



**Great Lakes
Environmental
Infrastructure Center**

Environmental Finance Center for EPA Region 5

Condition Assessment of Pumps and Motors in Wastewater Systems

Thursday 10/8/2026 | 1:00 PM – 2:00 PM

Instructor: Gregory Pearson,





Great Lakes Environmental Infrastructure Center

Environmental Finance Center for EPA Region 5

Serve small communities (population of less than 10,000) throughout EPA Region 5: Indiana, Illinois, Michigan, Minnesota, Ohio, Wisconsin, and 35 federally recognized American Indian governments, and nationwide through Environmental Finance Network EPA projects

Training, Research, and Technical Assistance, with a mission to help water and wastewater utilities increase technical, managerial, and financial capacity (TMF).

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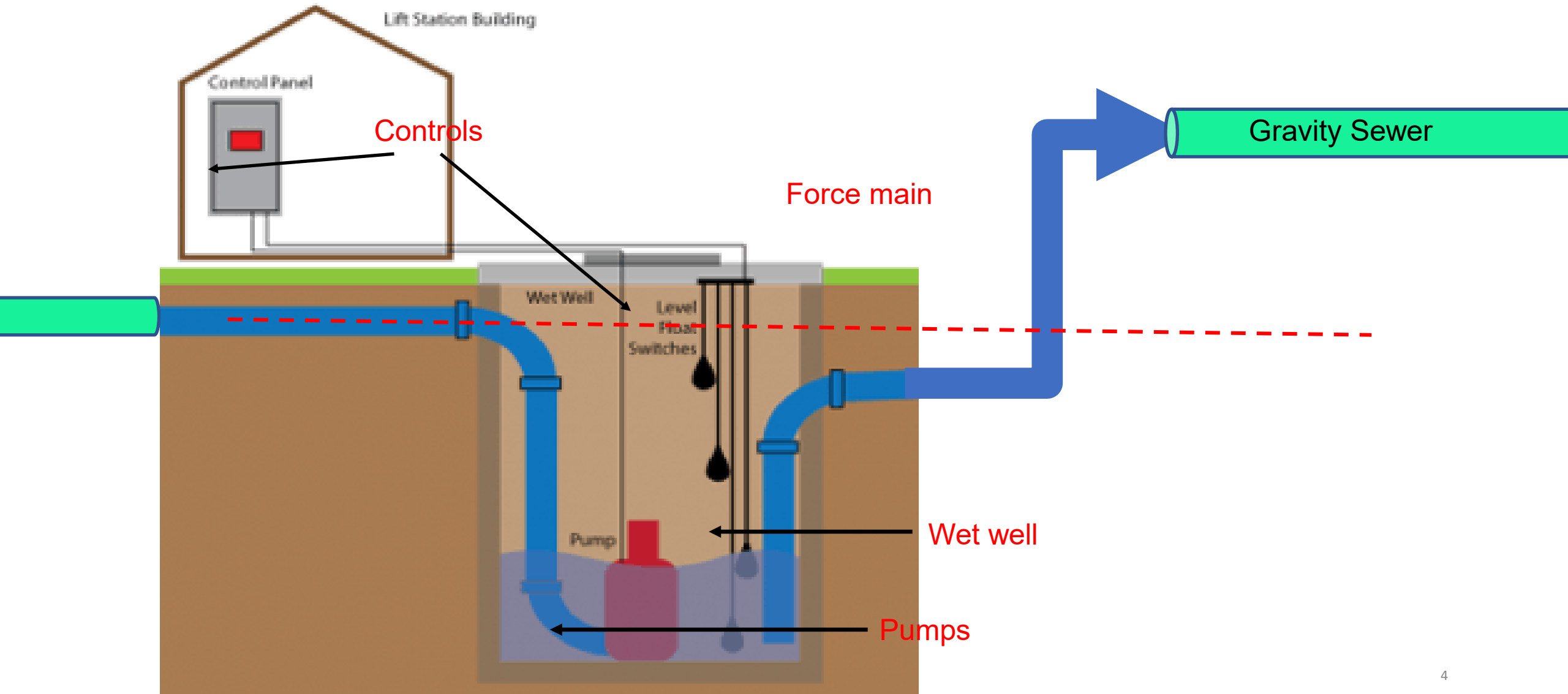
Michigan Technological University





Condition Assessment of Pumps and Motors

Wastewater lift stations are facilities designed to move wastewater from lower to higher elevation through pipes.

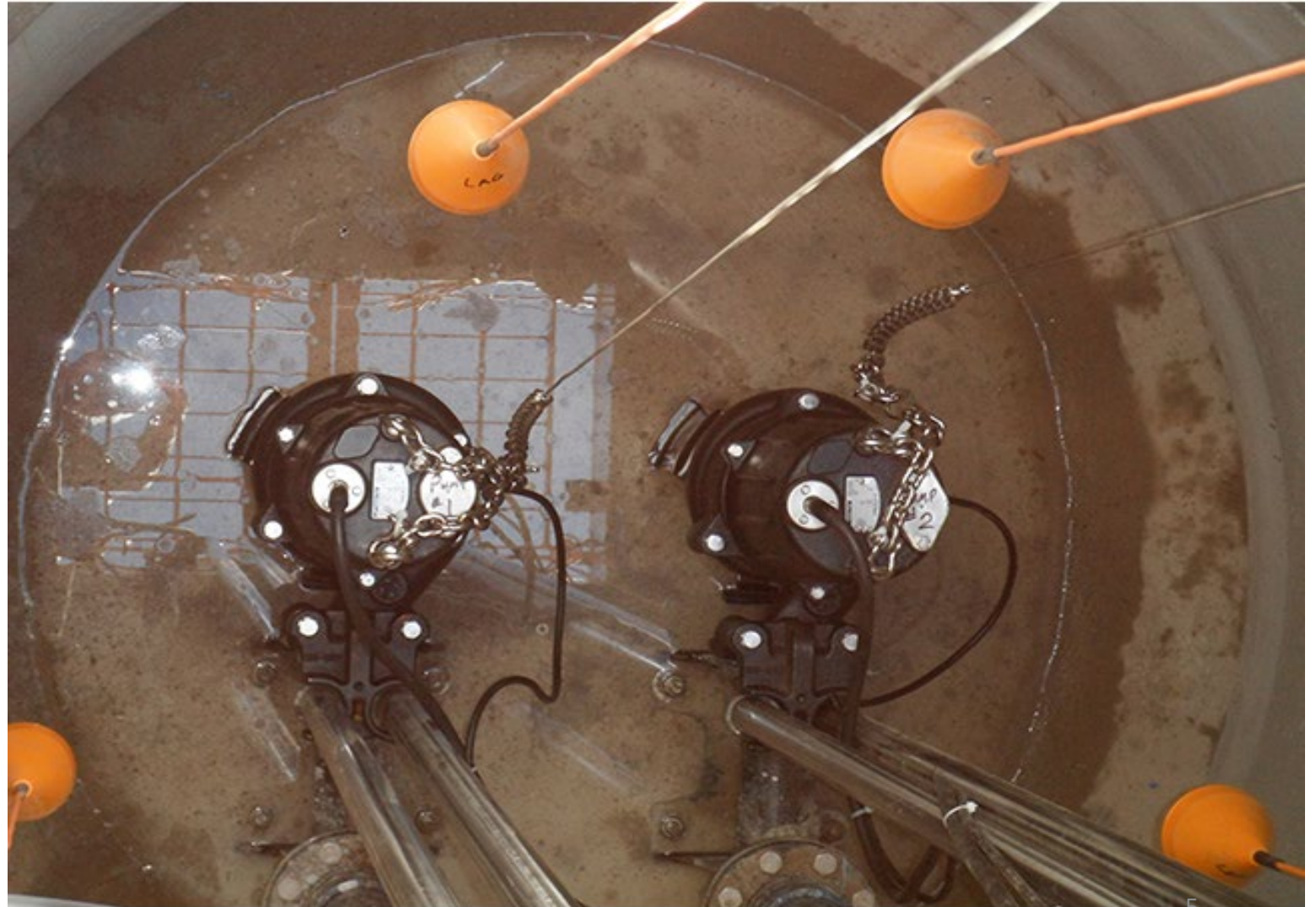


Wastewater Lift Stations

Two pumps in the lift station provides redundancy

The pumps are alternated as the lead and lag pump.

Visually inspect for debris and proper operation.

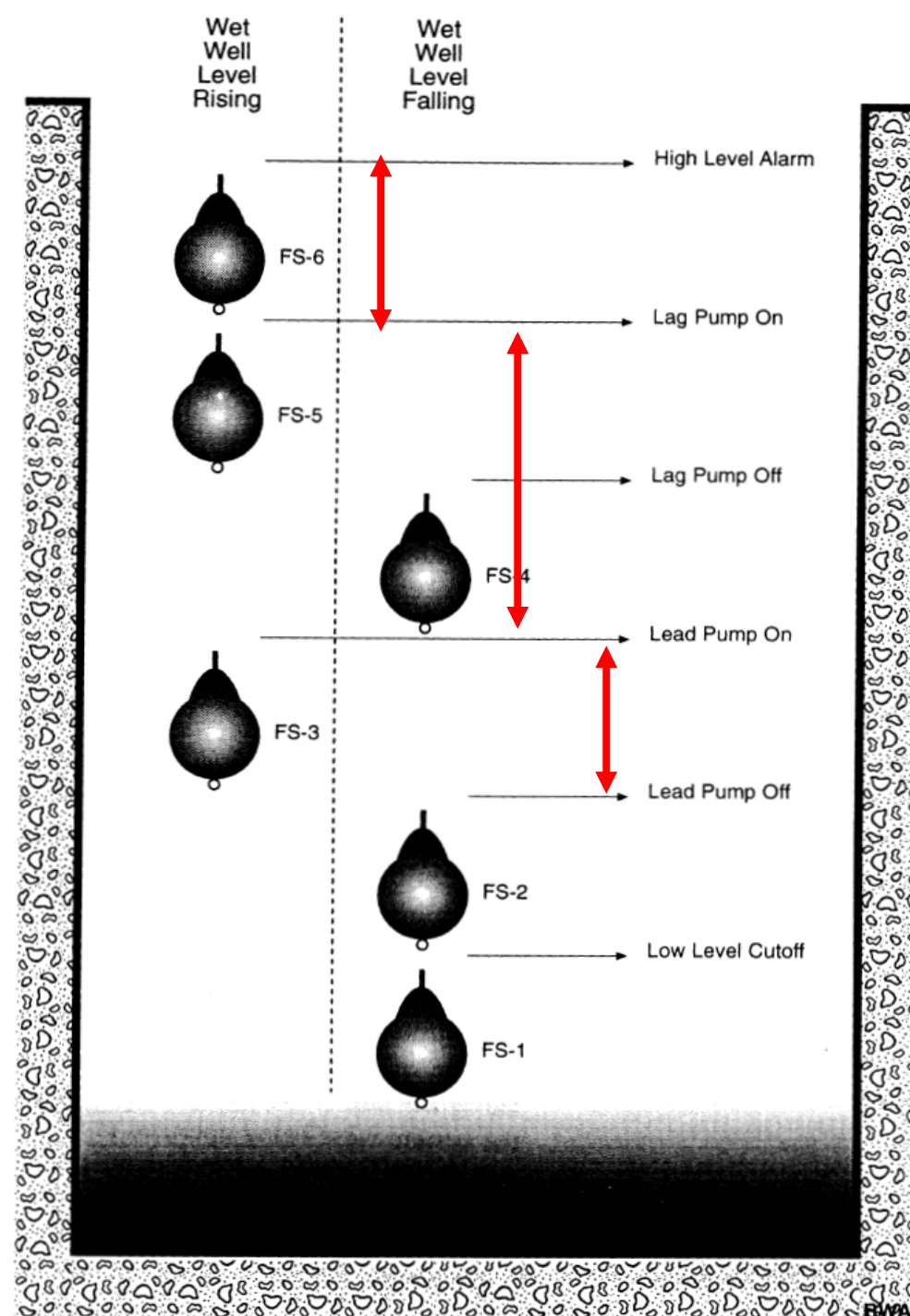


Design Parameter Examples

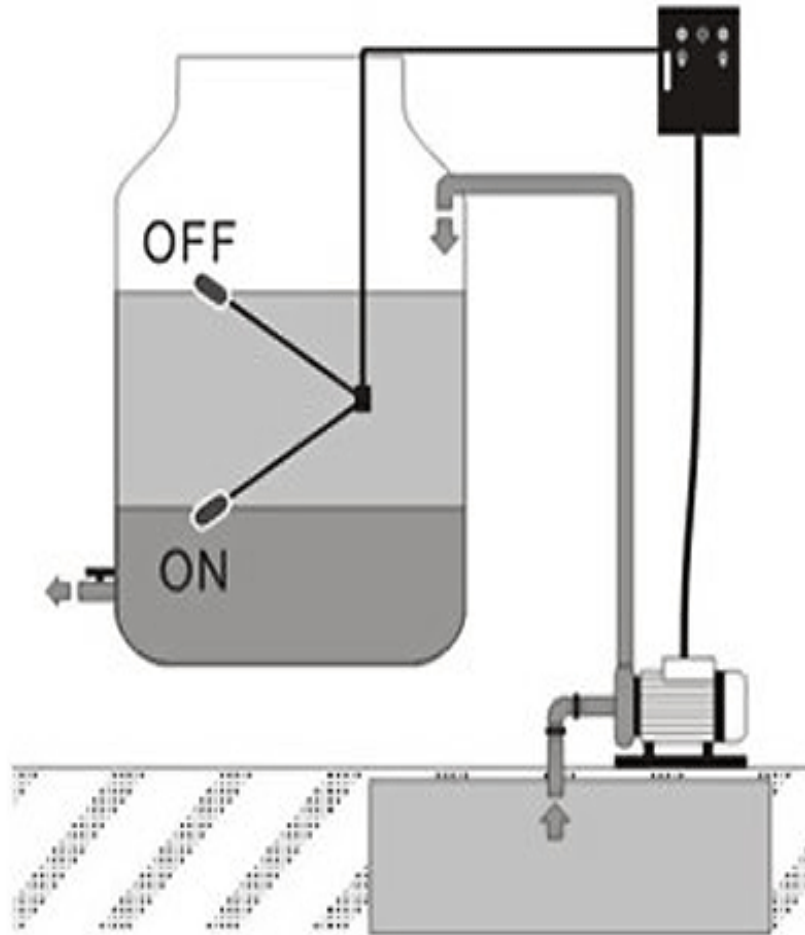
High level alarm - 6" above lag pump minimum

lag pump on – 12" above lead pump- minimum

lead pump on – set to handle normal flows at an acceptable cycling rate (max starts per hour)



