WHITE PAPER

PRÜFTECHNIK

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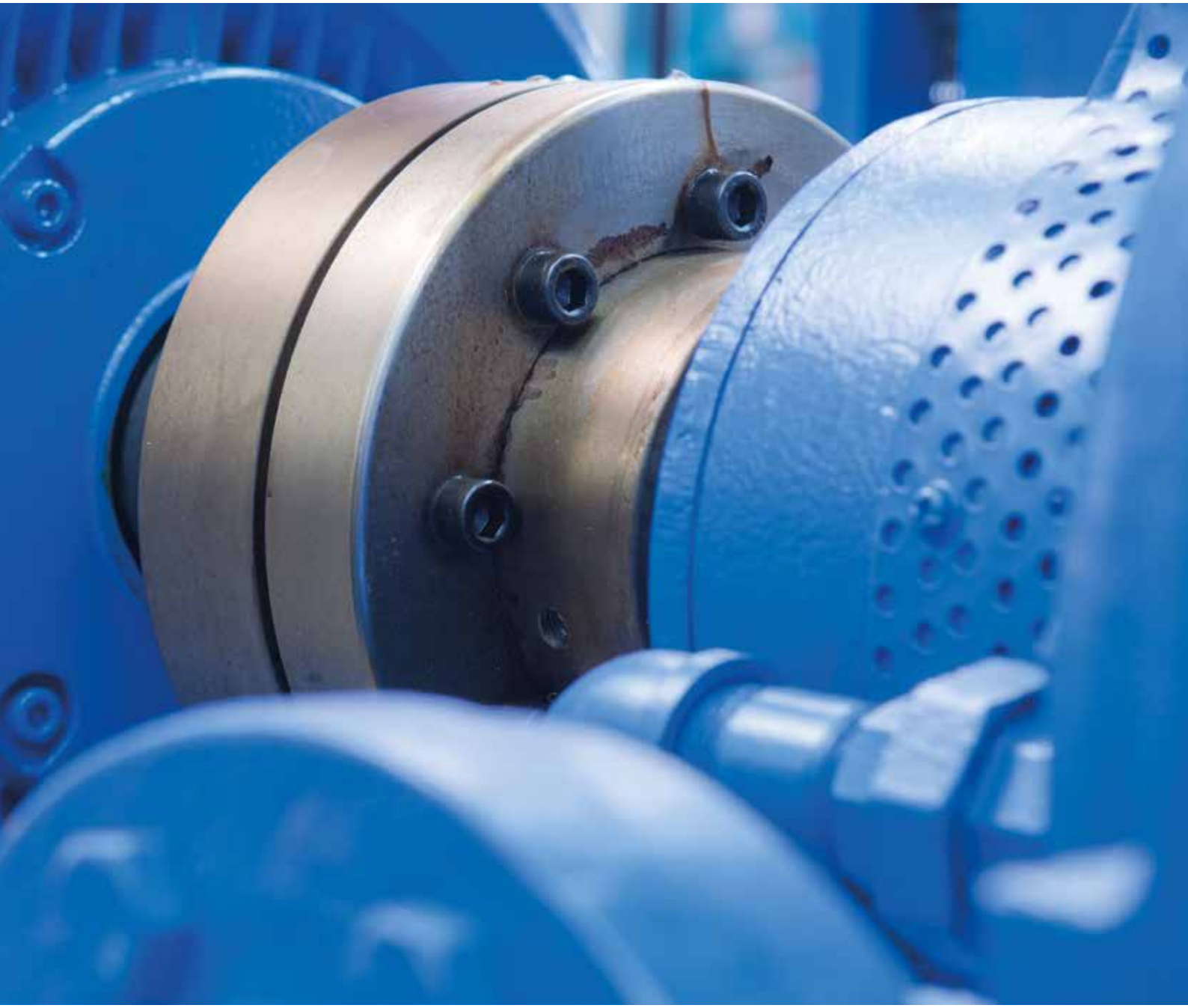
WASTED ENERGY MEANS WASTED DOLLARS

