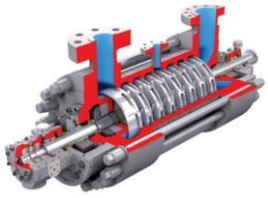
Usage of Epoxy Grout for Long Term Reliability of Pumps

Christopher Matthews-Ewald
Industrial Applications Engineer
ITW Performance Polymers
CHINOOK Industrial Ltd.



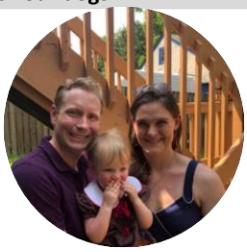
CPS CALGARY PUMP SYMPOSIUM

CALGARY PUMP SYMPOSIUM 2019 1

Presenters

Christopher Matthews-Ewald

- **Industrial Applications Engineer**
- **Primary support for Industrial Applications, US Military marine and marine training for Western Hemisphere**
- **B.S. in Civil & Environmental Engineering from Georgia Institute of Technology**
- **Spare Time – Spending time with family, reading, playing with our dogs**



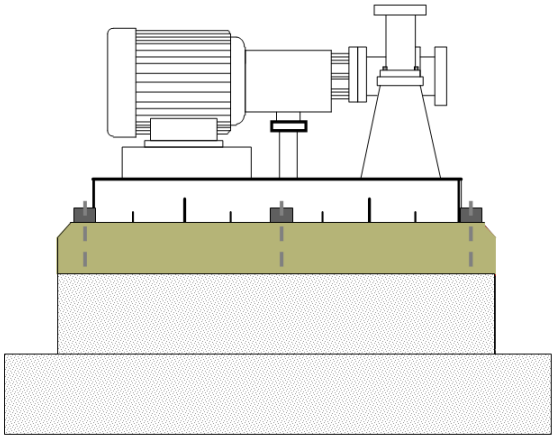
CALGARY PUMP SYMPOSIUM

www.calgarypumpsymposium.ca September 26-27, 2019

Presentation Agenda

- Goals for Achieving Pump Reliability
- The Equipment System
- Foundation Design for Pump Dependability
- Threats to Pump Performance
- Case Study

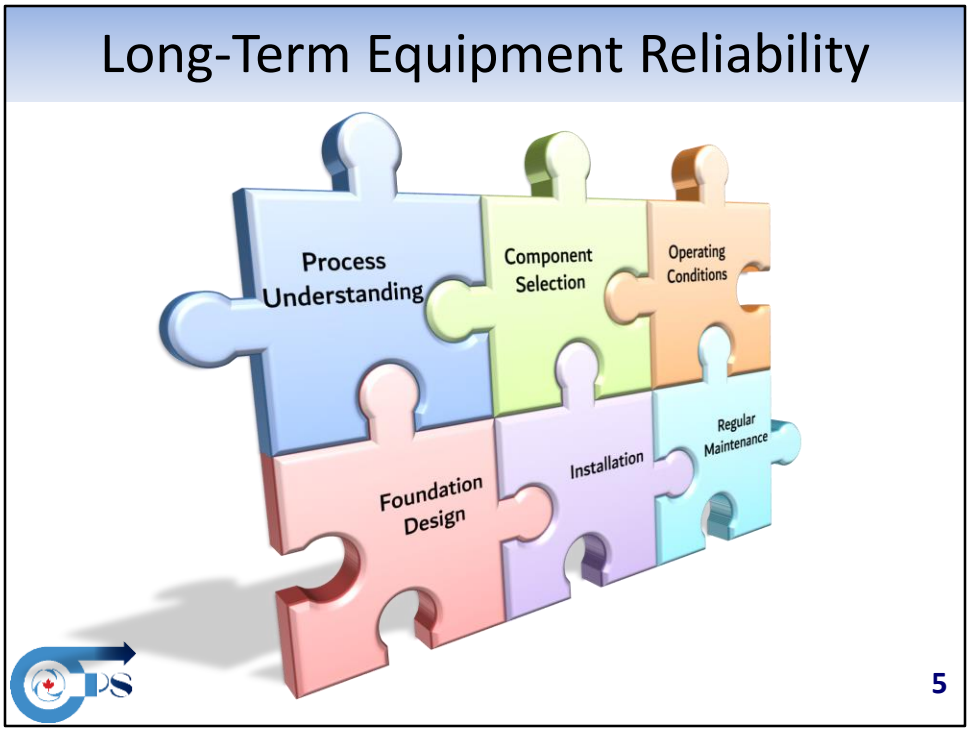
Why are we here?



4

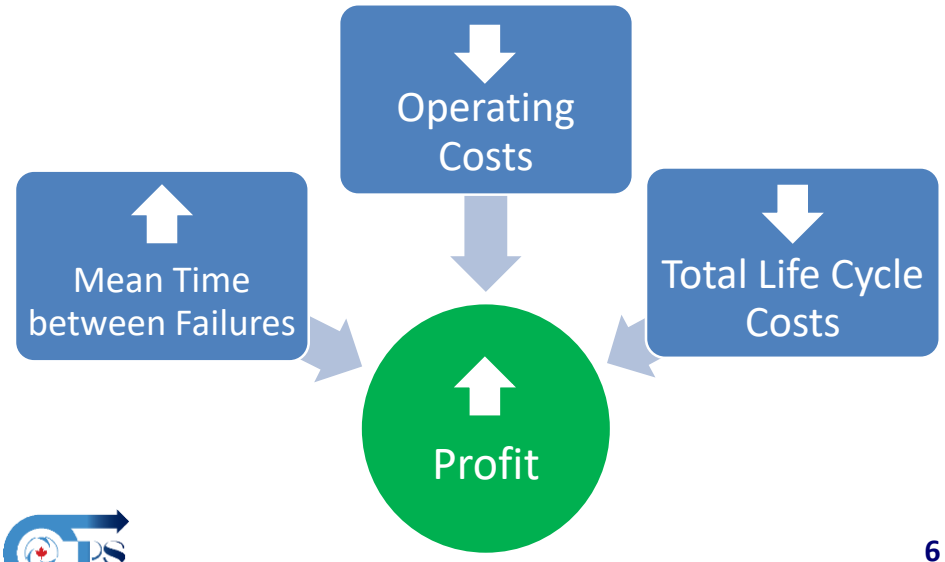
What are the goals with operating pumps/equipment?