Float system maintenance

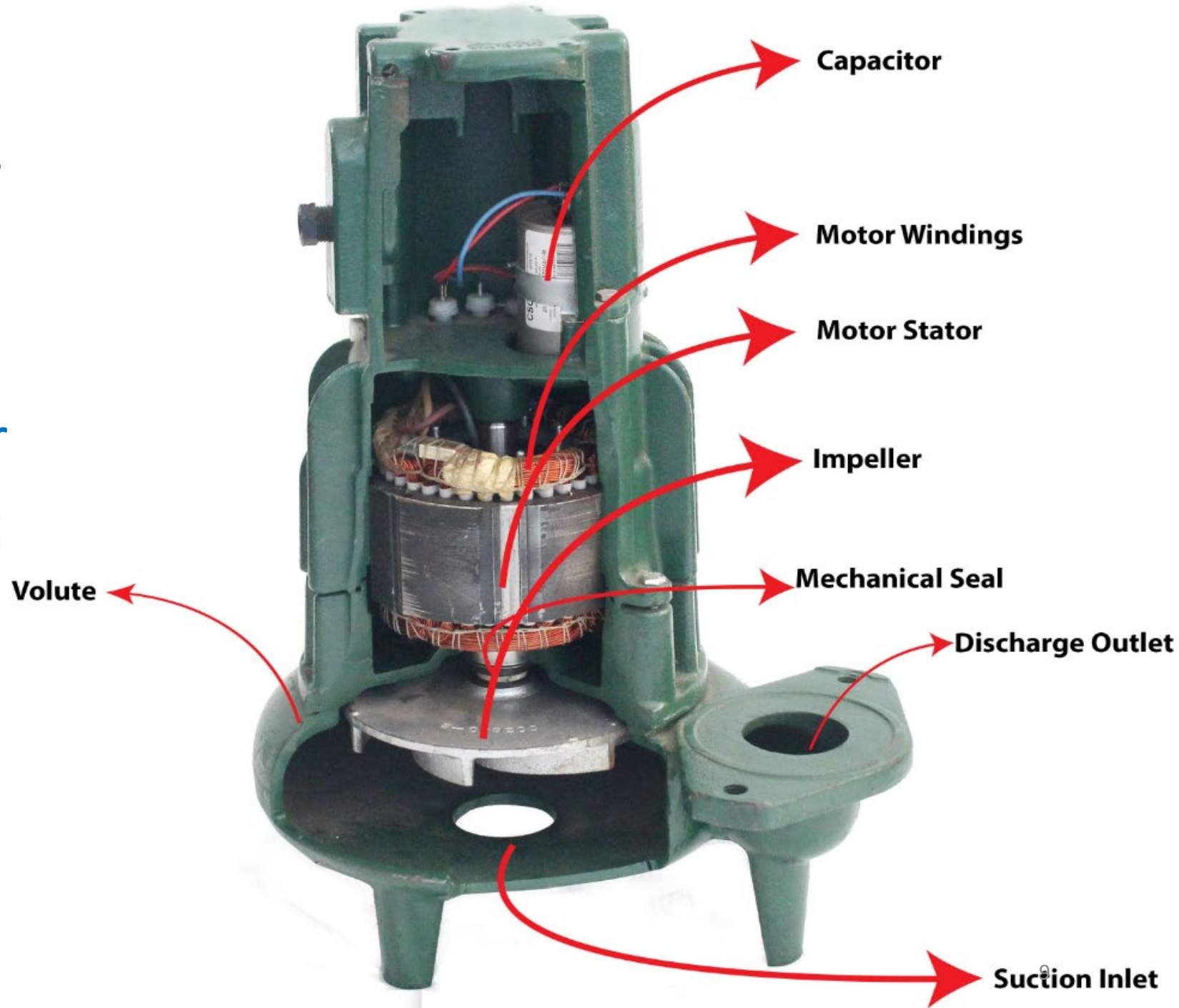


- Float switches turn pumps on and off.
- Floats also operate high-level and low-level warning devices.
- Rated for 1,000,000 cycles +/-
- Must be inspected, cleaned, and tested by lifting to ensure correct operation.

Testing float switches by lifting each float



Pump inside diameter
to allow the average
size of waste solids to
pass through.
Normally 2.5 inches or
larger

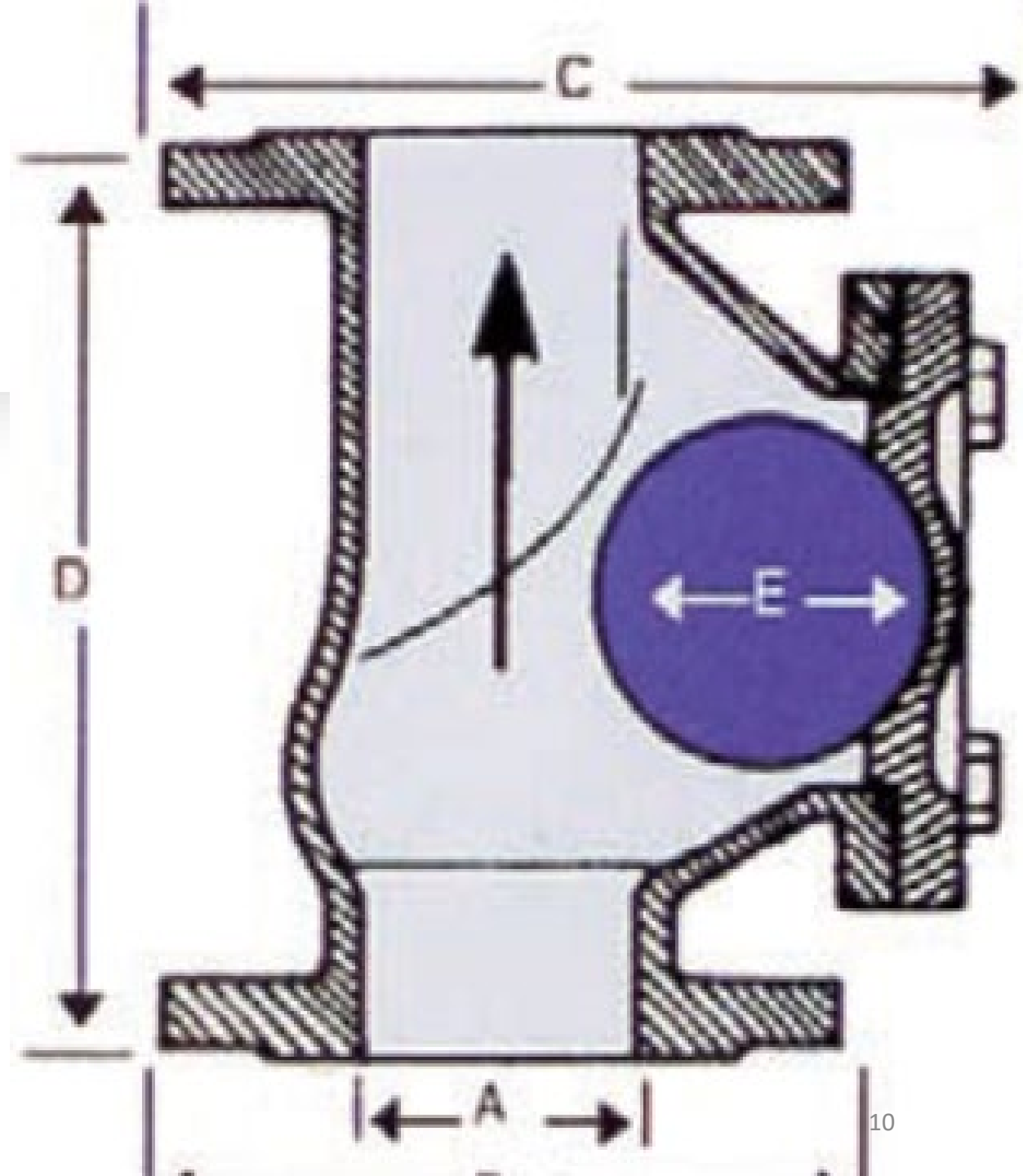


Hour meter readings

A record of the motor hours, along with dates and times should be kept. Important to track total hours for maintenance.

Overall hours of runtime should be approximately equal. If the hours differ between the pumps by more than 10% it can indicate a problem:

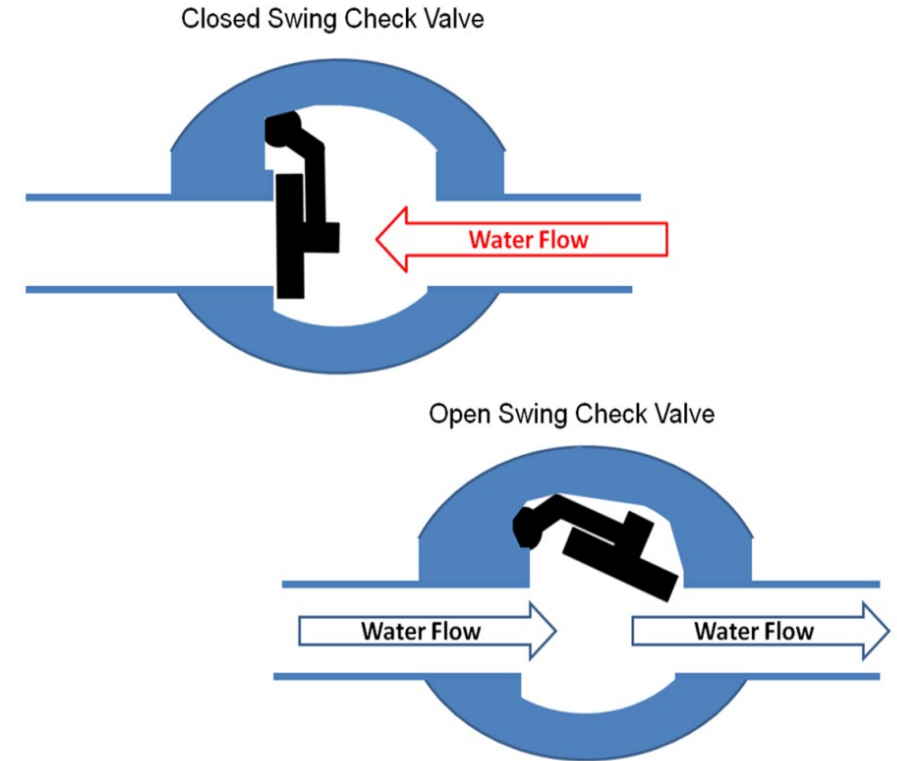
- **Grease or solids** partially clogging pump flow
- **Pump impeller wear** or bearing failure.
- **Motor problems** – check amperage draw (if twice normal draw it could mean the motor is locked due to solids – also check electrical breakers.

