.0
37.0	89.0	89.5	45.0
45.0	89.0	89.5	55.0
55.0	89.0	89.5	75.0
75.0	89.5	90.0	90.0
90.0	89.5	90.0	110.0
110.0	89.5	90.0	132.0
132.0	90.0	90.5	160.0
160.0	90.0	90.5	200.0
200.0	90.0	90.5	220.0
220.0	90.0	90.5	250.0
250.0	90.0	90.5	300.0
300.0	90.0	90.5	330.0
330.0	90.0	90.5	375.0
375.0	90.0	90.5	

Mech. power [kW]	Motor power, interpolation X		Efficiencies 2-pole	Efficiencies 4-pole
6.6	5.5	lower limit	88	88.5
	7.5	upper limit	88	88.5

Extrapolated efficiencies

	2-pole	4-pole
Number of pole pairs	1	2
Efficiency	**88.0**	**88.5**

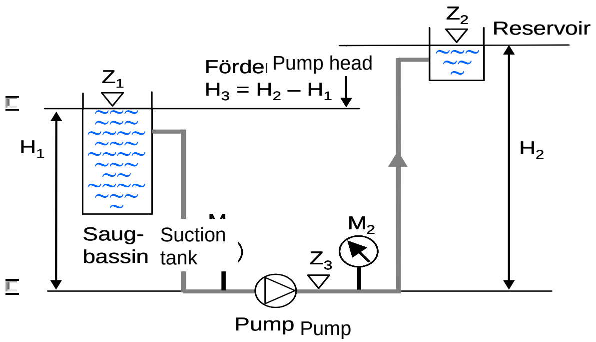

Efficiency, 0.8 - 75 kW
Efficiency
100
95
90
85
80
75
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Power [kW]
2-pole
4-pole
6-pole


Efficiency, 90 - 375 kW
96.2
96
95.8
95.6
95.4
95.2
95
94.8
Efficiency
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
Power [kW]
2-pole
4-pole
6-pole

Erfassung Förderhöhe: Messungen bei laufender Pumpe!

Instruction: Principally, three scenarios exist for pumping of water in water supply applications. Please select one, enter the required values and transfer the value of the field "Pump head=" into the table sheet "Rough check".(Use the link to find the right place.)

Suction tank above the pump



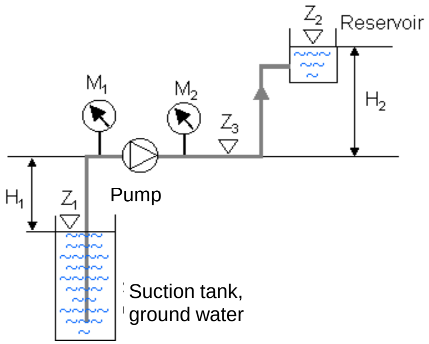
Please enter the values being measured (Enter only measured data. Do not calculate values!):

H_1		m	Height difference between pump and water level in the suction tank [m]
H_2		m	Height difference between pump and water level in the upper reservoir [m]
M_1		bar	Pressure gauge indication. Pressure gauge on suction side, installed between suction tank and pump [bar]
M_2		bar	Pressure gauge indication. Pressure gauge on discharge side, installed between pump and reservoir [bar]

Enter the below value (in metre of water) in the table sheet "Rough check" (click here)

Pump head ΔH_{dyn}= 0 mH_2O (metre of water)

Suction tank / ground water impoundment **below** pump



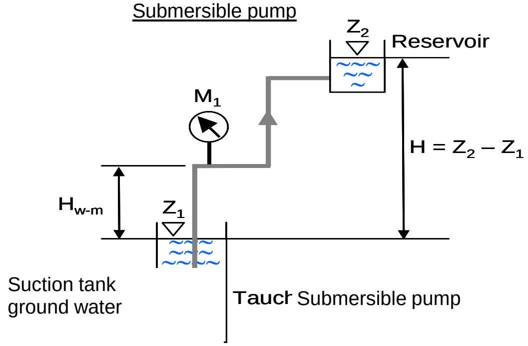
Please enter the values being measured (Enter only measured data. Do not calculate values!):