- Efficiency
- Keep them running with as little cost and effort as possible
- Ideal world – Perfectly operating equipment with no associated operating costs and no risk of downtime

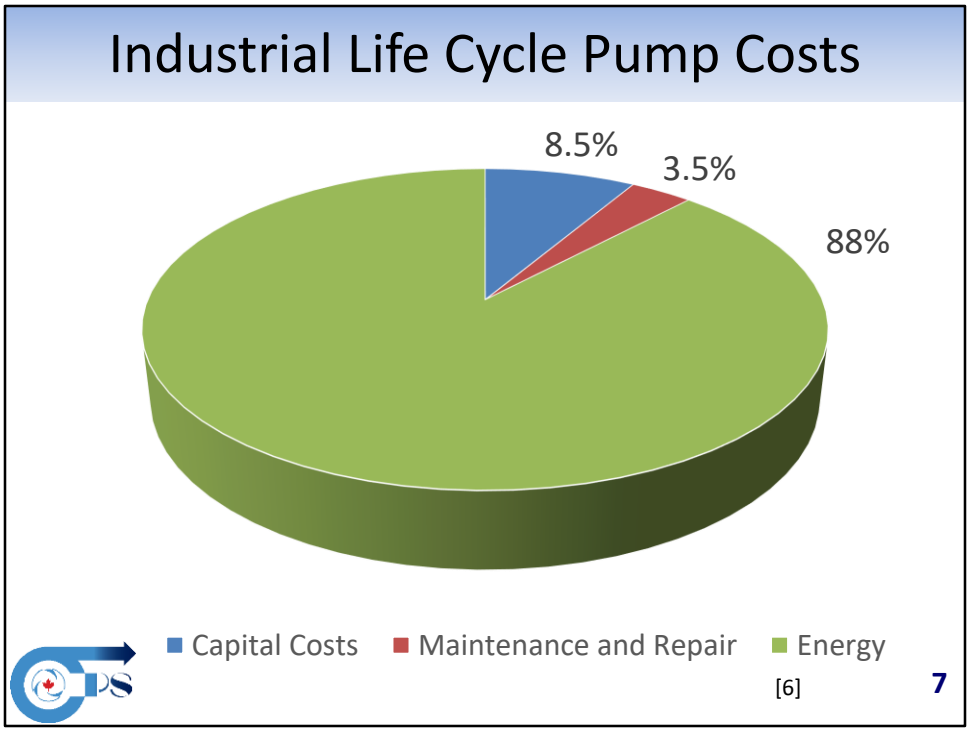


- Process Understanding
- Best-in-class Component Selection
- Understanding Operating Conditions
- Effective Foundation Design
- Best Installation Practices
- Regular Maintenance

Goals for Achieving Pump Reliability



6



- Capital Costs (installed, all inclusive)
- Maintenance and Repair, including parts and labor
- Energy (electricity at 6¢/kWh)

Power consumption can be reduced 3 ways

1. Reduce flow through the pump
2. Reduce pressure drop in the piping system
3. Increase the efficiency of the pumping system

Table 2. These five causes account for 40% of wasted energy in pumping.

1.	Low efficiency due to wrong pump choice	4%
2.	Poor installation or maintenance	3%
3.	Low pump efficiency due to wear	3%
4.	Poor system design (piping, valves, etc.)	10%
5.	Poor system control strategy	20%
		40%

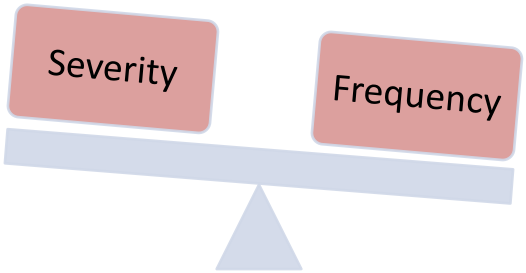
"It is significant that only 6% of energy losses are caused by operational issues, while 34% are built in at the design stage — that is, they are attributable to decisions made during design and the increasingly common practice of fast-tracking this critical step."[9]

[10]

- *“Pumping systems account for nearly 20% of the world’s electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations”*
- *“Some studies have shown that 30% to 50% of the energy consumed by pump systems could be saved through equipment or control system changes.”*