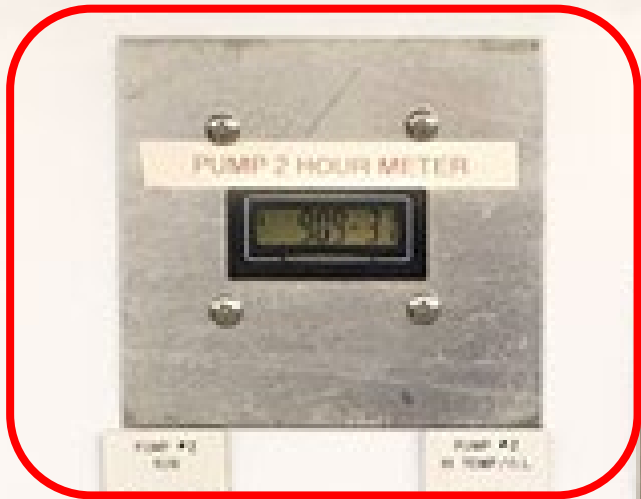
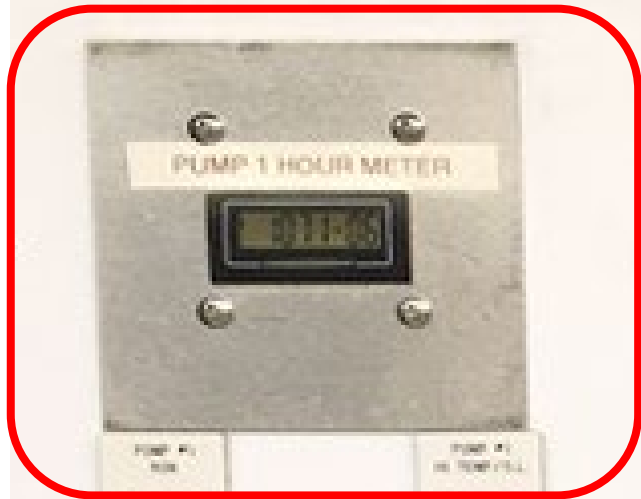


Increased total run time of lift station pumps – possible causes

- Partially clogged or blocked check valve allowing sewage to flow back into the lift station.
- Force main is clogged with grease and solids
- Inflow and infiltration
- Higher water use or population increase

Bar screens or grinders can minimize pump clogging problems.





480 VOLTS



COMMUNICATION FAIL



Hour Meters

Fats, rags, oils, grease

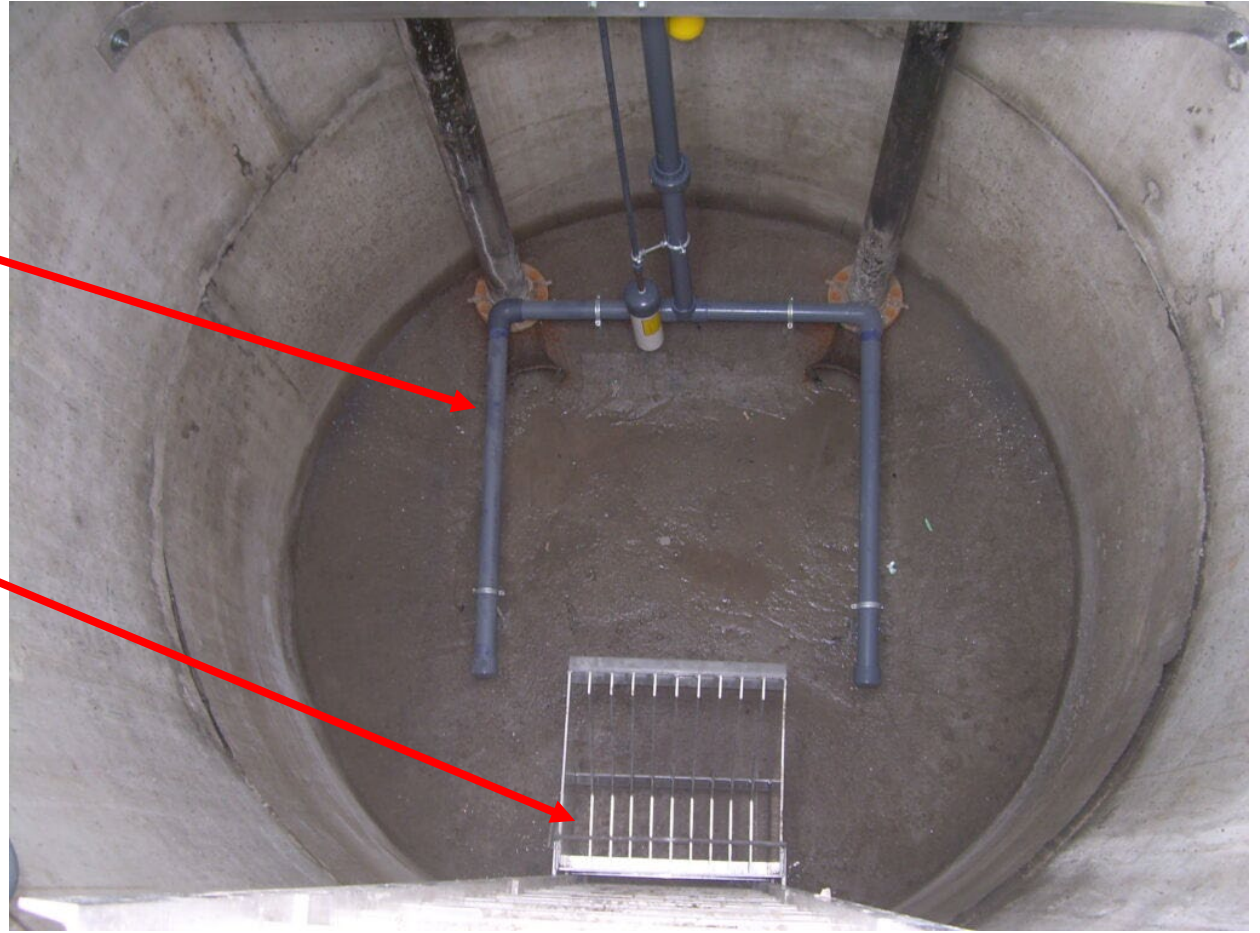
Determine the type of problem.

- a) **Wastewater solids:**
grinder pumps
- b) **Fats and oils:**
ensure grease traps installed and clean more frequently
- c) **Rags:** Bar screens, specialized cutter pumps



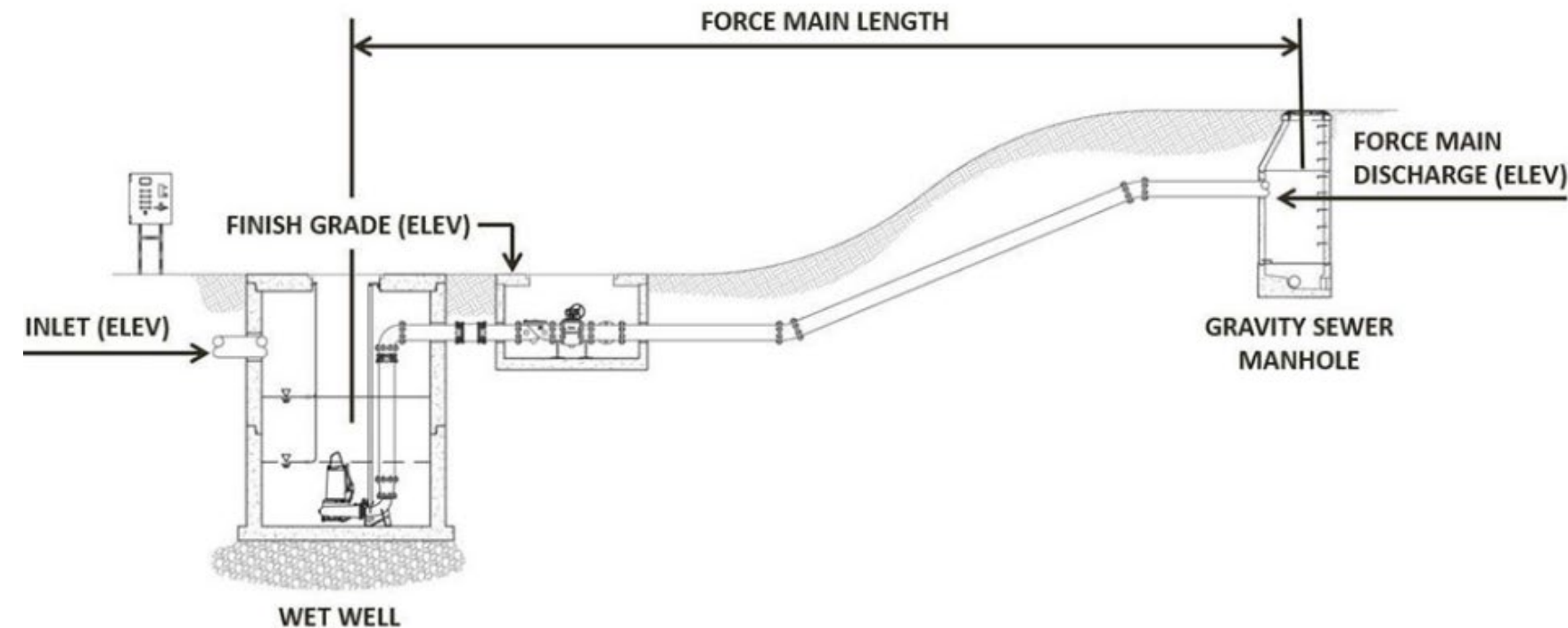
Use of aeration to break up grease.

Bar screen to collect rags.



Pressure gage on wastewater force main

- Increasing pressure over time can indicate the force main, or components is becoming clogged with grease or debris and needs to be cleaned.
- Decreasing pressure can indicate a leak.



Drawdown test

A drawdown test is simply a way to periodically check the flow rate of each pump.

Each pump is operated on hand to empty a known volume of wastewater from the wet well and is timed.

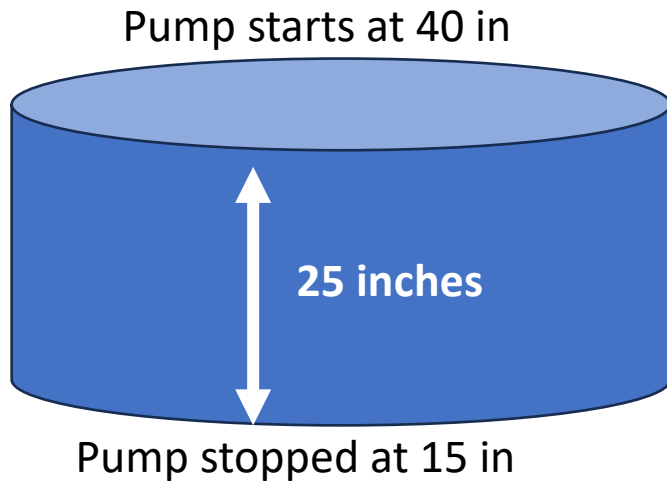
$$\frac{\text{Gallons pumped}}{\text{Time in minutes}} = \text{Actual gpm}$$

$$\text{Pump Efficiency \%} = \frac{\text{Actual gpm}}{\text{Rated gpm}} \times 100\%$$

Calculating volume and pumping rate

A pump is started when the liquid level is 40 inches and stopped after 2 minutes when the liquid level was pumped down to 15 inches.

If the wet well is 3 feet in diameter, how many gallons were pumped and what was the pumping rate??