HOW PRECISION ALIGNMENT BRINGS DOWN ENERGY COSTS



HOW PRECISION ALIGNMENT BRINGS DOWN ENERGY COSTS

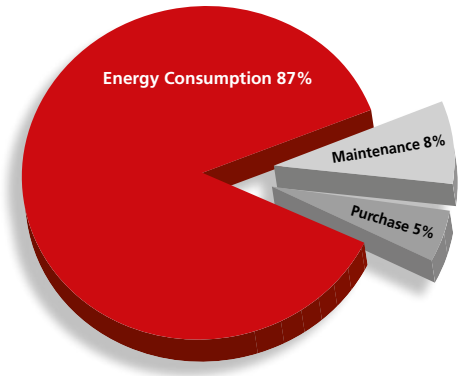
Electrical energy represents a substantial portion of industrial operating expenses. It is an unavoidable cost of doing business that all too often seems resistant to control or moderation. However, PRUFTECHNIK, the inventor of laser shaft alignment, provides a solution. Drawing on over 40 years of experience in industrial alignment, PRUFTECHNIK demonstrates how precision alignment brings down energy costs.
The idea is simple. Reduced energy consumption means reduced energy costs. Because precision alignment saves energy, it saves money. Understanding what we mean by precision alignment and why precision is important reveals the reasons why.

Wasted Energy Means Wasted Dollars

Energy costs can represent a major part of the expenses associated with manufacturing equipment. With heavy machinery, energy costs often dwarf purchase price and maintenance charges.

In fact, energy consumption may approach 90% of the lifetime cost of owning and operating in-line equipment.

Thus, reducing energy consumption leaps to the forefront of any effort to reduce costs in industrial operations.



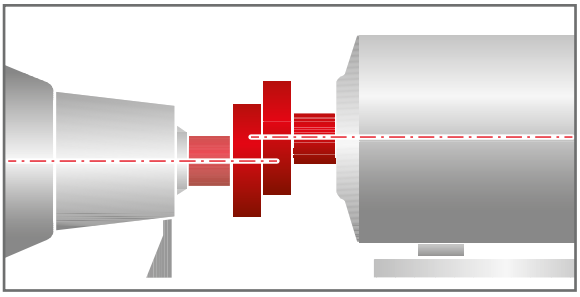
Electrical energy consumption accounts for the vast majority of the cost of a pump over its service life.

Costs of owning and operating industrial equipment

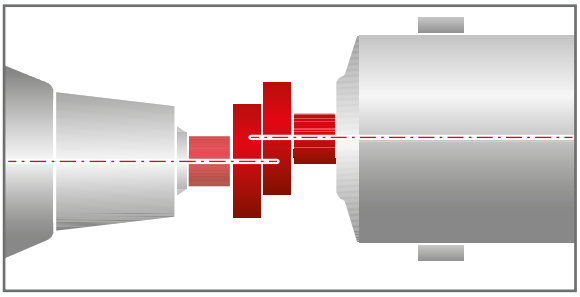
The savings that can accrue from precision alignment are often overlooked. While energy represents hundreds of thousands of dollars of operating expenses, a significant portion of that expenditure is pure waste. Misalignment of coupled machines squanders valuable energy dollars. Precision alignment of machine shafts have been demonstrated to cut energy costs by as much as 10%. Moreover, correctable misalignment conditions also shorten the service life of machines, increase machine failure, cause work stoppages and plant slowdowns, and reduce product quality. Misalignment is expensive and unnecessary. Precision alignment of coupled machines increases the mean time between failures and dramatically reduces energy consumption. A precision laser alignment program can save thousands of dollars over the life of a single machine.

What Do We Mean by Precision Alignment?