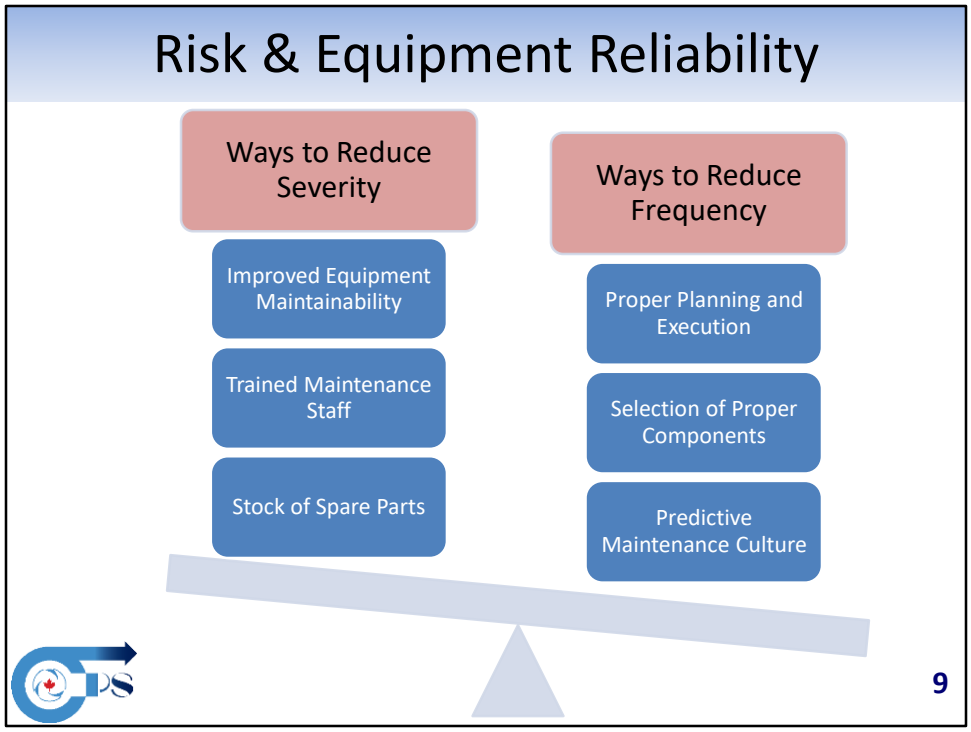
Risk & Equipment Reliability

- Risk ($/yr) = Consequence of Occurrence ($) x Frequency of Occurrence (/yr)[9]
  - Where Frequency of Occurrence = [Frequency of Event x Probability of Failure]



8

[9] Main takeaway is that there are two primary components to reducing operational risk – to reduce the severity of an occurrence and to reduce the likelihood of an occurrence.



- While both are important, reducing likelihood provides greater cost savings, and resulting greater profitability
    - Due to fewer failures that require a stop in production

[9]

While both aspects are important, a focus on reducing the likelihood of occurrence results in greater cost savings and profitability, since less failures occur that necessitate potential stops in production.

> *"Over the same period there is less profit lost with chance-reduction strategies than consequence-reduction strategies. Fewer failure incidents occur because chance reduction stops opportunities developing. Add-up the savings from failure costs not spent and you get a very profitable operation. The lower cost strategy is clear: chance reduction delivers less failures because fewer defects are present to rob resources and waste money."*

Ways to minimize severity

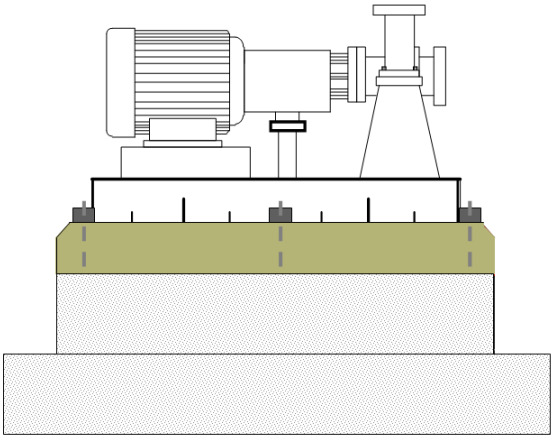
- Maintaining stock of spare parts
- Training maintenance staff to quickly respond when failures occur
- Improving equipment maintainability to allow quicker repairs

Ways to Reduce Likelihood

- Predictive and Regular Maintenance

- Selection of equipment and system components to match operational requirements
- Proper planning and execution

The Equipment System



10

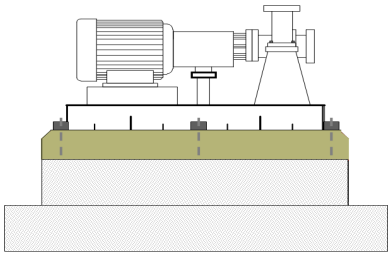
For achieving the reliability goals of increased asset efficiency and reduced associated costs, which directly lead to greater profitability, it is imperative to

- Fully understand the potential operating environment
- Select best-of-class components to match
- Dedicate time and resources to creating detailed specification and installation procedures according to industry accepted best practices and guidance.

For proper consideration, understand the relationship between components and their interconnectivity. With this, we will focus on the overall equipment system and the contributions to reliability.

The Equipment System

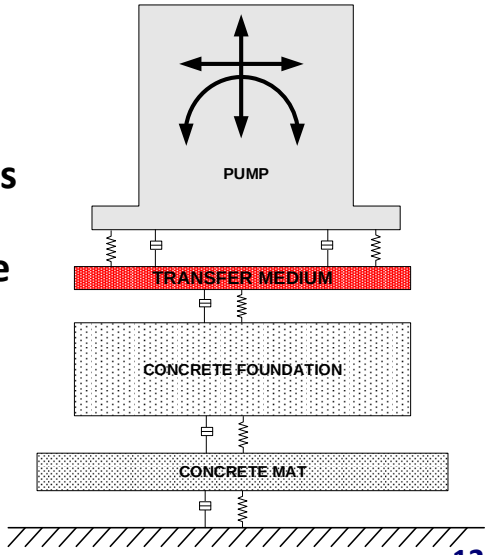
Pump
Baseplate
Transfer Medium
Anchor Bolts/Leveling Devices
Concrete Foundation
Sub-surface/Soil



An Equipment System is more than individual components placed together.

The Equipment System

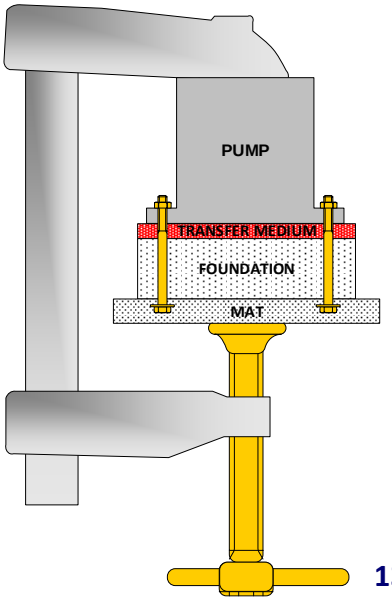
An Equipment System is a series of interacting components that move and vibrate together.



12

The Equipment System

An Equipment System is a series of interacting components that move and vibrate together.