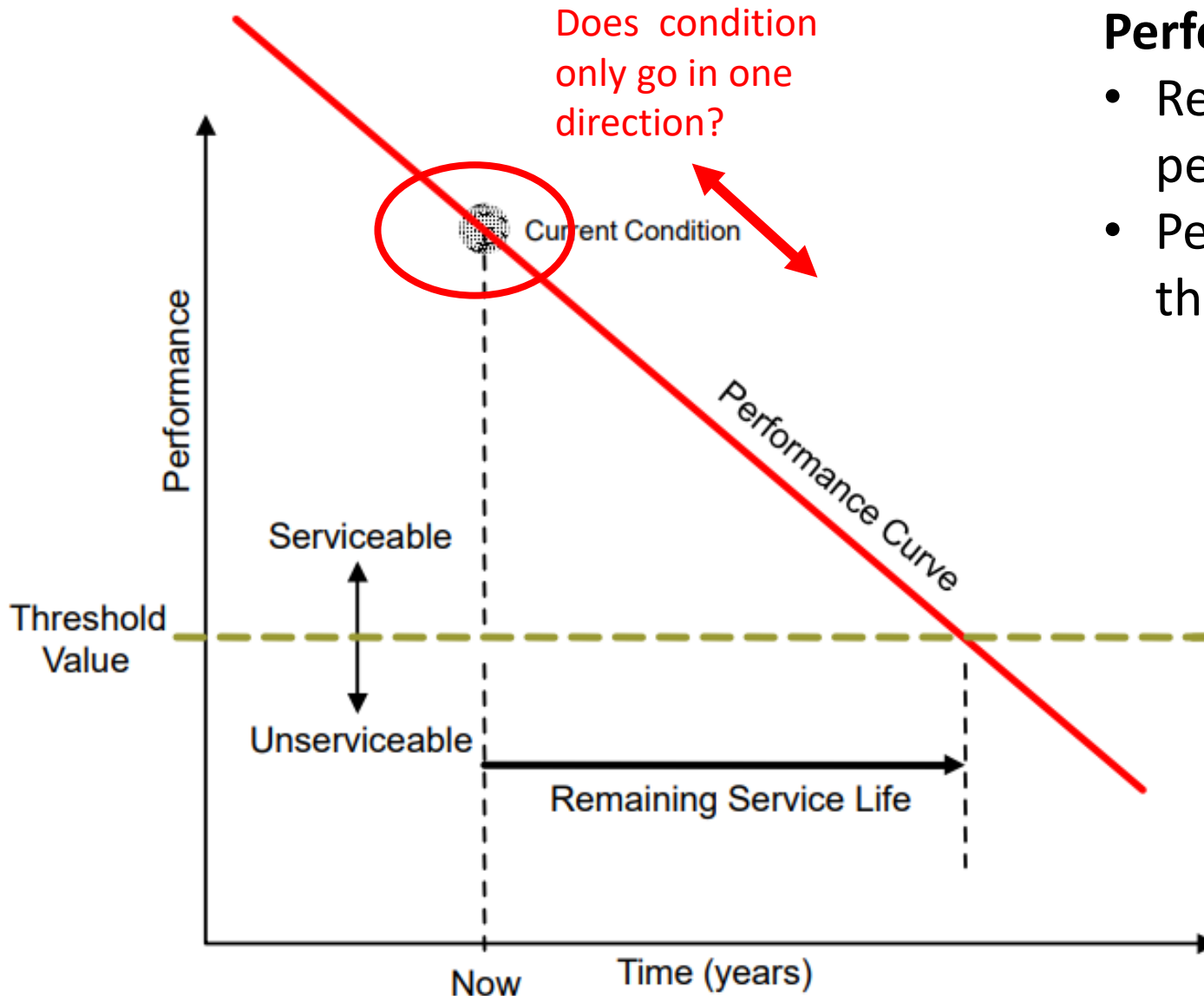


$$\text{Volume} = D \times D \times 0.785 \times H \times 7.48 \text{ gal/cf}$$

$$\text{Volume} = 3\text{ft} \times 3\text{ft} \times 0.785 \times [25/12] \text{ ft} \times 7.48 \text{ gal/cf} \\ = \mathbf{110.1 \text{ gallons}}$$

$$\text{Pumping rate} = \frac{\mathbf{110.1 \text{ gallons}}}{\mathbf{2 \text{ min}}} = \mathbf{55 \text{ GPM}}$$

Asset Condition (Performance Curve)

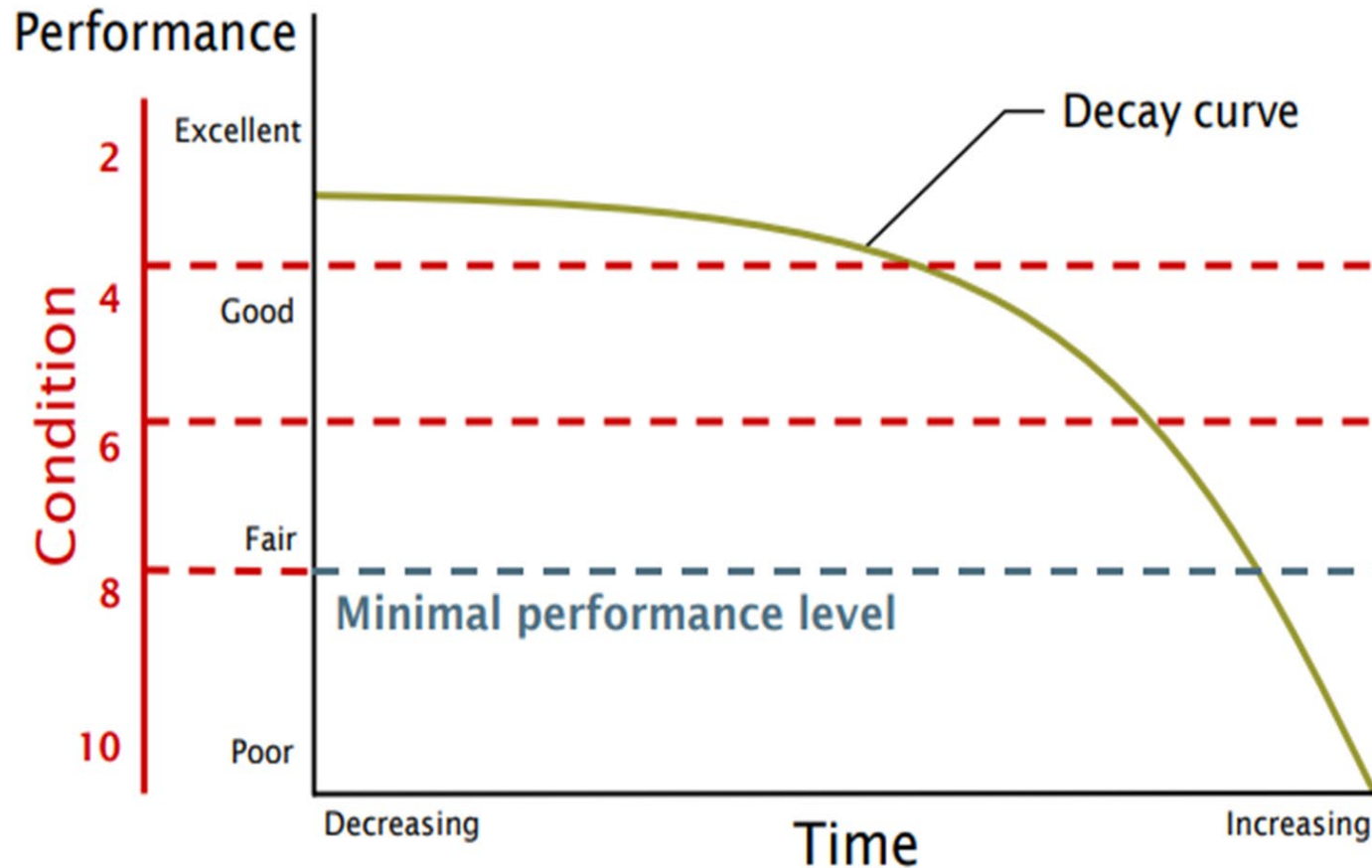


Performance Curve (conceptual)

- Replacement decisions are based on performance data
- Performance will eventually fall below the threshold

Threshold Value: The point at which the asset can no longer deliver the necessary service level. At this point the asset must be repaired, rehabbed or replaced

Asset Condition (Decay Curve)



Decay Curve (Conceptual)

- Expect increasing number of breakdowns as you near the end of an asset's useful life.
- Increasing breakdowns alert you to the fact you are nearing this stage.

Performance decreases at accelerating rate.

Criticality analysis



Criticality is determined by

1. The likelihood that the asset could fail (probability of failure)
2. The consequence to the system if the asset fails (consequence of failure)

These two factors are rated using a numerical scale and then multiplied to calculate an overall criticality score which can be compared to other similar assets.

$$\text{POF} \times \text{COF} = \text{Criticality}$$



Probability of Failure (POF)

Based on *condition assessment* combined with root causes and environmental factors present in operating conditions.

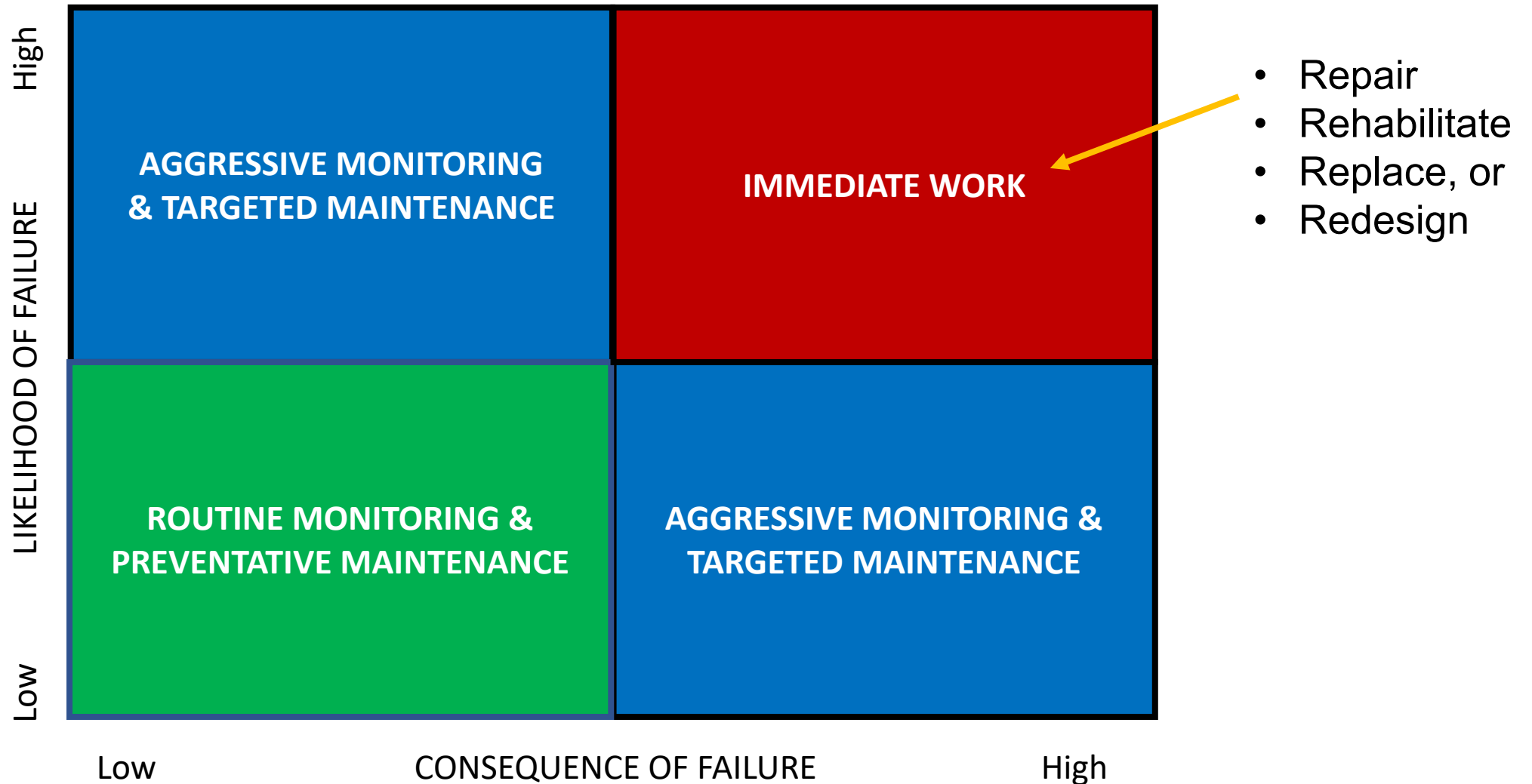
Probability of Failure	
Performance Rating	Description
1	Improbable: Failure is very unlikely
2	Remote: Failure is unlikely but possible.
3	Possible: Failure could occur sometime within the expected useful asset life cycle.
4	Probable: Likely to fail within a defined short-term planning cycle.
5	Imminent: Asset expected to fail at any time. Requires immediate attention.

Consequence of Failure (CoF)

CoF quantifies the degree of disruption or impact to the water users, community, and utility.

Consequence of Failure	
Consequence Rating	Description
1	Insignificant disruption
2	Minor disruption.
3	Moderate disruption.
4	Major disruption.
5	Catastrophic disruption (system-wide)

Relationship Between Criticality, Maintenance, and Inspection



Criticality Example

Use criticality risk analysis to determine which lift station pumps have the greater priority.

Lift Station #1: This lift station serves approximately 20 residences. The two 5-HP pumps are over 15 years old, and efficiency has decreased from 70 to 64%. Mega Ohm readings show around 1.0 Megs for both pumps. PoF is rated as a 4 “probable” and CoF is rated as a 3 “moderate disruption”.

Lift Station #2: This lift station serves approximately half the town and is near a protected stream. The two 25-HP pumps are 10 years old. Mega Ohm readings are near 1.5 Megs for both pumps. PoF is rated as a 3 “possible” and CoF is rated as a 5 “catastrophic”

Criticality Matrix

	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Consequence of Failure

Probability of Failure

Main #1

$$4 \text{ (PoF)} \times 3 \text{ (CoF)} = 12 \text{ (Criticality)}$$

Main #2

$$3 \text{ (PoF)} \times 5 \text{ (CoF)} = 15 \text{ (Criticality)}$$

Insulation resistance

Mega Ohm testing (Megger)

Uses a very low current and high voltage to test insulation between leads and ground.

Can help to identify shorts or deteriorated insulation.