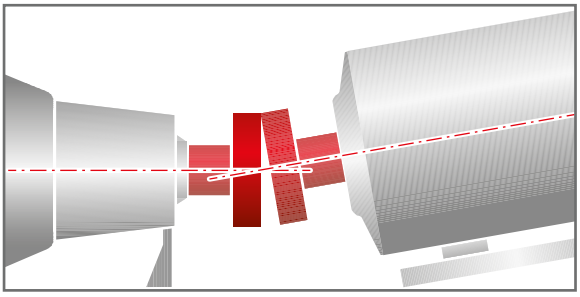
"Alignment" describes the positioning of two or more machines so that they can effectively transfer power from one to another. With rotating equipment, such as a motor and pump combination for example, machines are set up so that their shafts are collinear. In other words, they are positioned such that during operation their axes of rotation turn precisely together along a single unified line. Accurate positioning is important because the more precisely the machines are aligned, the more efficiently the rotational power is transferred.



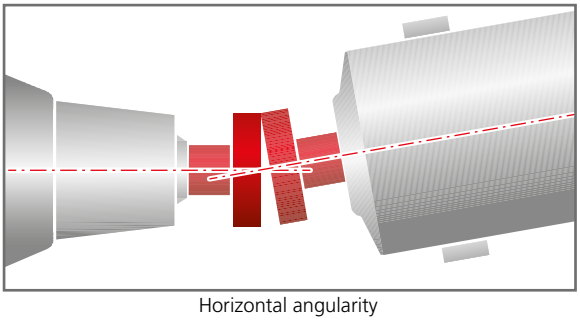
Vertical offset



Horizontal offset



Vertical angularity



Horizontal angularity

Alignment is defined by two important conditions: gap, also known as angularity, and offset. These conditions describe the relationship between the center axes of machine shafts when machines are coupled together. Misalignment occurs when the coupled shafts are positioned so that their gaps or offsets are outside acceptable limits.

Proper alignment requires an understanding of more than just the static positioning of machines. A number of factors influence alignment and create differences between a machine that is running and a machine that is at rest or "cold".
Important factors to consider include:

- catenary bows (normal sagging due to the weight of the shafts)
- operational conditions such as the thermal expansion of machines as they run
- the influence of torque
- the stability of machine feet
- the pressure of attached piping or other equipment
- play or looseness in the bearings
- operational RPMs (revolutions per minute)

All must be accounted for, and alignment must be adjusted accordingly. As a result, the operational or "live" alignment values of a machine under normal operating conditions may be different from those of a static or cold one.

Precision alignment means reducing the measured gaps and offsets to within limits that provide for the most efficient power transfer from shaft to shaft when a machine is operating.

Precision alignment will reduce shaft loads and destructive vibrations, limit overheating, slow wear on bearings, seals, and shafts, reduce breakdowns and unscheduled maintenance, improve product quality, and significantly save energy.

Why Is Precision Important?

A variety of factors combine to determine acceptable tolerances for shaft alignment. The style of coupling used, the equipment power rating, the expected revolutions per minute, the length of any spacer couplings, and the service life of the machines all influence the limits that define appropriate alignment. Frequently the difference between acceptable and out of tolerance alignment is a matter of 100ths of a millimeter. The difference between 0.05 and 0.06 millimeters may not sound big, but these seemingly small misalignment values have an outsized impact on the efficient and energy saving operation of a machine.
Despite its importance, however, misalignment of coupled machines is common. Studies show that more than 90% of industrial equipment is misaligned. One survey by a leading rotating equipment service organization revealed that the vast majority of industrial machines are operating outside of appropriate alignment tolerances. Of 160 coupled machines running at 3600 rpm and randomly chosen for testing, only 7% were aligned within generally accepted industry limits.