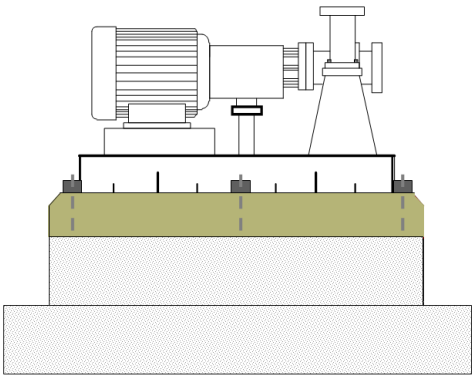


13

- Envision a vise holding all of the components together and in compression.
- Eliminates breaks between the components, creating connectivity.
- The system acts as a single entity- what we refer to as a monolithic foundation system.

Foundation Design for Pump Dependability

- Keep equipment in position
- Mitigate forces due to equipment operation
- Preserve foundation mass



14

Looking back at the main ways to increase pump reliability and overall profitability…

- Increase Mean Time Between Failures
- Decrease Overall Operating Costs
- Decrease Total Life Cycle Costs

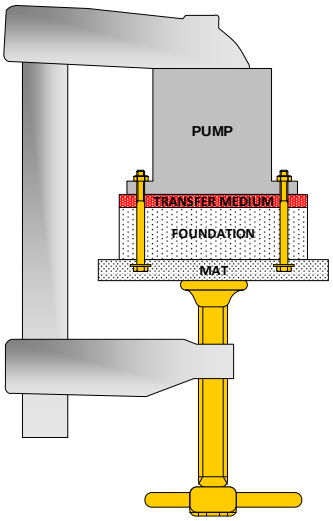
To be effective, a foundation design must accomplish the following functions to effectively meet the reliability goals.

- Keep equipment in position
- Mitigate forces due to equipment operation
- Preserve foundation mass

Foundation Design for Pump Dependability

What is the role of an effective transfer medium in pump foundations?

1. Maintain precise alignment
2. Effectively transfer vibrations and unbalanced loads
3. Protection of foundation



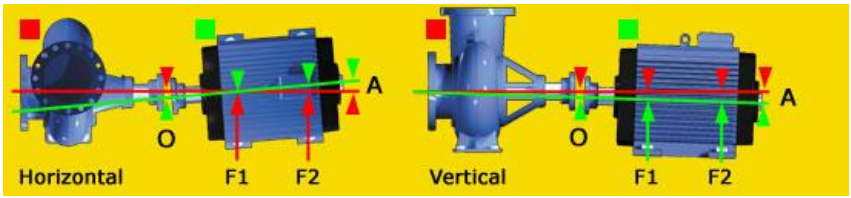
15

1. Maintain precise alignment throughout the lifetime of the equipment
2. Effectively transfer vibrations and unbalanced loads generated during equipment operation
3. Protection of foundation

Role of Precise Alignment

Why precise alignment is important

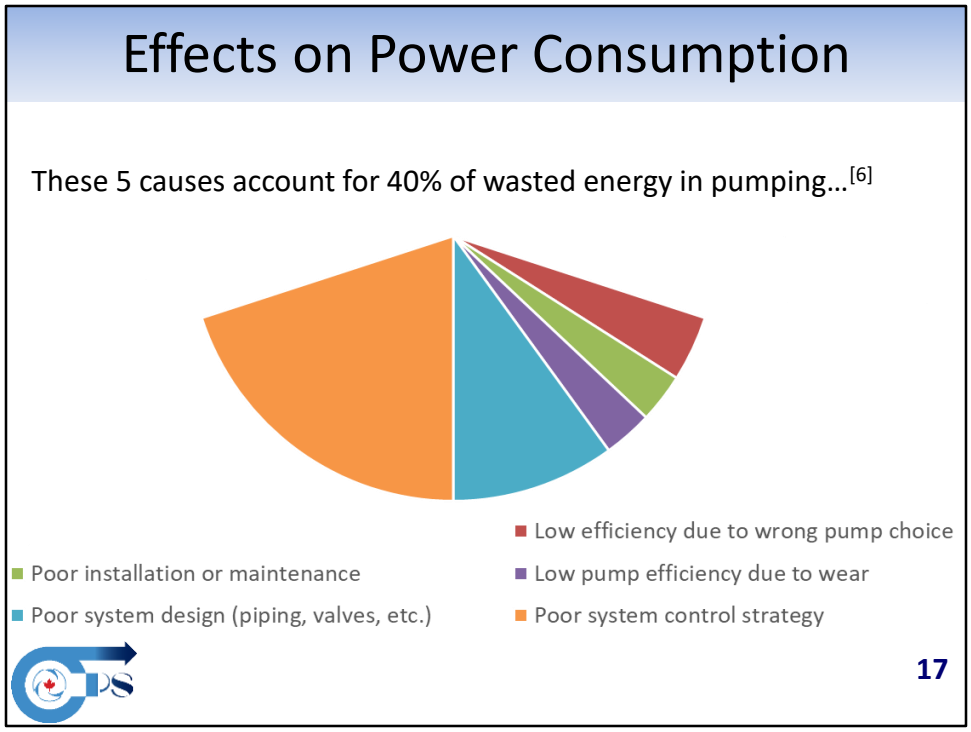
1. Decreased shaft deflection
2. Increased operating efficiency
3. Decreased operating costs



16

- Note, transfer mediums only lock-in the alignment established during the installation process. If the alignment is incorrect at this point, significant intervention may be necessary to correct. This is why proper planning and execution is key to pump dependability.
- When proper components are selected and installed according to best practices, transfer medium will last longer than the equipment they support.
- Role of Precise Alignment in Meeting the Overall Reliability Goals

1. Decreased shaft deflection
    - 25% increase in bearing load leads to 50% reduction in rated bearing life [2]
2. Increased operating efficiency
3. Decreased operating costs



Studies have shown that as much as 30-50% of the energy consumed by pump systems could be saved through equipment or control system changes."

Table 2. These five causes account for 40% of wasted energy in pumping.