Mega Ohm interpretation

Table 1. Typical Insulation Resistance of Single- and Three-Phase Electric Motors

Motor Environment and Condition	Megohm Value	Ohms Value
New motor (without drop cable for submersibles)	>200.0 (0.20)	>200,000,000
Motor in good condition that can be reused	>10.0 (0.01)	>10,000,000
New motor in well with drop cable (submersibles)	>2.0 (0.002)	>2,000,000
Motor in operable condition but beginning to fail	1.0-2.0 (0.001-0.002)	1,000,000-2,000,000
Generally accepted minimum insulation resistance	1.0 (0.001)	1,000,000
Damage to motor and/or cable (consider ASAP repair)	<0.50 (0.0005)	<500,000
Impending failure to motor (requires immediate repair)	<0.25 (0.00025)	<250,000

Insulation resistance should ideally be greater than 10,000,000 Ohms

Electrical testing for pump motors

1. **Measure amperage draw** for each leg of three-phase motors and check for increases and imbalance. **Amperage imbalance should be less than 5%.**
2. **Measure insulation resistance** of pump wiring (annually or every few years). Insulation can break down over time and can contribute to problems in older motors.
3. **Measure voltage imbalance and transient voltage spikes: Voltage imbalances over 1%** or transient voltage spikes of 50 volts or greater can create additional heat and reduce component life.



Calculating amperage imbalance

L1 = 11.1 amps | L2 = 12.0 amps | L3 = 13.2 amps

Step 1: Find the average amp draw

$$\frac{11.1a + 12.0a + 13.2a}{3} = \frac{36.3 \text{ amps}}{3} = 12.1$$

Step 2: Compare the % variation from the average for each measurement

L1 $\frac{12.1 - 11.1}{12.1} \times 100\% = 8.3\%$

L2 $\frac{12.1 - 12.0}{12.1} \times 100\% = 0.8\%$

L3 $\frac{13.2 - 12.1}{12.1} \times 100\% = 9.1\%$

- Try rotating the leads – L1 to L2, L2 to L3, and L3 to L1 and re-check the amperage draw.
- Voltage can also be measured for each lead. If an imbalance moves with the lead, it means it is due to the power supply or panel.
- If imbalance remains for the same positions, it can mean there is an issue with the pump motor windings or connections.



Checking resistance of motor leads

Testing resistance between motor leads – make sure that the leads are clean and dry and check for burn marks and wear.

Test the following T1 to T3 | T2 to T3 | T1 to T2

- The reading for each should be between 0.3 to 2 ohms.
- 0 means there is a short.
- Over 2 ohms or infinite means an open circuit

Check for resistance imbalance.

Resistance unbalance indicates connection issues, if these values are out of balance by more than 5% from average, it could indicate loose or corroded terminals.

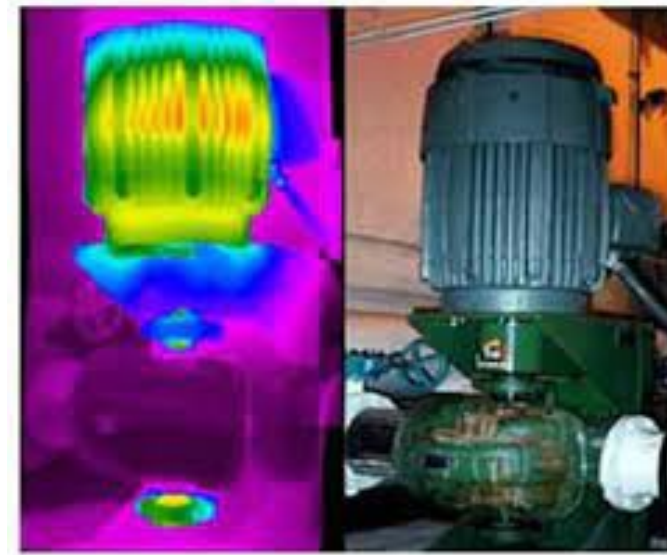


Sources of information for condition assessment of pumps and motors

- Vibration analysis
- Infrared bearing inspection
- Ultrasound
- Electrical testing
- Water to wire efficiency



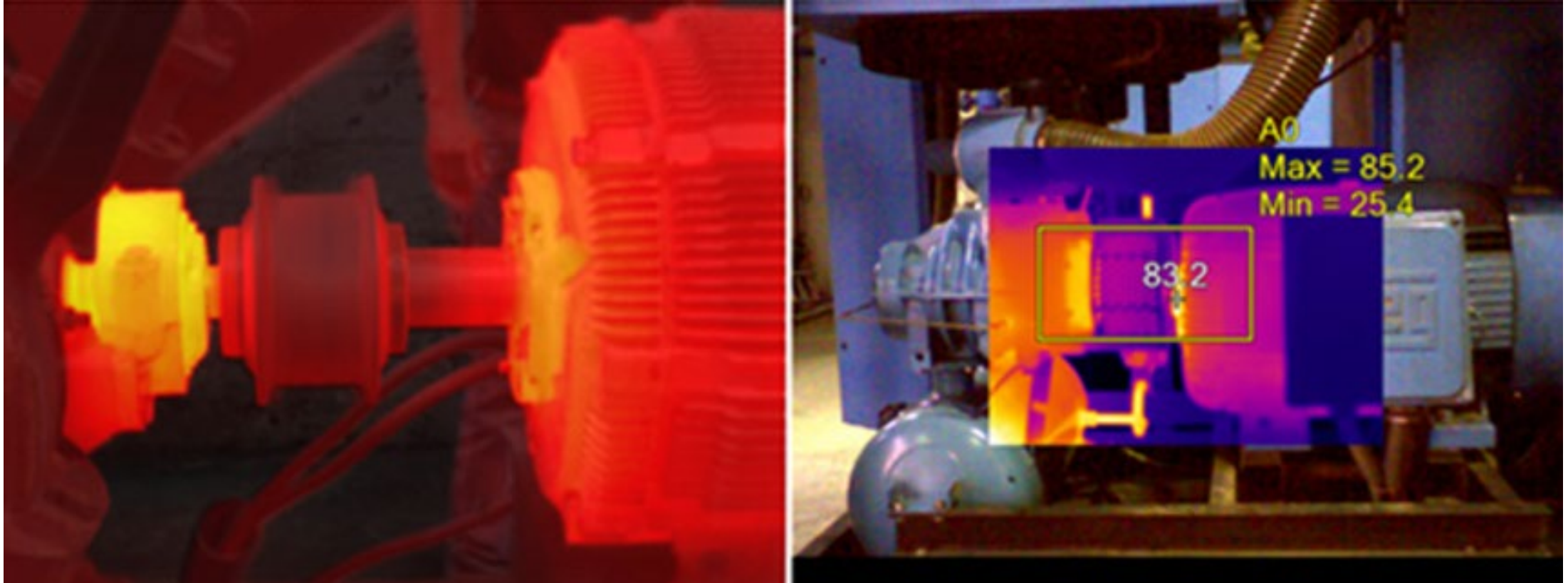
Operator using ultrasound: Increase in noise can indicate impending problems.



Infrared thermal image showing elevated bearing temperatures in a pump



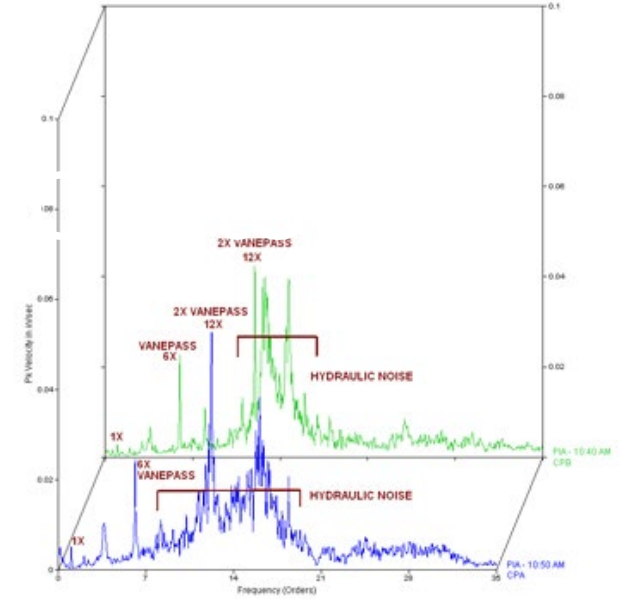
Vibration analysis: An increase in vibration over time can indicate bearing, impeller, or alignment problems



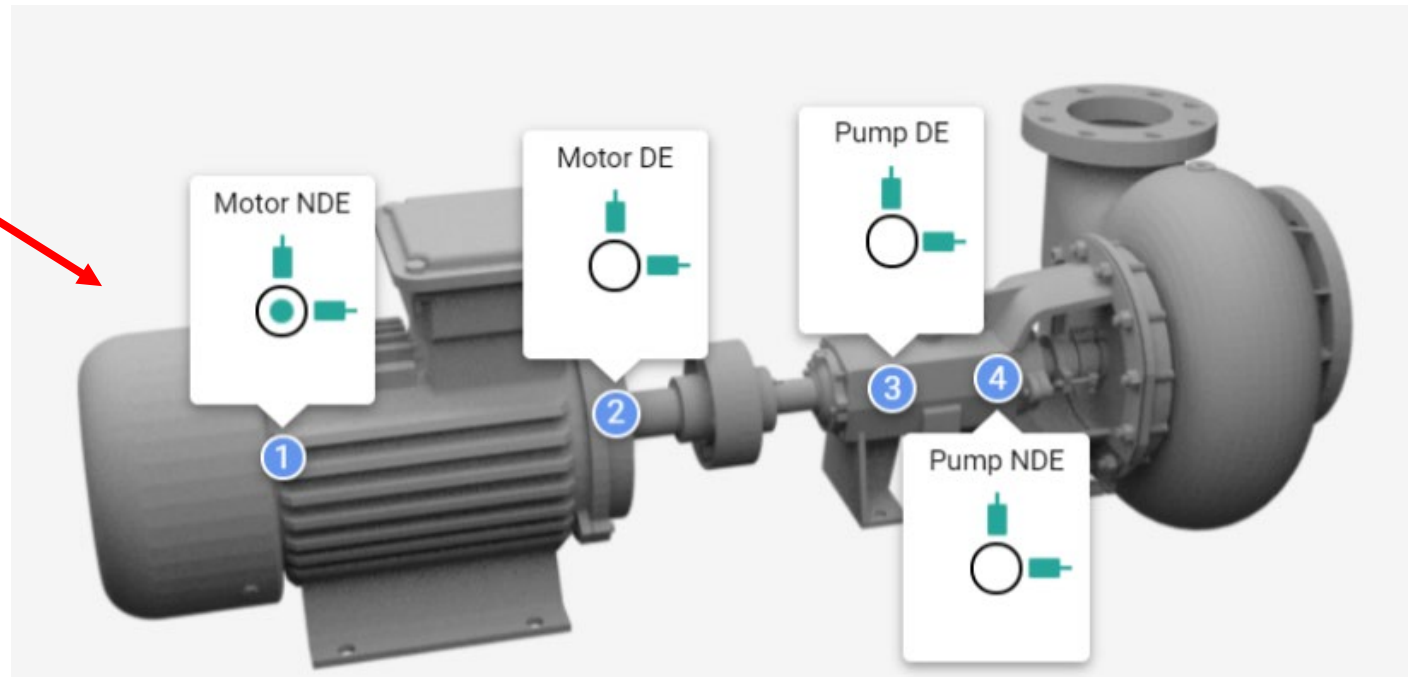
Infrared image of pump motors showing impending bearing problems.



Vibration analysis
Compares changes in vibration over time to detect impending problems (and sources of vibration).



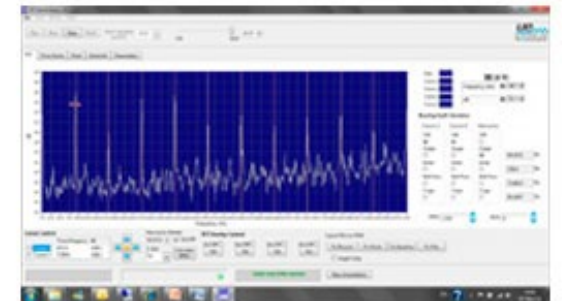
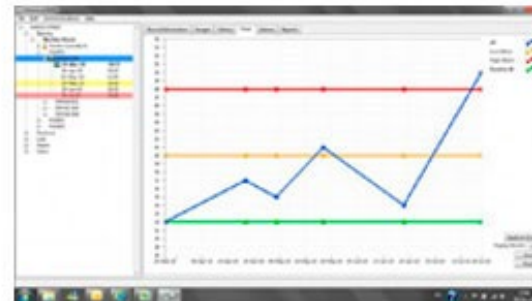
Measurement points for a pump and motor to measure vibration frequency and amplitude. Primarily used to detect bearing problems



Ultrasound

Detects minute changes in noise from bearings below the auditory range of humans. Sound from bearing is compared over time (Much more sensitive than vibration analysis).

- 8 dB gain over baseline indicates pre-failure or lack of lubrication.
- 12 dB increase indicates the beginning of the failure mode.
- 16 dB gain indicates advanced failure condition
- 35-50 dB gain warns of catastrophic failure.



Wire to water efficiency

Compares electrical power going in, to the water horsepower derived from head and flow

Example: A pump motor draws 18.65 KW of power and produces 800 gpm and 90 ft of head.