Offset (mm)	Machines measured (%)	
0.00 - 0.05	7%	Acceptable alignment
0.06 - 0.10	10%	out of tolerance
0.11 - 0.20	23%	
0.21 - 0.50	31%	
0.51 - 1.00	18%	
>1.00	11%	

Statistics courtesy of a major UK chemical company

There are a number of reasons why coupled machines might be misaligned. Before PRUFTECHNIK introduced its innovative precision laser alignment systems, machine alignment could be haphazard at best. Historically machines were often aligned by eye or by resting a straightedge along the top of the couplings. This kind of coupling alignment was inadequate because it did not measure alignment at the point of power transfer on the shafts but instead at the couplings which were often only roughly machined. Sometimes alignment was attempted using a Vernier or feeler gauge, but again, this method would align only the couplings and not the rotating shafts. Precision alignment cannot be achieved this way. Moreover, these methods rely on the powers of the human eye. As wonderful as they are, human eyes simply do not possess the resolution necessary for precision alignment of modern machinery with their narrow alignment tolerances.

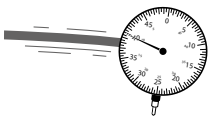
Common attempts at more accurate alignment often produce poor results. Devices such as dial gauges are sometimes employed by in-house maintenance managers to try to achieve better alignment. However, using dial indicators requires complicated calculations and careful, highly experienced users. They demand painstaking, cumbersome, and lengthy set up, meticulous checking and re-checking of mechanical linkages, positioning, perpendicularity, and squareness, work that can all too easily be overwhelmed and wasted by a sticking dial hand or too low resolution. Competent use of these kind of meters is easily disrupted by human factors. Simple reading errors or the smallest imprecision in set up or adjustment can make obtaining accurate results impossible.

Advances in alignment technology now eliminate the errors inherent in old-fashioned dial indicators. Laser systems for precision shaft alignment produce error-free and accurate measurements with a resolution as fine as one micron (0.00004 inches).

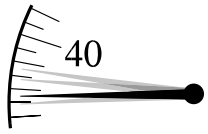
Readings can be taken at any desired position while eliminating

problems from sagging brackets, tilted axles, loose linkages, and human errors. With laser alignment, there is no need to disassemble couplings or to take readings at fixed, predetermined locations. Laser results are easily repeatable and measure alignment both horizontally and vertically in one shot. Moreover, lasers can be used to evaluate alignment while a machine is actually running! Live evaluation means that true operating conditions can be precisely and accurately measured and adjusted.

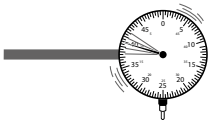
How accurate are dial indicator readings?



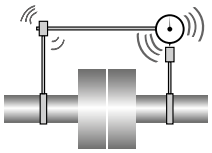
Sagging indicator brackets
Sag should always be measured before actual alignment readings are taken irrespective of how solid the bracket appears.



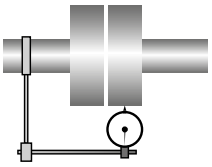
Low resolution
Up to 0.005 mm rounding error may occur with each reading – which easily results in an error of up to 0.04 mm in the calculated results.



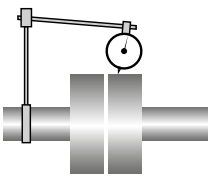
Sticking/jumping dial hands
Sometimes the indicator must be tapped in order for the needle to settle on its final value.



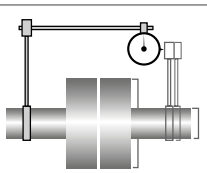
Play in mechanical linkages
Slight amounts of looseness may not be noticed, yet produce large errors in results.



Reading errors
Human errors occur all too often when dials must be read under cramped, poorly-lit conditions and severe time constraints.

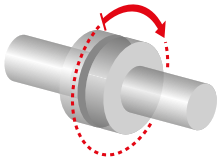


Tilted dial indicator
The indicator may not be mounted perpendicular to the measurement surface so that part of the displacement reading is lost.

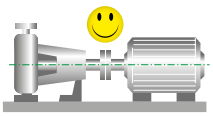


Axial shaft play
This can affect face readings taken to measure angularity unless two axially mounted indicators are used.