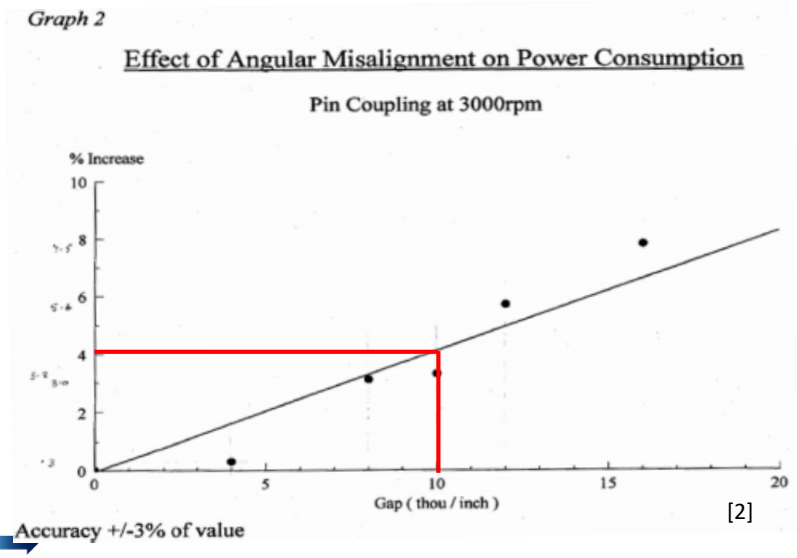
1.	Low efficiency due to wrong pump choice	4%
2.	Poor installation or maintenance	3%
3.	Low pump efficiency due to wear	3%
4.	Poor system design (piping, valves, etc.)	10%
5.	Poor system control strategy	20%

"It is significant that only 6% of energy losses are caused by operational issues, while 34% are built in at the design stage — that is, they are attributable to decisions made during design and the increasingly common practice of fast-tracking this critical step."[9]

[10]

- *"Pumping systems account for nearly 20% of the world's electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations"*
- *"Some studies have shown that 30% to 50% of the energy consumed by pump systems could be saved through equipment or control system changes."*

Effects of Alignment on Power Consumption



[2]

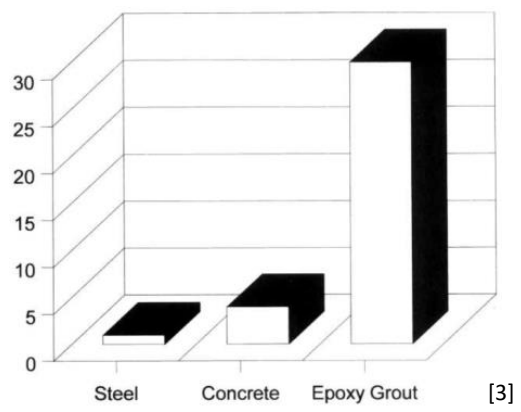
18

- This graph is from work published by Heinz Bloch.
- An angular misalignment of just 10 thou/in at the pin coupling leads to a 4% increase in overall power consumption.
- When considering that power consumption accounts for nearly 90% of the Total Life Cycle Costs, this shows the profound impact that alignment has on the

[2] *"The resulting recommendations were to align machinery to within 0.005 inch/0.12 mm shaft offsets and to limit deviations in hub gap to 0.0005 inches/inch of hub diameter. Lambley further documented that adhering to these recommendations would reduce ICI's power consumption by about 1%. "*

Benefits of Vibration Damping [1]

- Decreased wear on seals and bearings
- Increased operating efficiency



[3]

19

- Failures attributed to bearings and seals are among the greatest threats to achieving pump reliability.
- Concrete, and similarly cementious grout, has about 3-5 times the vibration absorption capacity as steel.
- Low Modulus epoxy grouts have nearly 30 times the vibration absorption capacity as steel, and 6-10 times the capacity of cement based products.

- A foundation is an engineered mass.
- The goal of all foundation design is to install it such that the natural frequency of the machine is reduced as much as possible. Since high frequency vibrations cause greater wear to bearings and seals. Moving the frequency of vibration from high to low reduces these problem. In fact, the goal is typically make the natural frequency of the machine as low as possible, typically by increasing the mass.

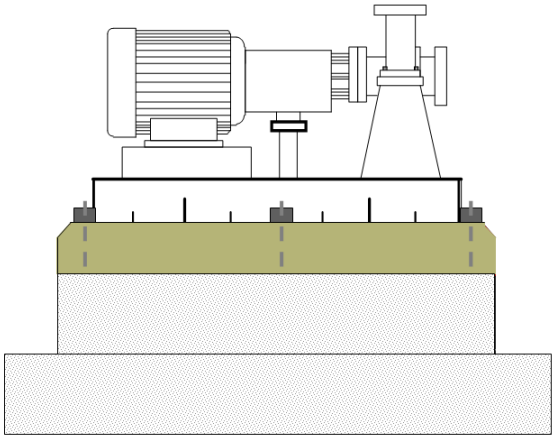
Common Sources of Damage to Foundations

1. High vibrations from dynamic equipment
2. Impact
3. Freeze/thaw
4. Chemical attack

21

- As a whole, oil and water cause greatest amount of damage to foundations.

The Equipment System



22

With understanding the vital role that transfer mediums play in a foundation system, it is imperative to select best-of-class components that best fulfill the requirements of an effective design.

1. Maintain precise alignment throughout the lifetime of the equipment
2. Effectively transfer vibrations and unbalanced loads generated during equipment operation
3. Protection of foundation

Role of Specific Transfer Mediums

Concrete	Large Masses, General civil/construction installations
Cementious Grout	Static or low dynamic loaded equipment needing alignment
Epoxy Grout	Dynamic equipment requiring high loading resistance, high chemical resistance and precise alignment

Characteristics of Transfer Mediums

	Concrete	Cementious Grout	Epoxy Grout
Composed of…	Cement, water, aggregate	Cement-aggregate blend and water	Resin, hardener and bags of aggregate
Consistency	Water-dependent	Water-dependent	Lumpy Oatmeal
Flowability	Water-dependent	Water-dependent	Fair to Poor
Working Time	2 to 3 hours	1 to 1.5 hours	1 to 4 hours
Initial Cure Time	28 days	7-21 days	18 - 72 hours
Cost	$	$$	$$$