Motor horsepower = $18.65 \text{ KW} \div 0.746 \text{ KW} = 25 \text{ HP}$

Water horsepower = $\frac{800 \text{ gpm} \times 90 \text{ feet of head}}{3960 \text{ ft-gpm/hp}} = 18.2 \text{ HP}$

Efficiency = $\frac{18.2 \text{ HP} \times 100\%}{25 \text{ HP}} = 72.8 \%$



Condition composite scoring

A 50-HP electrical turbine pump motor is 35 years old and is beyond its expected life of 25 years.

- A recent inspection revealed that insulation resistance of the windings has been decreasing over time.
- The motor is functioning properly with no history of breakdowns, operating 8-hours per day on average and supplying the flow and head currently needed for the system.
- Wire to water efficiency of the pump and motor has decreased from 70% to 65%
- Cost to replace the pump motor is \$8,500 including installation.

Analysis

Criteria	Rating	Notes
Remaining useful life	4 (poor)	Beyond expected life
Results of inspections	4 (poor)	Decreasing insulation resistance & efficiency.
Performance history	2 (good)	No history of breakdowns
Maintainability	4 (poor)	Cheaper to replace than to rewind motor
Service level comparison	2 (good)	Provides adequate flow and pressure
Average Rating	3.2 (fair)	Average of all criteria



Poll 1

1. Which of the following indicates the need to repair or replace a pump motor?

- a) Ultrasound measurements have increased by 8db in the bearing.
- b) Resistance measurements for motor leads are 0.45 Ohms, 0.4 Ohms and 0.35 Ohms.
- c) Amperage imbalance is 3%
- d) MegaOhm reading is less than 250,000 Ohms

Poll 2

A pump motor draws 15 kW of power. How much HP is this?

- a) 20.1 HP
- b) 14.3 HP
- c) 11.2 HP
- d) 7.5 HP

$$15 \text{ kW} \div 0.746 \text{ kW/HP} = 20.1 \text{ HP}$$

Blower Motors

Blower motors in wastewater treatment plants operate in some of the most punishing industrial environments. The most common issues that decrease their lifespan can be grouped into four main categories:



Causes of Blower Motor Failures

Environmental Conditions: Hydrogen Sulfide (H₂S) Gas, low ventilation, high temperatures and humidity.

Operational Factors: High back pressure due to fouled diffusers or sludge accumulation, clogged intake filters, and surges

Mechanical Factors: Bearing failure, misalignment, and imbalanced impellers.

Electrical Factors: Voltage imbalances and harmonic distortion of VFD signals





Oversizing blower systems

The most common and destructive mis-sizing issue for aeration blowers is oversizing the blower capacity

Surges

The blower runs so slowly that air begins to move backward, causing the motor to surge, causing electrical spikes which can lead to insulation failures and stress on bearings.

VFD operating below the required cooling speed

To compensate for an oversized blower, a VFD may be installed to operate at a lower air flow.

This leads to the internal cooling fan spinning more slowly and lower cooling. At the same time, the motor must still overcome the same torque to push air through a 10- to 12-foot water column leading to overheating.

High Speed Turbine Blowers

High-speed blowers have a much higher RPM (typically 20,000 to 40,000 RPM).

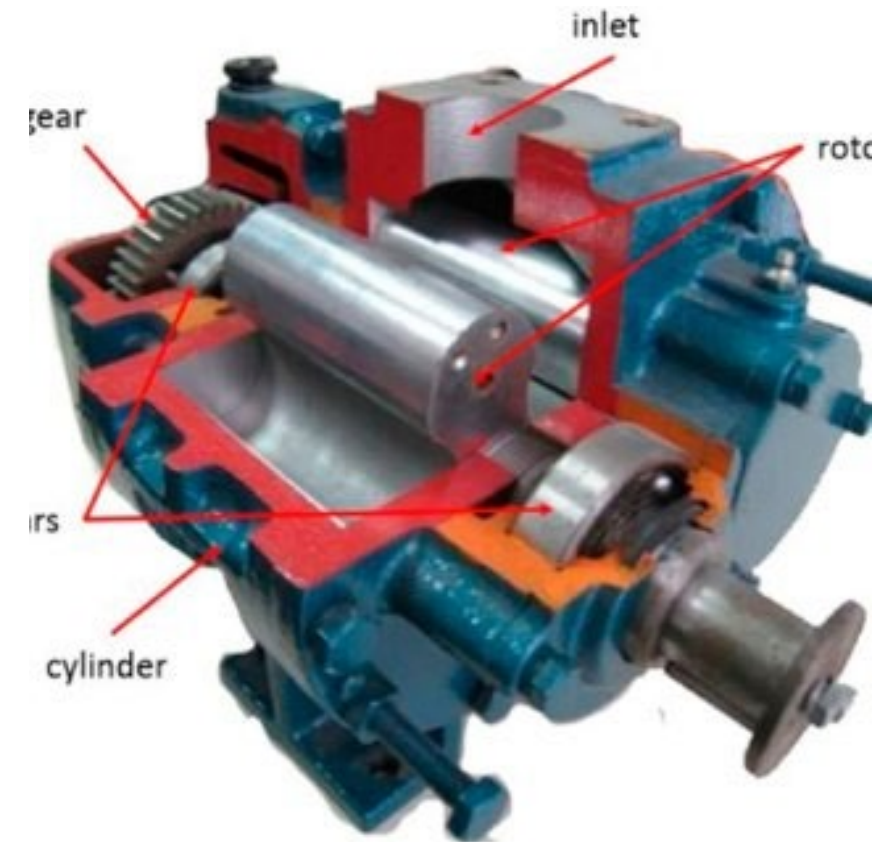
They can increase efficiency and are typically used in larger systems.



Lobe type blowers

Positive displacement air flow with rotating meshing lobes.

Can create a pulsating air flow – engineers solve this by a spiral design.

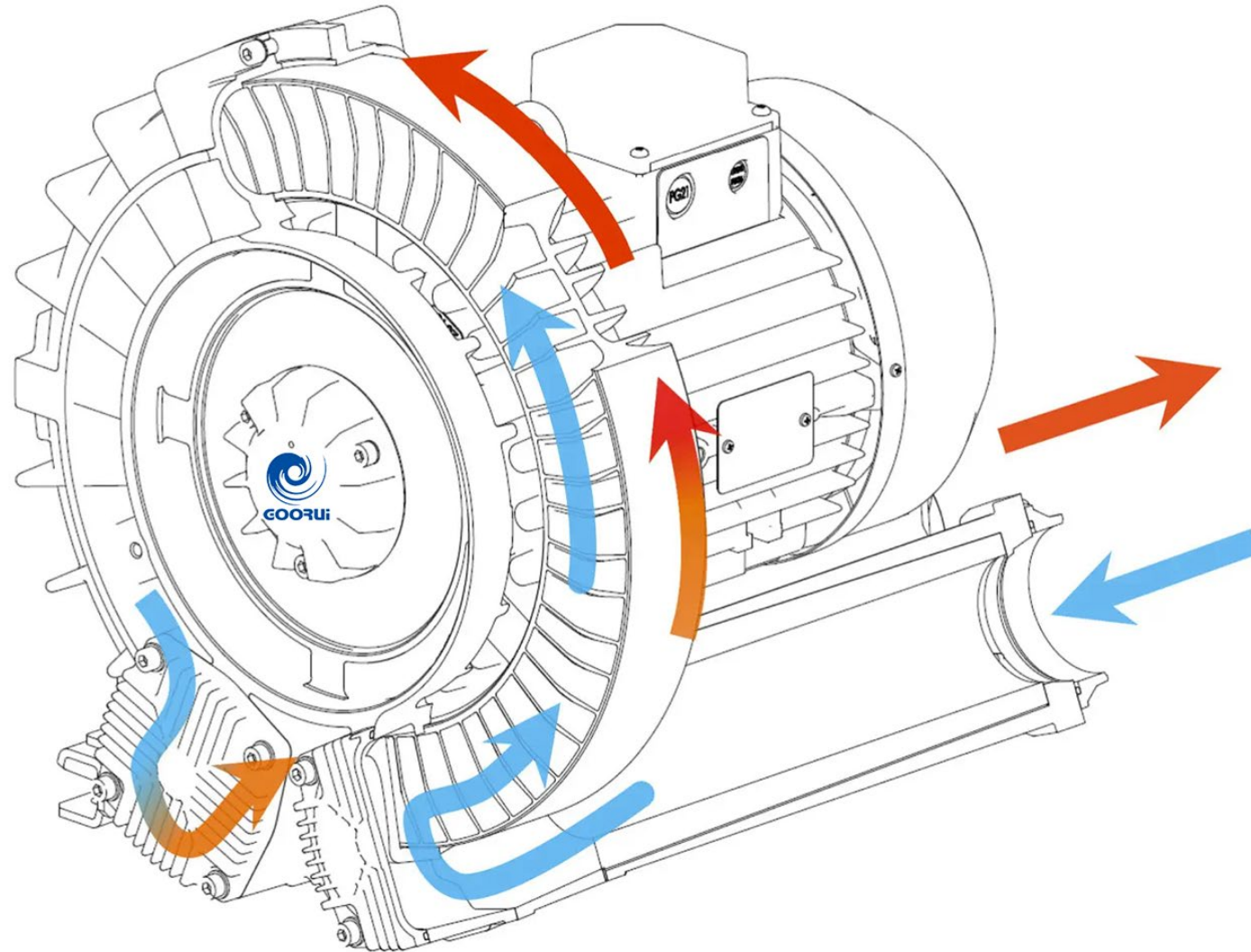


Regenerative (step-up) blowers

Stage 1 (The First Pass): Ambient air enters the main intake, travels around the first circumferential side channel, and exits the first stage at a moderate pressure.

Stage 2 (The Step-Up): The already-compressed air enters the second channel and is further compressed, doubling the pressure capacity before it finally exits into the discharge pipe.

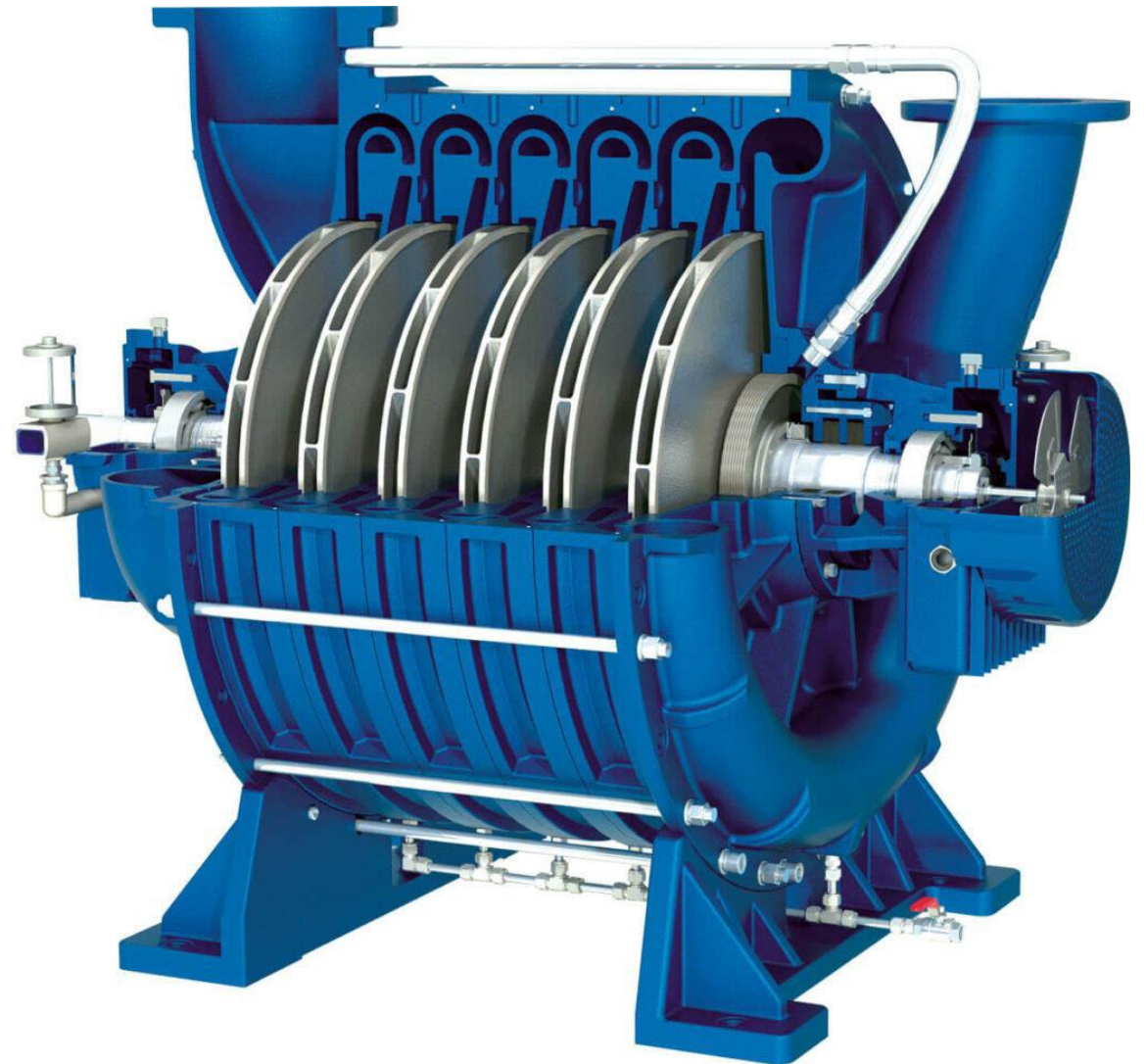
Lighter duty – provide 1 to 5 psi for shallower applications.