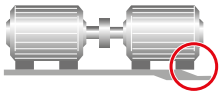
Benefits of precision laser alignment systems



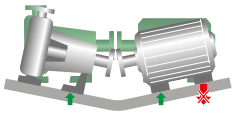
Continuous SWEEP mode
Measurement data is automatically and continuously collected from any start position as the shafts are rotated capturing a large number of measurement points to accurately determine the alignment condition.



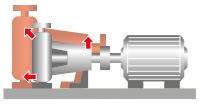
Tolerances (TolChek®)
Avoid unnecessary moves by automatically evaluating alignment condition with respect to tolerances using the "smiley" which is also active during live machine correction.



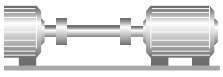
Soft foot
For good alignment, soft foot must be eliminated. The machine feet should rest properly on the foundation. Soft foot is measured, corrected and documented.



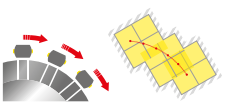
Base-bound or bolt-bound
Problems arising from base-bound or bolt-bound feet are resolved by redefining fixed/movable feet.



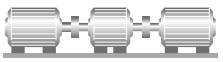
Thermal growth and target specifications
The specifications can be input to take into account the expected positional change of the machine during operation.



Choose coupling type
Short flex, single plane, cardan or spacer couplings can be selected to apply the correct tolerance and display criteria for your machines.



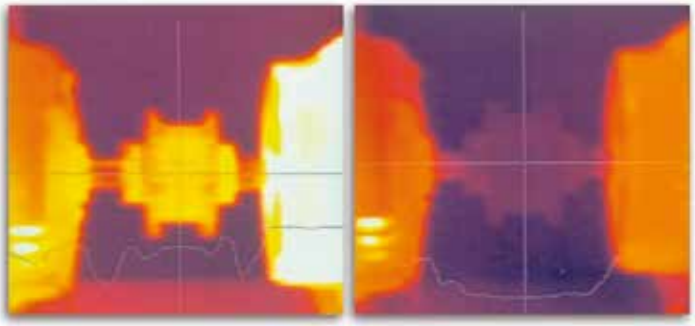
InfiniRange®
The measurement range of the detector can be infinitely extended to accommodate gross misalignment. This is ideal to perform and document initial rough alignment and easily handle long spans across spacer shafts.



Machine train alignment
Measure and display the entire alignment condition of machine train; allowing the user to make the optimal machine adjustment.

Warning Signs of Misalignment

It's not always easy to detect misalignment on machines in operation. One good investigative option is to employ equipment analysis that measures vibration or temperature increase. Vibration monitoring or thermography can help reveal a misalignment condition before wear or damage occurs.



Thermography showing coupling overheating (left)

Without advanced technical instrumentation, there are signals that indicate an immediate and urgent need for precision laser alignment of equipment. Such signals include:

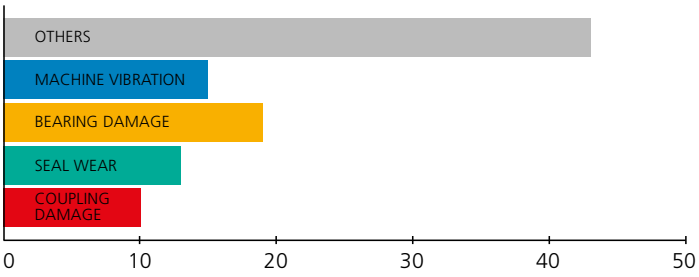
- Excessive vibration
- Increased temperature, especially at critical junctions
- Loose or broken coupling bolts
- Loose shim packs or dowel pins
- Excessive oil leakage at bearing seals
- Excessive wear or coupling failures
- Broken shafts or cracking close to bearings or coupling hubs
- Designed coupling indicators such as the formation of rubber powder inside coupling shrouds
- Shortened machine life

Observation of any of these conditions means that the affected machines are not operating as effectively or efficiently as possible and that an alignment service check is overdue.