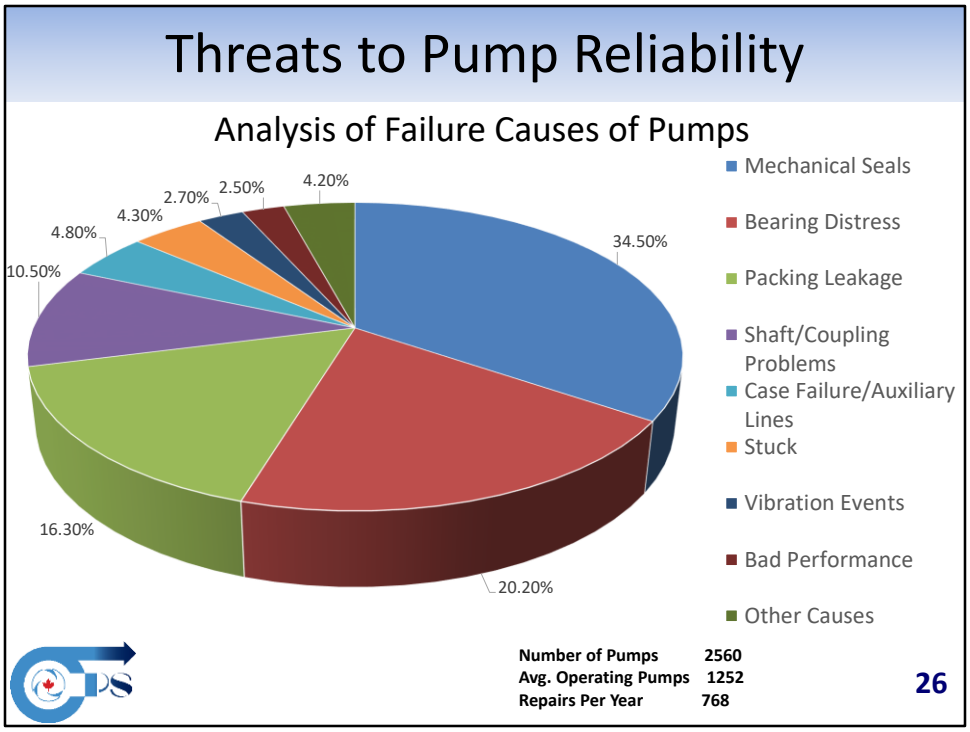
24

Properties of Transfer Mediums

	Concrete	Cementious Grout	Epoxy Grout
Compressive Strength	3000 – 5000 psi *20 - 35 MPa*	3500 – 9000 psi *25 - 60 MPa*	11,500 – 18,000 psi *80 - 125 MPa*
Tensile Strength	200 – 600 psi *1.5 – 4.0 MPa*	350 - 1200 psi *2.5 – 8.3 MPa*	1500 – 3000 psi *10 - 20 MPa*
Shrinkage	Water-dependent	Water-dependent	0.04%
Vibration Damping	Very Little	Little	High
Adhesive Bond	Very Low	Low	Very High
Typical Installation Life	5-10 years	10-15 years	>30 years

25

- Epoxy grouts have 6-10 times the vibration absorption capacity as concrete and cementious grout.
- Epoxy grouts create nearly 20 times the adhesive bond as cement based technology.



[1] *"About 7% of pump population consumes 60% of the money spent on pump maintenance and repair."*

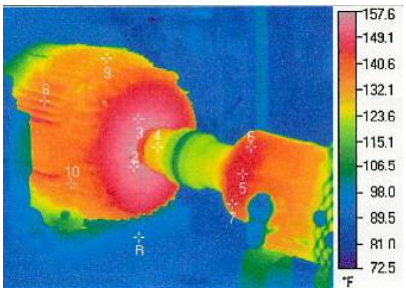
~70% of failures related to seals, bearings, and packings.

Mechanical Seals	**34.50%**
Bearing Distress	**20.20%**
Packing Leakage	**16.30%**
Shaft/Coupling Problems	**10.50%**
Case Failure/Auxiliary Lines 4.80%	
Stuck	**4.30%**
Vibration Events	**2.70%**
Bad Performance	**2.50%**
Other Causes	**4.20%**

Threats to Pump Reliability

Root Causes[1]

- Faulty Design
- Material Defects
- Fabrication or Processing Errors
- Assembly or Installation Defects
- Unintended Service Conditions
- Maintenance Deficiencies



27

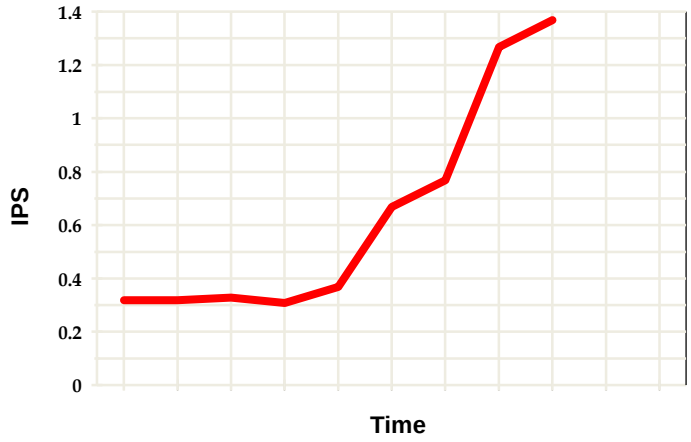
- Faulty Design
- Material Defects
- Fabrication or Processing Errors
- Assembly or Installation Defects
- Unintended Service Conditions
- Maintenance Deficiencies

[1]
"Timely and up-front action by the owner-purchaser is one of the keys to failure avoidance. This up-front action includes development of detailed specifications for process pumps and some key components that go into good process pumps. Once a process pump arrives in the field, it must be properly installed and maintained. To be effective, the facility must adopt work processes that harmonize with best-of-class thinking."