H_1	2	m	Height difference between water level in the suction tank / ground water and pump [m]
H_2	23	m	Height difference between pump and water level in the reservoir [m]
M_1	-0.2	bar	Pressure gauge indication. Pressure gauge on suction side betw. suction tank/ground water and pump [bar]
M_2	2.2	bar	Pressure gauge indication. Pressure gauge on discharge side, installed between pump and reservoir [bar]

Enter the below value (in metre of water) in the table sheet "Rough check" (click here)

Pump head ΔH_{dyn}= 25 mH_2O (metre of water)

Submersible pump



Please enter the values being measured (Enter only measured data. Do not calculate values!):

H		m	Height difference between water level in the suction tank / ground water and reservoir; $H = Z_2 - Z_1$ [m]
H_{w-m}		m	Height difference between water level in the suction tank / ground water and pressure gauge M_1 [m]
M_1		bar	Pressure gauge indication

Enter the below value (in metre of water) in the table sheet "Rough check" (click here)

Pump head ΔH_{dyn}= 0 mH_2O (metre of water)

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Analysis and procedure for the energetic optimisation of pumps in water supply applications

„Pump check“

Rough check – method of calculation

energieschweiz

InfraWatt

Lucerne University of Applied Sciences and Arts
HOCHSCHULE LUZERN
Engineering & Architecture

GRUNDFOS

HÄNY
Pumpen, Turbinen und Systeme

SEMAFOR

PLANAIR
Ingénieurs conseils en énergies et environnement

Ryser Ingenieure AG

Rough check – method of calculation

0. Constants

Definition of
- acceleration of gravity
- density of water
- limit value for the acceptable difference of the phase currents
- lifetime of the pumps.

1. Input: Sizing in general

1.1. Number of stages in case of high pressure pumps
 1.1.1. Single stage low pressure pump
 1.1.2. Multistage high pressure pump
  1.1.2.1. Number of stages

1.2. Information about the water supply system

1.3. Kind of pump / design

1.4. Make / manufacturer

1.5. Serial number

1.6. Sizing data (read from nameplate)

1.6.1.	Flow rate of the pump:	Q	[l/s]
1.6.2.	Pump head:	H	[m]
1.6.3.	Mechanical rated motor power:	$P_n = P_{mech}$	[W]
	=> if P_{mech} > 375 kW => recommend a fine check.		
1.6.4.	Rated motor speed	n_n	[1/min]
1.6.5.	Motor efficiency at nominal load	η_{mot}	[-]
1.6.6.	Rated motor current	I_n	[A]
1.6.7.	cos φ_n at nominal load	cos φ_n	[-]
1.6.8.	Rated motor voltage	U_n	[V]

1.7. Kind of pump
 1.7.1. Dry installed pump
 1.7.2. Submersible pump

1.8. Operating hours per year in [h/a]

1.9. Energy costs in [CHF/a] (overall average)

2. Measurement at running pump: duty point

2.1. Effective flow rate Q_{eff} [l/s]
2.2. Measured pump head ΔH_{dyn} [m]
2.3. Current measurement

2.3.1. Information about blind current compensation

2.3.2. Information about frequency converter incl. set frequency in [Hz]

2.3.3. Phase currents I_{phase} (3x) [A]

3. General questions

3.1. Can it be seen from the motor / pump / complete system that renewal, optimization and/or reconstruction is needed?
3.2. Estimation of the repair/maintenance costs for the motor / pump / complete system)
3.3. Has the piping been changed? What have been changed?

4. Calculation of total efficiency – actual value (processing of input values)

4.1. Calculation of the hydraulic power:

$P_{hyd} = Q_{eff} * \Delta H_{dyn} * \rho * g$ [W] with: Q [m³/s]
ΔH_{dyn} [m]
ρ [kg/m3]
g [m/s²]

4.2. Calculation of the electrical power:

Electrical power at nominal load:

$P_{elect,n} = U_n * I_n * \sqrt{3} * \cos \varphi_n$ [W]

Approximate calculation of power consumption with Tannerscher formula (see apendix „Rough check - Determination of the electrical power of an asynchronous motor")