Centrifugal Blowers

Includes multiple impellers or stages to gradually increase pressure to 7 to 15 psi.

- Each stage adds pressure head
- Built for long service life and to service deeper aeration tanks.



Estimating blower pressure requirements

PSI should typically exceed water head by 1.5 to 2.5 psi

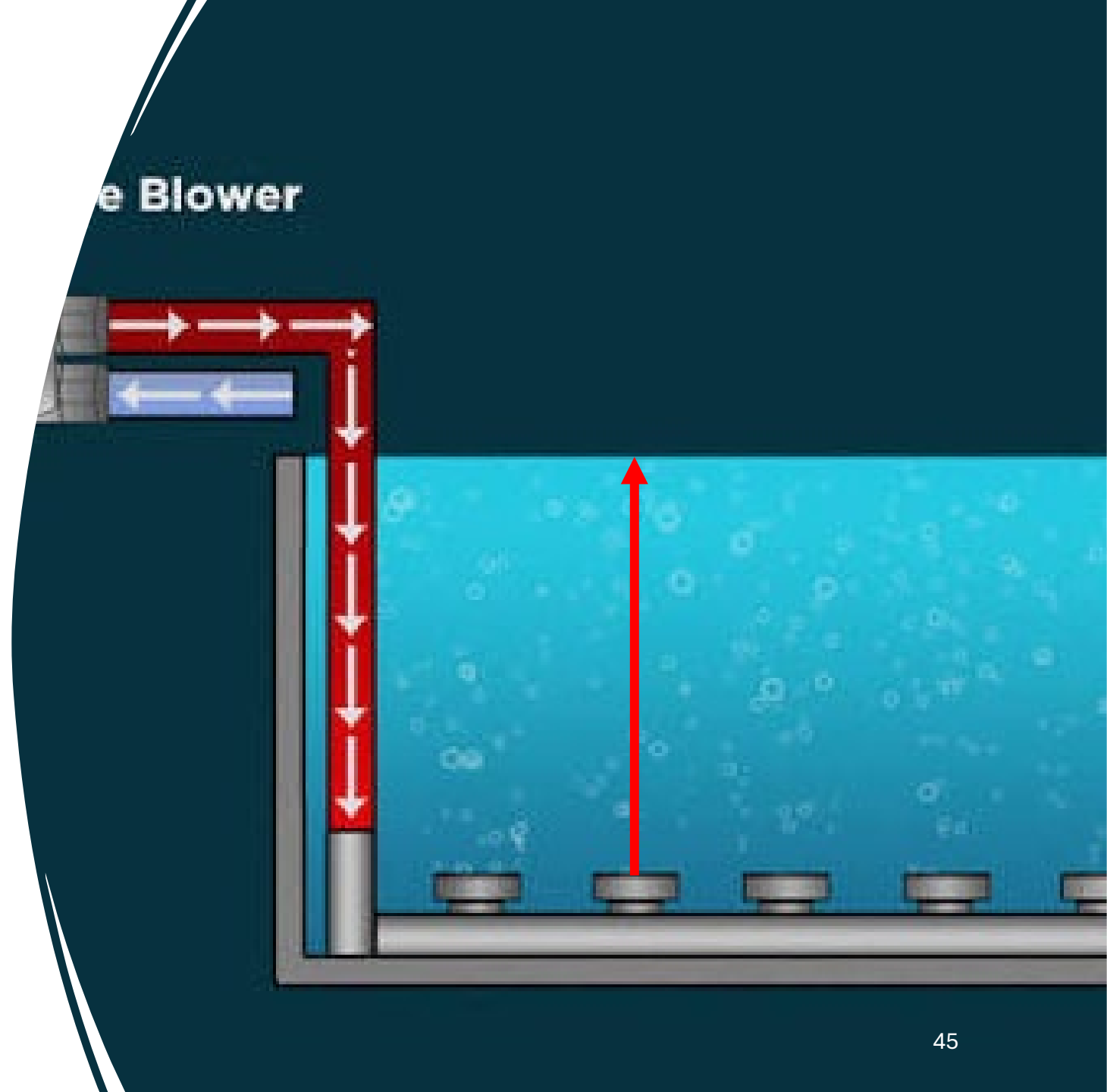
Example: Determine the blower pressure required for aeration of a 12-foot-deep aeration tank

Step 1: The required pressure just to overcome the head is:

$$P = 12 \text{ feet} \div 2.31 \text{ ft/psi} = 5.2 \text{ psi}$$

Step 2: Add 2 psi: $5.2 \text{ psi} + 2 \text{ psi} = 7.2 \text{ psi}$

Keep in mind, this is just an estimate for the liquid head – engineers will also calculate the friction added by the piping and air diffusers



Poll 3

What air pressure is equivalent to a liquid head of 10 feet?

- a) 43.3 psi
- b) 23.1 psi
- c) 4.33 psi
- d) 2.31 psi

$$10 \text{ feet} \div 2.31 \text{ ft/psi} = 4.33 \text{ psi}$$

Improved efficiency of pumps and aerators

Measure with kWh used per MG of wastewater pumped or treated.
Unit is kWh/MG.

An aeration system used 260 kWh per MG of treated wastewater prior to optimization. Operators took the following actions:

- (1) Adjusted the impellers
- (2) sealed leaks in air piping
- (3) installed VFD controllers and D.O. sensors
- (4) installed a fine bubbler system.

After optimization, the system now uses 175 kWh per MG of treated wastewater.

% efficiency increase: $\frac{260 \text{ kWh/MG} - 175 \text{ kWh/MG}}{260 \text{ kWh/MG}} \times 100\% = \mathbf{32.7\%}$



Wire to Water Efficiency

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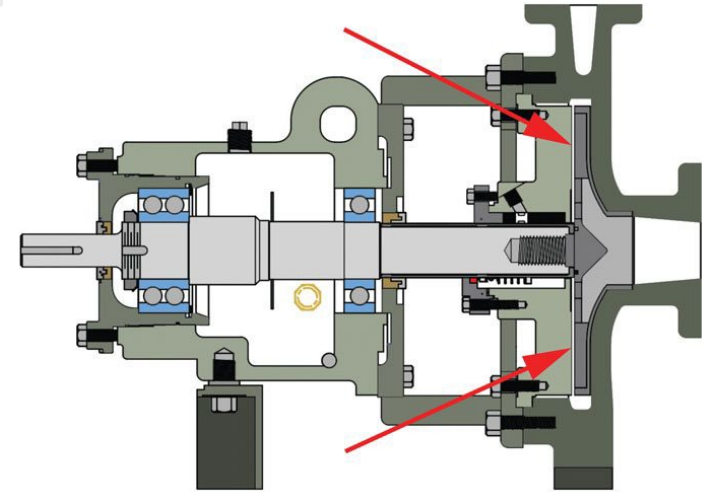


Compare over time!

Factors that can cause efficiency loss

Mechanical & Hydraulic Losses

- **Impeller Clearance:** Excess clearance allows internal recirculation
- **Cavitation:** Distorts hydraulic flow and damages the impeller
- **Friction:** Worn bearings and damaged seals convert motor power into heat
- **Shaft Misalignment:** Vibration and physical binding lead to power losses
- **Foot valve problems:** Clogging or leakage



Clearance between the impeller and casing. Can lose efficiency if the gap increases just 0.005 inches.

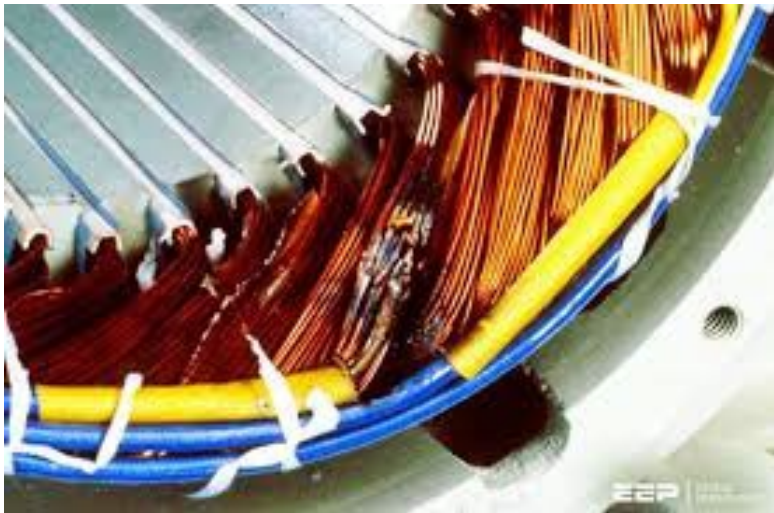


Cavitation damage to the impeller

Factors that can cause efficiency loss

Electrical & motor Losses

- **Insulation resistance loss:** creates internal short circuits.
- **Power Imbalances:** Voltage or amperage imbalances
- **Corroded electrical connections:** Increased resistance and lower voltage.

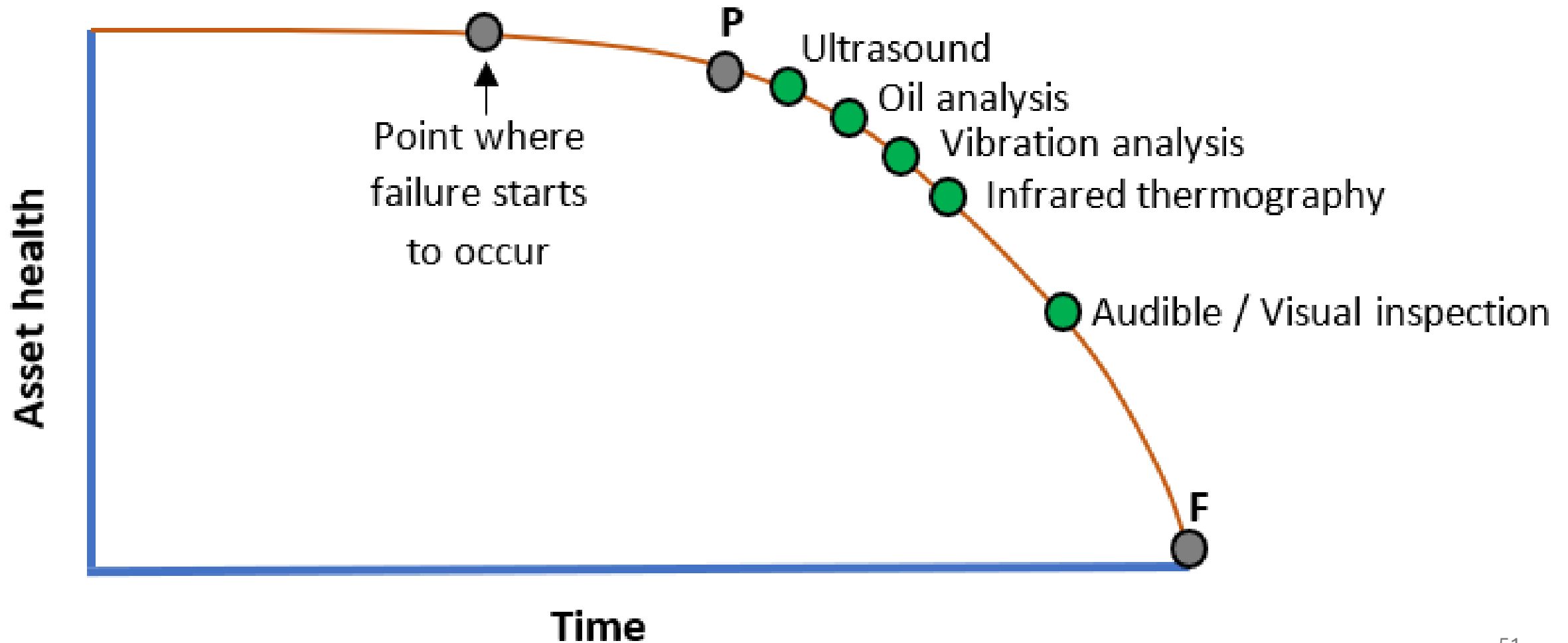


Failed insulation led to a short



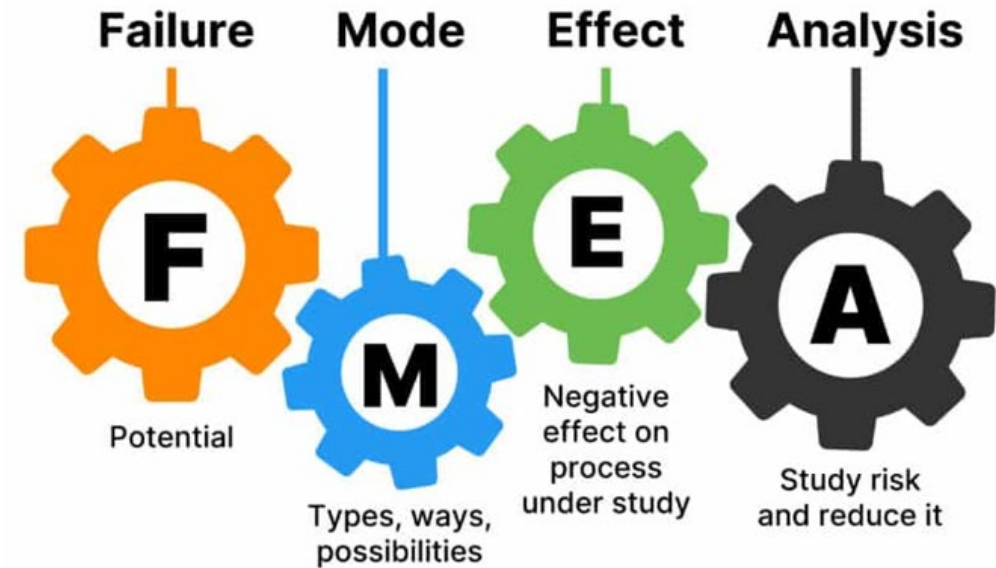
Corroded electrical connections

Predicting motor and bearing failures



Failure Mode Effect Analysis

1. **Failure:** Types of failures that can occur
2. **Mode:** Ways that assets can fail
3. **Effect:** The effect of each type of failure
4. **Analysis:** Risk levels and mitigation strategies