Case Study

- 4 Process Water Pumps
- Steel Base Mounted Directly to Concrete Foundation

Case Study



- Increased sustained vibrations during operation
- Maintenance Costs USD$8,000 per pump/ annually

30

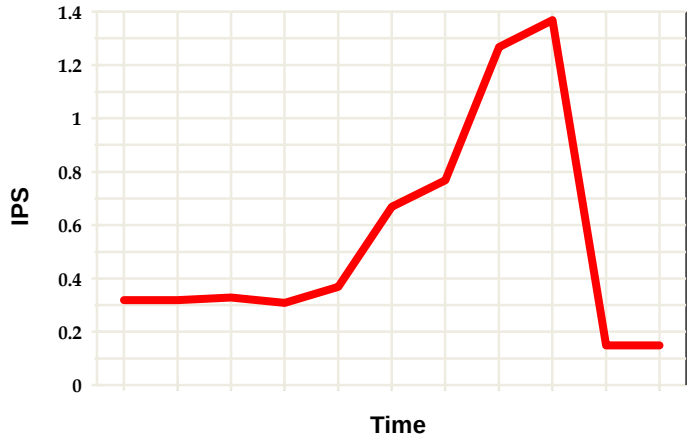
Hazards of Vibrations to Pumps

1. Increased maintenance costs
2. Increased operating costs
3. More frequent and less predictable failures

31

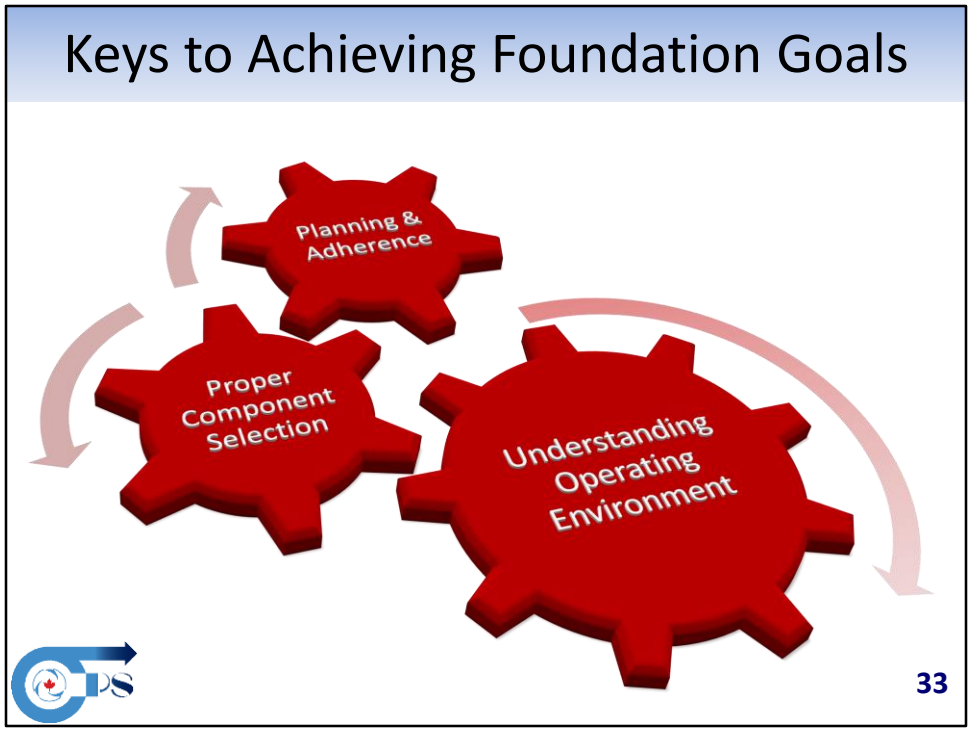
1. Increased maintenance costs
   - Replacing bearings, seals,
2. Increased operating costs
   - Overcoming inefficiencies leads to greater power consumption,
3. More frequent and less predictable failures
   - Equipment breakdown, especially to critical equipment that results in loss of production, is much more costly to bottom line than regularly scheduled and executed maintenance, even when including techniques designed to reduce the severity of a failure (trained maintenance staff and supply of spare parts).

Case Study



- Installed New Concrete Foundation & Epoxy Grout
- Avg Vibrations reduced from 1.4 IPS to less than 0.15 IPS
- US$40,000 ROI in 13 months

32



- Two Most Significant Costs are Maintenance and Energy Consumption
  - To minimize, best to match the components to the application
- 6% of energy losses from operation issues, while 34% are a result of decisions made during design.
- Up front planning includes development and following of detailed specifications
- Best installation practices with regular maintenance

[8]

"Maintenance and energy consumption represent by far the two most significant costs throughout the life of a pump. The answer to minimising these costs lies in ensuring a well-designed pumping system, where the pump is specified as correctly as possible to the demands of the application. "

[1]

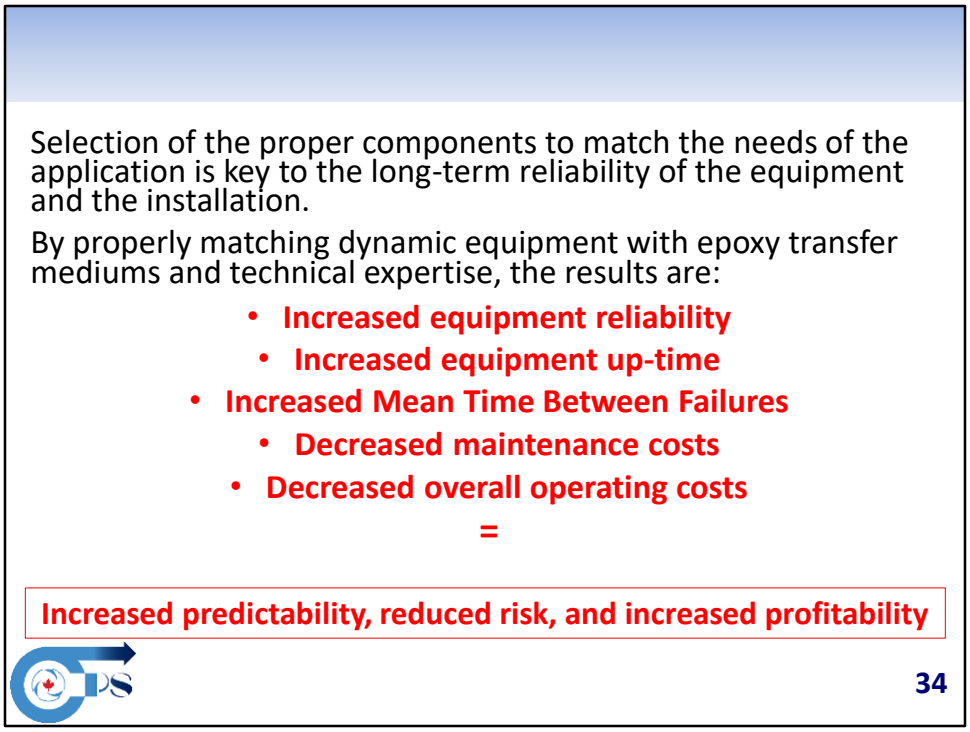
"About 7% of pump population consumes 60% of the money spent on pump maintenance and repair."