Approximate coefficient $p_0 = -0.3612 + 0.00251 * P_n$

Approximate coefficient $px = 1.3644 - 0.002565 * P_n$

Load ratio $L_v = P_{elect} / P_{elect,n} = p_0 + p_x * \text{mean value} (I_1, I_2, I_3) / I_n$

Power consumption

$P_{elect} = L_v * P_{elect,n}$

4.3. Total efficiency:

$\eta_{total,measured} = P_{hydr} / P_{elect}$

5. Calculation of total efficiency – optimal value

5.1. Number of pole pairs ppz = round(3000/n_n)

5.2. Spezific speed

$n_q = n_n * \sqrt{Q_{eff}} / H^{3/4}$ with: n [1/min]
Q_{eff} [m^3/s]
H = ΔH_{dyn}/number of stages [m]

5.2.1. Weighting according to impeller type: Table, which shows the maximal reachable hydraulic efficiency as a function of n_q: $\eta_{hydr,max}$

5.2.2. Weighting according to frame size (Q): Smaller pumps have due to their construction a lower efficiency than larger pumps with the same speed (n_q): f_Q

5.2.3. Reduction in case of large number of stages with empiric coefficient f_r

5.3. With the above mentioned influences the best possible pump efficiency can be calculated:

$H_{pump, opt} = \eta_{hydr,max} * f_Q * f_r$

5.4. Optimal mechanical power:

$P_{mech, opt} = P_{hyd} / \eta_{pump,opt}$

Best possible motor efficiency:

$\eta_{mot,opt}$ in formula for $P_{mech,opt}$ (reference table for dry installed pumps and circulator pumps)

5.5. Best possible total efficiency:

$\eta_{tot,opt} = \eta_{pump, opt} * \eta_{motor,opt}$

---

6. Results – Comparison of actual and optimal value

6.1. Energy efficiency (E coefficient)

$E = \eta_{tot,measured} / \eta_{tot,opt}$ („How many % of the best possible total efficiency does the existing pump reaches at the duty point?")

If E > 1 -> fault during data input

If E < 1 -> check is okay

Potential for optimization = 1 – E (expressed in %)

6.2. Potential for energy savings

Actual energy $E_{act} = P_{elect}$ * operating hours

Optimal energy $E_{opt} = P_{hyd} / \eta_{tot,opt}$ * operating hours

Potential for energy savings = $E_{act} - E_{opt}$ in [kWh/a]

Potential for energy savings in % related to the actual condition = Potential for energy savings / E_{act}

6.3. Potential savings of energy costs (EK)

Actual energy costs per year $EK_{act} = P_{elect}$ * operating hours * energy price

Optimal energy costs per year $EK_{opt} = P_{hyd} / \eta_{tot,opt}$ * operating hours * energy price

Annual savings of energy costs = $EK_{act} - EK_{opt}$

Savings of energy costs over the lifetime of the pump = Annual savings of energy costs * lifetime

6.4. Comparison sizing – measurements

Validation of pump head:
The result of the term $(H - \Delta H_{dyn}) / H$ must not be more than 20 %.

Validation of flow rate:
The result of the term $(Q - Q_{eff}) / Q$ must not be more than 20 %.

Fine check: At least one of the following conditions must be fulfilled to recommend a fine check.

- Potential for optimization (6.1) > 10 %
- Pump head: Sizing data and measurement (6.4) shows a difference > 20 %
- Flow rate: Sizing data and measurement (6.4) shows a difference > 20 %
- Motor power (1.6.3) > 375 kW
- At least one of the general questions (3) have to be answered with YES, IN THE MEDIUM TERM or HIGH.

Caution: The whole test covers only the motor and pumps, but NOT all other system components and operating modes (system characteristic, management, ….)

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Analysis and procedure for the energetic optimisation of pumps in water supply applications

„Pump check“

Fine check – instructions

Project pump check
“Fine check“

Pump and system analysis at a pump for determining the energetic and economic potential for optimization

Customer

Object

Pump

Pump type

Serial number

Order

Author

Fine check made by

Template and instructions for a fine check

This template and instructions specify the structure of the fine check, the minimum requirements to the data to be collected as well as their evaluation.