Hidden Costs of Misalignment

Energy expenses may be one of the most significant and yet overlooked costs of misalignment.

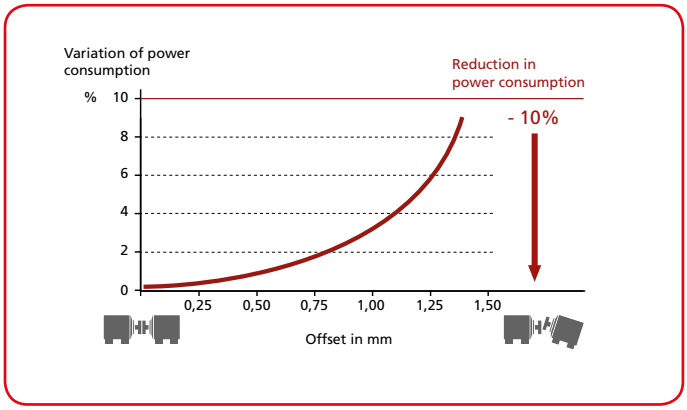
Misalignment is expensive. In fact, misalignment can cost millions. Evidence suggests that more than 50% of machine breakdowns can be directly attributed to misalignment. Excessive vibrations, worn or damaged bearings, leaky or cracked seals, damage to couplings or shafts, increased bearing loads, all attributable to misalignment, lead to unscheduled work stoppages, delays, and lost production. They waste machine time, man-hours, and money. They shorten machine life and reduce quality. And, they waste energy. Energy expenses may be one of the most significant and yet overlooked costs of misalignment.



Most common effects of misalignment

Precision Alignment Saves Energy

Shaft misalignment has a startlingly large impact on energy consumption. Independent studies have demonstrated that misalignment may significantly increase energy usage and cost.



Power consumption in relation to offset. Courtesy of ® ICI PLC

In one academic study conducted over a six week period of normal operation, researchers evaluated the influence of alignment on electrical energy consumption at a chemical processing plant. At the start of the study, they precisely aligned, carefully balanced, and refitted the test machines with new bearings. Controlling for coupling style, the researchers adjusted the alignment of the tested machines at set intervals. Misalignment was gradually increased, and the resulting impact on power usage was recorded. In order to simulate normal operating conditions, the study monitored the amount of power drawn over multiple days for each setting. The results of this study demonstrated that within normal operating parameters energy consumption increased directly with the degree of machine alignment. The researchers found that using a laser alignment system to align machines within precise tolerances across the plant would reduce energy consumption by as much as 10% and, evaluated conservatively, save more than $100,000 per year.

To calculate energy savings from precision alignment, there are a number of factors to consider. The degree of initial misalignment, the number and wattage of the aligned machines, the relevant number of operating hours per year, the type of coupling involved, and the cost of power all impact power usage. For example, studies show that a single circulating pump with a 75 kW motor running at 3000 RPMs and operating with a typical offset misalignment of 0.75mm will use 1.68% more power than the same pump that is precisely aligned to within 0.05 mm.
That is, the misaligned pump is using much more power than it should. Factoring in the cost of that wasted power, we can calculate the savings. Energy prices vary widely, but using a mid-level global price of about $0.16 per kW, we see that precision alignment of that single pump could lead to an immediate savings of almost $ 1,700 dollars per year. Aligning multiple or larger machines translates to a corresponding and substantial reduction in operating costs.

To explore power savings of different combinationsof various sized machines and electrical usage rates, a useful online calculator can be found at: **http://www.pruftechnik.com/roi_us**.