"Timely and up-front action by the owner-purchaser is one of the keys to failure avoidance. This up-front action includes development of detailed specifications for process pumps and some key components that go into good process pumps. Once a process pump arrives in the

field, it must be properly installed and maintained. To be effective, the facility must adopt work processes that harmonize with best-of-class thinking."

"It is significant that only 6% of energy losses are caused by operational issues, while 34% are built in at the design stage — that is, they are attributable to decisions made during design and the increasingly common practice of fast-tracking this critical step."[9]

"Some studies have shown that 30% to 50% of the energy consumed by pump systems could be saved through equipment or control system changes."[10]



[1] *"Timely and up-front action by the owner-purchaser is one of the keys to failure avoidance. This up-front action includes development of detailed specifications for process pumps and some key components that go into good process pumps. Once a process pump arrives in the field, it must be properly installed and maintained. To be effective, the facility must adopt work processes that harmonize with best-of-class thinking."*

Selection of the proper transfer medium to match the needs of the application is key to the long-term reliability of the equipment and the installation.
By properly matching dynamic equipment with epoxy transfer mediums and technical expertise, the results are:

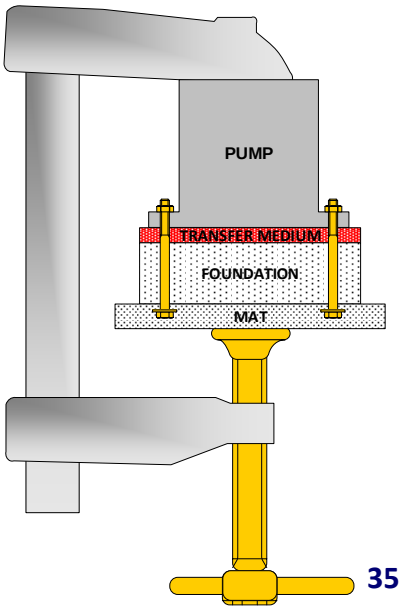
- **Increased equipment reliability**
- **Increased equipment up-time**
- **Increased Mean Time Between Failures**
- **Decreased maintenance costs**
- **Decreased overall operating costs**

- **Increased predictability, reduced risk, and increased profitability**

Thank You!

For any further questions or assistance, please contact me at:

Christopher Matthews-Ewald
Industrial Applications Engineer
ITW Performance Polymers
E-mail: cewald@itwpp.com
Customer Service/Tech Service:
+00 1 215-855-8450



References

1. Bloch, Heinz P. (2011). *Pump Wisdom.* Hoboken, New Jersey: John Wiley & Sons.
2. Bloch, Heinz P. (2012, April). Pump Alignment Saves Power. *Hydrocarbon Processing.* Retrieved from: http://www.heinzbloch.com/docs/HB_Tech_Paper_24.pdf.
3. Harrison, Donald M. (2013). *The Grouting Handbook: A Step-by-Step Guide for Foundation Design and Machinery Installation* (Second). Waltham, MA: ELSEVIER.
4. Hodgson, Judy; Walters, Trey (2002). *Optimizing Pumping Systems To Minimize First Or Life-Cycle Cost* (pp 1-8). Proceedings of the 19th International Pump Users Symposium. Texas A&M University. Turbomachinery Laboratories. Available electronically from http : / /hdl .handle .net /1969 .1 /164030.
5. Kuly, James A. (2010, October). *Best Practices in Compressor Mounting.* Paper presented at the 7th Conference of the European Forum on Reciprocating Compressors, Florence, Italy.
6. Kumana, J. D., & Suarez, M. R. (2018, February). *Analyzing the Performance of Pump Networks Part 2: Improving Pump Efficiency*. Retrieved from: https://www.aiche.org/resources/publications/cep/2018/february/analyzing-performance-pump-networks-part-2-improving-pump-efficiency.
7. Monroe, Todd R., & Monroe, Perry C. (2007). *Road To Reliable Pumps* (pp 99-112). Proceedings of the 23rd International Pump Users Symposium. Texas A&M University. Turbomachinery Laboratories. doi: 10.21423/R1CD63.
8. Smith, Steve. (2016). *The True Life Cycle Costs of Buying & Owning Industrial Pumps.* Retrieved from Process Industry Informer website: https://www.processindustryinformer.com/technical-article/true-life-cycle-costs-buying-owning-industrial-pumps/.
9. Sondalini, Mike. *What is the connection between equipment risk and equipment reliability and how does it affect your maintenance strategy selection?*. Retrieved from Lifetime Reliability Solutions website: https://www.lifetime-reliability.com/cms/free-articles/reliability-improvement/only-path-to-reliability-excellence/link-between-risk-and-reliability/.
10. U.S. Department of Energy, Office of Industrial Technologies. *Pump Life Cycle Costs – A Guide to LCC Analysis for Pumping Systems* (January 2001). Retrieved from https://www.energy.gov/sites/prod/files/2014/05/f16/pumplcc_1001.pdf.