Disclaimer
This product has been developed for supporting the decision making process of energy-saving measures at pumps in water supply applications. A warranty for the correctness and completeness of the obtained results and information can not be given. Principally, any liabilities are excluded that are referred to material or more imaginary damages caused by the use or disuse of the presented information or the use of incorrect and incomplete data.

Contents

1 Summary

What has been done?
Which water supply is affected?
Which pump is affected?
When has the fine check been made?
What is the result? (*Be brief!*)

2 Starting situation, task

What is the aim and what can be expected from this fine check?
Reason for conducting the fine check.
What will be done within the fine check?
What will be not done within the fine check?
Where have problems arisen?
How was the procedure?

3 Data basis

Which documents were available for the fine check?
Which documents were missing?

4 Schematic overview of the results

Summary of the most important results of the measurements.
Summary of the recommended economic energy-saving measures together with the potential for savings in kWh/a and CHF/a.

5 Measurement setup / measuring points / measurement parameters

5.1 Schematic illustration of the measurement object

Which pump is the measurement object?
Description of the inlet pressure with pressure losses -> inlet pressure at the pump
Description of the pump discharge -> discharge pressure at the pump
Geodetic pump heads

5.2 Measuring instruments being used

List of the measuring instruments being used, both fix (installed) and mobile. Indication of the respective measurement accuracy.

5.3 Defined measurement procedure for the „fine check"

At least:

- Measurement of the duty point (validation of rough check)
- Measurement of at least 3 duty points at differently closed insulating valve: Recording of the pump characteristic.
- Indication of the timing (new duty point, wait 5 minutes, measurement, …)

6 Measurement results in tabular form

6.1 Date, time and duration of the measurement process

List the date, time and duration of the measurement process. The measurement has to correspond to the normal operating conditions.

6.2 Hydraulical measurement data

Hydraulical measurement data of the pump:
Aim is the determination of the hydraulic power P_{hydr}

- Pressure measurement on the suction side
- Pressure measurement on the discharge side
- Stationary flowmetering (Inductive flowmeter)
- Mobile flowmetering (Ultrasonic flow measurement)

How and where are the respective measurement parameters collected?

6.3 Electrical measured data

Electrical measurement data of the motor:
Aim is the determination of the electrical power P_{elec}

- Phase voltages U
- Phase currents I
- Cos φ
- Insulating resistance of the windings

Caution: Blind current compensation and frequency converter! Soft starter?
How and where are the respective measurement parameters collected?

6.4 Mechanical measurements at the motor and pump

Mechanical measurement data:

- Frequency band recording of the body vibrations FFT
- Effective rated speed of the system
- Evaluation of cavitation at running pump
- Alignment of motor – pump
- Condition of anti-friction bearings
- Gaskets

How and where are the respective measurement parameters collected?

6.5 General optical condition

Description of the general optical condition: Running of pipes, high points, pipe cross sections, controls and instruments (age, maintenance), etc.

7 Interpretation of the measurement results

7.1 Results of the rough check

Repetition of the results of the rough check: Voltage, current, pump head, flow rate, total efficiency and potential for optimization (both energetically and moneywise).

7.2 Validation of the rough check results with data from own measurement

Make a pump rough check with own collected data. Are there differences compared to the rough check the water supply company has made? If yes, what are the reasons? Which conclusions are to draw?

7.3 Analysis of the current duty point

Compare the current duty point with the sizing point on the basis of the measurement.
Interpretation of the differences, finding of the reasons.

7.4 Calculated curve for the „mechanical power requirements of the pump"

On the basis of the collected data only the total efficiency of the motor-pump unit can be determined. To determine the power requirements of the pump a *calculation* or *estimation* of the mechanical power requirements is needed. This is determined by means of the measured data, the motor condition, the control components (soft starter, frequency converter, compensation, etc.), the age of the motor, etc. That makes it possible to compare the calculated power requirements with the original power requirements of the pump, so that a statement about the pump quality can be made. The same applies for the comparison of the current efficiency of the pump with the original efficiency of the pump. However, it has to be point out, that it is an estimation only.