A Precision Alignment Program: Return on Investment

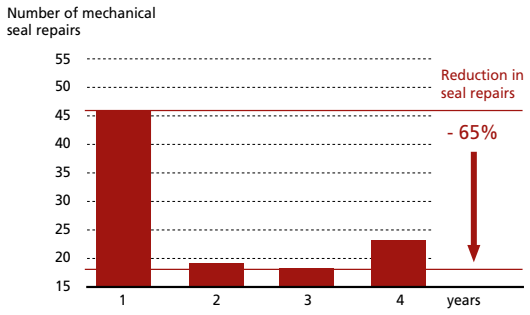
With precision laser alignment, savings will begin to accrue whenever an alignment program begins, whether at initial commissioning of equipment or after machines are already in service. Program expenses can be recouped very quickly. For example, measured solely against operating costs, an alignment program that includes just five 200 kW machines could cover the expense of introducing precision alignment in as little as one year.

Alignment programs benefit from economies of scale; the greater the number of machines aligned, the more quickly the purchase cost of alignment equipment will be recouped.

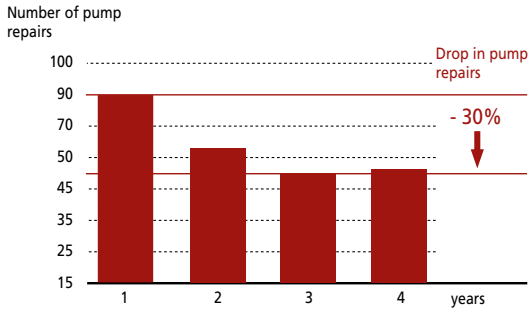
In industries where rotating machines make up a large proportion of the operating equipment, program costs are recouped almost immediately.

Moreover, precision alignment offers benefits in addition to the immediate energy savings. Implementation of a regular precision alignment program means that repairs on mechanical seals will decline by up to 65%; pump repairs can drop by 30%; and the expected service life of bearings may increase by as much as 50%.

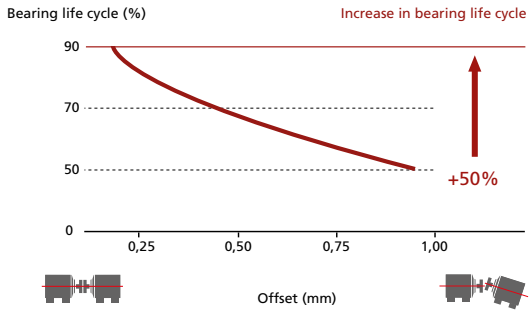
When savings on maintenance costs like these are included in the calculation, a precision alignment program can achieve returns on the investment almost immediately.
The guaranteed benefits of precision alignment make establishment of a laser alignment program essential; the innovative laser technologies developed by PRUFTECHNIK make it possible. PRUFTECHNIK laser alignment and condition monitoring instruments are designed to be user-friendly and intuitive. Sag-free brackets are available for any type of shaft or coupling, and they set up quickly, even in tight or hard to reach spaces. Simple on-screen wizards make it easy to enter the required machine data. PRUFTECHNIK's precision laser system can check alignment while machines are in operation and over time to reveal the true align



Courtesy of HEOCHST AG Gendorf, Germany



Courtesy of HEOCHST AG Gendorf, Germany



Courtesy of University of Tennessee

Establishing an Alignment Maintenance Program is Key

ment condition of a "live" machine. Alignment software allows to present alignment data graphically in the form of a trend line or chart in order to monitor the alignment condition over time and help detect underlying machinery issues. With a resolution of 1 micron (0.00004 inches), accurate alignment values and tolerance checks guarantee precise, money saving results. Reports that conform to ISO requirements are generated directly from alignment instruments and can be sent wirelessly to anywhere in the world.

When faced with spiraling energy costs, precision alignment can be an easy way to fight back. For companies that use rotating equipment, a plant-wide alignment program can save millions of kilowatts and tens, or even hundreds of thousands of dollars in energy costs. The added benefits of machine reliability and production improvement make a precision alignment program a cost-saving essential. PRUFTECHNIK precision alignment systems and expert alignment engineers provide the products, services, and support that deliver precision alignment solutions worldwide.

PRÜFTECHNIK
PROVEN QUALITY
- Made in Germany
- Global Presence
- Qualified Support
- Quality Service

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