7.5 Comparison of the Q/H curve „fine check" with the original curve

On the basis of the measured data the current pump curve is determined. Afterwards compare the current pump curve with the original pump curve. Interpretation of the differences, finding of the reasons.

7.6 Evaluation of the electrical measurement data

Evaluation of the points at 6.3:

7.7 Evaluation of the mechanical condition of pump and motor

Evaluation of the points at 6.4:

7.8 Evaluation of the general optical condition

Evaluation of the general optical condition (point 6.5): where is the potential for optimization?

7.9 Measurement accuracy or fault tolerance

Indication of the measurement accuracy of the various results.

8 Current operational concept

Description of the current operational concept.

- When and how are the pumps running? Parallel operation? Redundances?
- Maintenance interval? Repair costs? Emergencies?
- How much water is pumped per year? What is the energy consumption?
- Does the operation vary according to the season?

9 Possible measures for energy optimization

9.1 Energy-saving measures at pump/motor

Listing of the different economic energy-saving measures at the pump/motor.

9.2 Energy-saving measures by changing of operation

Listing of the different economic energy-saving measures by changing the operational concept.

9.3 Cost-benefit calculation of the different variants of energy optimization measures

Cost-benefit calculation of the mentioned energy-saving measures with evaluation and ranking.
The costs for the replacement pump and for the work to replace the pump have to be shown separately.
A combination of the different energy-saving measures is possible.

9.4 Recommendation for realization

Recommendation, which energy-saving measures should be implemented.

10 Appendix

10.1 Hydraulic scheme and planning documents from the water supply company

10.2 Documentation of the existing pump

10.3 Documentation of the existing motor

10.4 List of the measuring instruments

10.5 Test report of the collected data

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Analysis and procedure for the energetic optimisation of pumps in water supply applications

„Pump check“

Fine check – data to be collected

Fine check: data to be collected and measurements to be performed

1. The pump characteristic has to gather at not less than 3 points.
   Parameters to measure:

   - Q [l/min] / H [m]
   - Q [l/min] / P [kW], whereas the current, the voltage and cos phi have to be known or measured for calculating P

2. Measurement of Q via a magnetic flow meter. Check, if the magnetic flow meter is installed as specified by the manufacturer (calming section before and after the measurement).

3. Plausibility check of the value measured by the magnetic flow meter via a mobile ultrasonic flow measurement (a must, if a magnetic flow meter is not available)

4. Measurement of H [m] with a calibrated digital manometer (on suction and discharge side)

5. Measurement of current, voltage and cos phi at all 3 phases. It is necessary to measure cos phi!

6. Consideration of blind current compensation

   - controlled or uncontrolled
   - throttled and not throttled

7. Water level in the well / suction basin / ground water intake reservoir → inlet pressure

8. Water level in the reservoir, where the water is pumped to

9. Detailed calculation of losses as from pump axis to manometer considering the pipe diameter (Bernoulli speed square) according to ISO 9906.

10. Presence of a frequency converter and kind of frequency converter, if any

11. Consideration of all starting assistance (soft starter) → losses → waiting period until measurement

12. Consideration of a frequency converter → losses → waiting period until measurement

13. Evaluation of the isolating condition of the motor winding.

14. Vibration measurement at the pump itself or in case of submersible pumps at the standpipe via a FFT-(Fast-Fourier-Transformation) frequency band analysis.

15. Alignment of motor - pump.

16. Evaluation of cavitation at the running pump

17. Condition of anti-friction bearings

18. Condition of gaskets in the motor and pump (visual check, leakage)

19. System analysis: operating mode / management / control

Report

20. Evaluation of all values with tolerances and of the complete measurement in a clearly understandable and self-explanatory report (comparisons with original curve: measured curve or curve in data booklet)

21. Evaluation of the complete system: Evaluation of the former sizing and the calculated parameters (if any)

22. Searching the pump fitting best and checking against the existing pump

23. Efficiency proof of the pump replacement or the energetic improvement measures.

General

24. The measuring tolerances or accuracy should be recorded by the executive person.

25. The fine check report should refer to the rough check. What has be done compared to the rough check? What are the differences? What are the explanation for the differences? etc.