Articles to learn more

Failure Mode Effect Analysis Examples and Explanations. <https://upkeep.com/learning/fmea/>

Failure Mode and Effects Analysis (FMEA) vs. Root Cause Failure Analysis (RCFA). <https://www.maxgrip.com/resource/article-failure-mode-and-effects-analysis-fmea-vs-root-cause-failure-analysis-rcfa/>

Failure Mode and Effects Analysis. <https://reliability.com/resources/articles/fmea-guide/>

Four Types of Analytics and What They Mean to Asset Management. <https://www.prometheusgroup.com/resources/posts/four-types-of-analytics-and-what-they-mean-to-asset-management>

FMEA: How to Use Failure Modes and Effects Analysis to Choose Sensors for Condition Monitoring. <https://el-watch.com/fmea-failure-modes-effects-analysis/#:~:text=How%20FMEA%20Data%20Informs%20Predictive,unnecessary%20tasks%20and%20associated%20costs.>

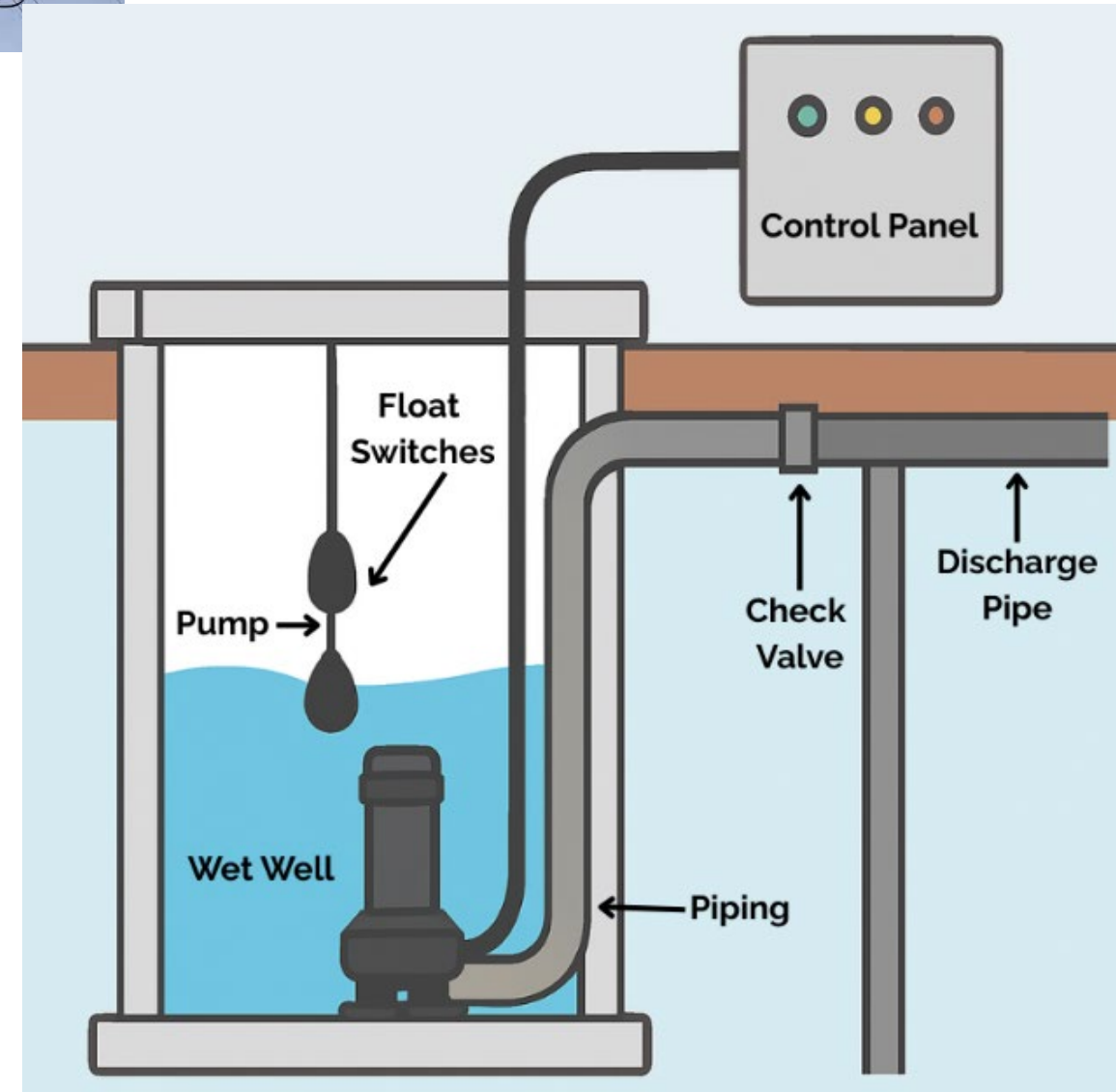
Lift station system



1. Electrical service to panel
2. Level float switches
3. Control Panel (relays, pump starters, alarms, level control sensors)
4. Pump Motor (windings, bearing)
5. Pump (impeller, bearings, casing)
6. Force main piping
7. Force main check valve

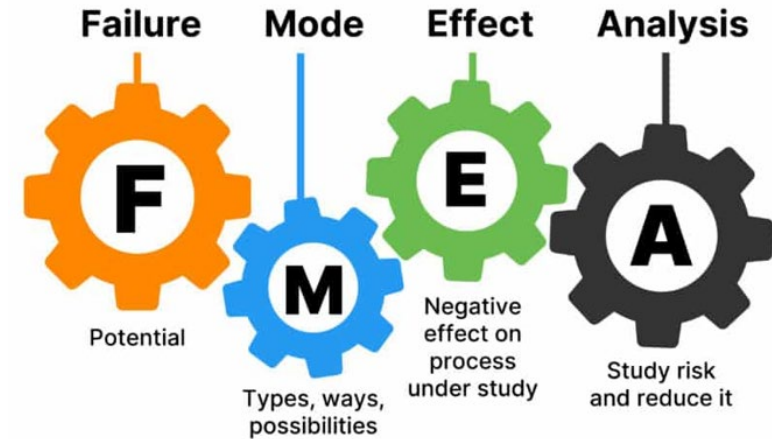
Inquiries

- i. What are critical points in the system that could cause the entire system to fail?
- ii. How can you prevent or mitigate asset failures?
- iii. How can you detect problems early?



Failure Mode Effect Analysis

1. **Failure:** Types of failures that can occur
2. **Mode:** Ways that assets can fail
3. **Effect:** The effect of each type of failure
4. **Analysis:** Risk levels and mitigation strategies



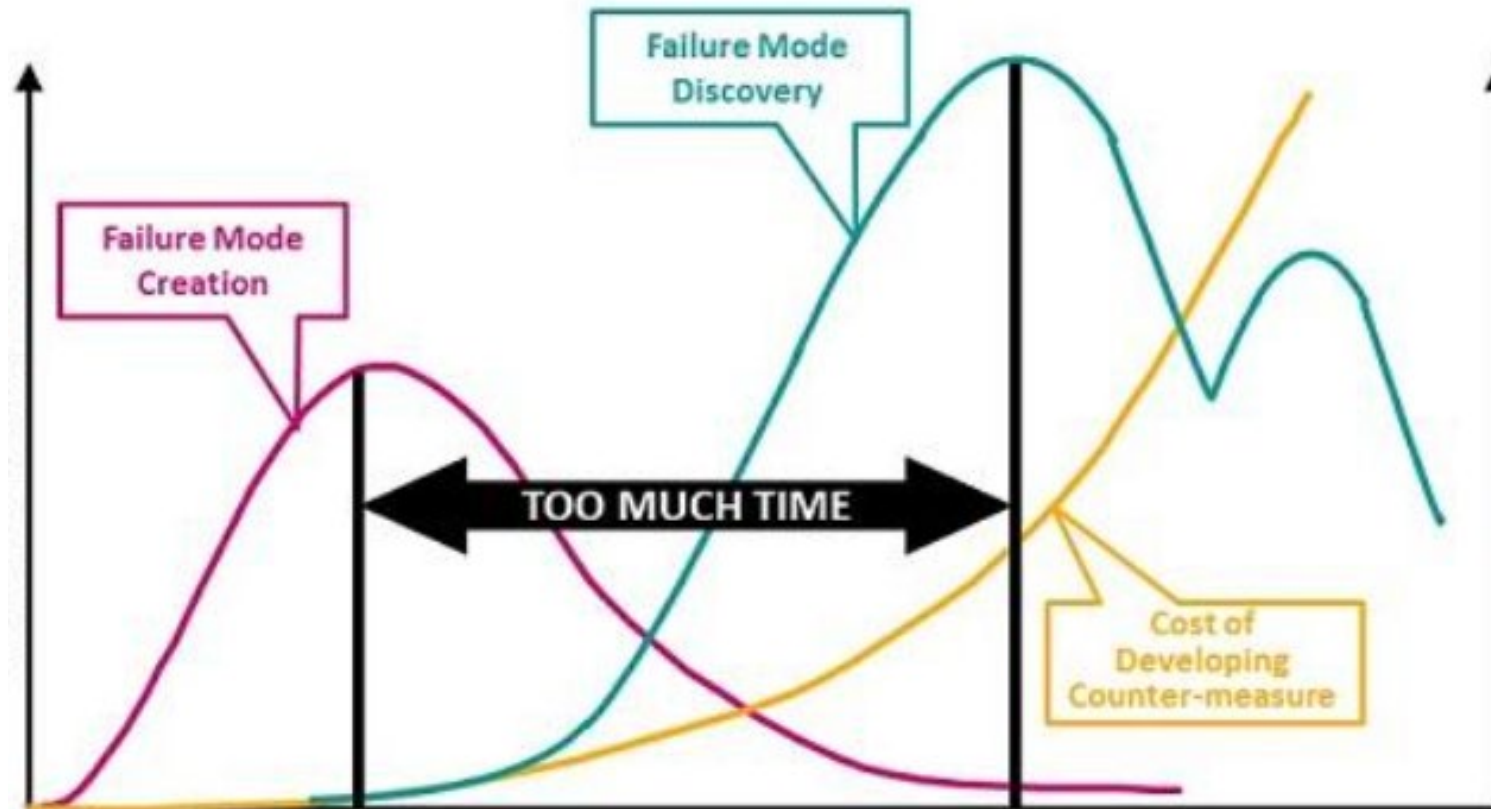
Lift Station Failure Types

- Sanitary sewer overflows
- Backups (basement floods)
- Pump clog or failure
- Force main check valve fails
- Motor or bearing failure
- Inflow exceeds capacity
- Sensor or control system failure
- WW release into water bodies

Lift Station

Component	Type of failure	Effect
Electrical service	Imbalances/ high or low voltages	Motor damage
Electrical panel	Poor connections/relay failure	Breaker trips, eff% loss
Floats or sensors	Float switch damage or fatigue	No pump control, SSO
Motor	Overheat, bearing, amp imbalance	Motor damage, outage
Pump	Impeller damage, clogs, cavitation	Eff% loss, outage
Force main	Leaks or clogs	SSO, eff% loss
Check valve	Stuck partially open, clogs	SSO, eff% loss

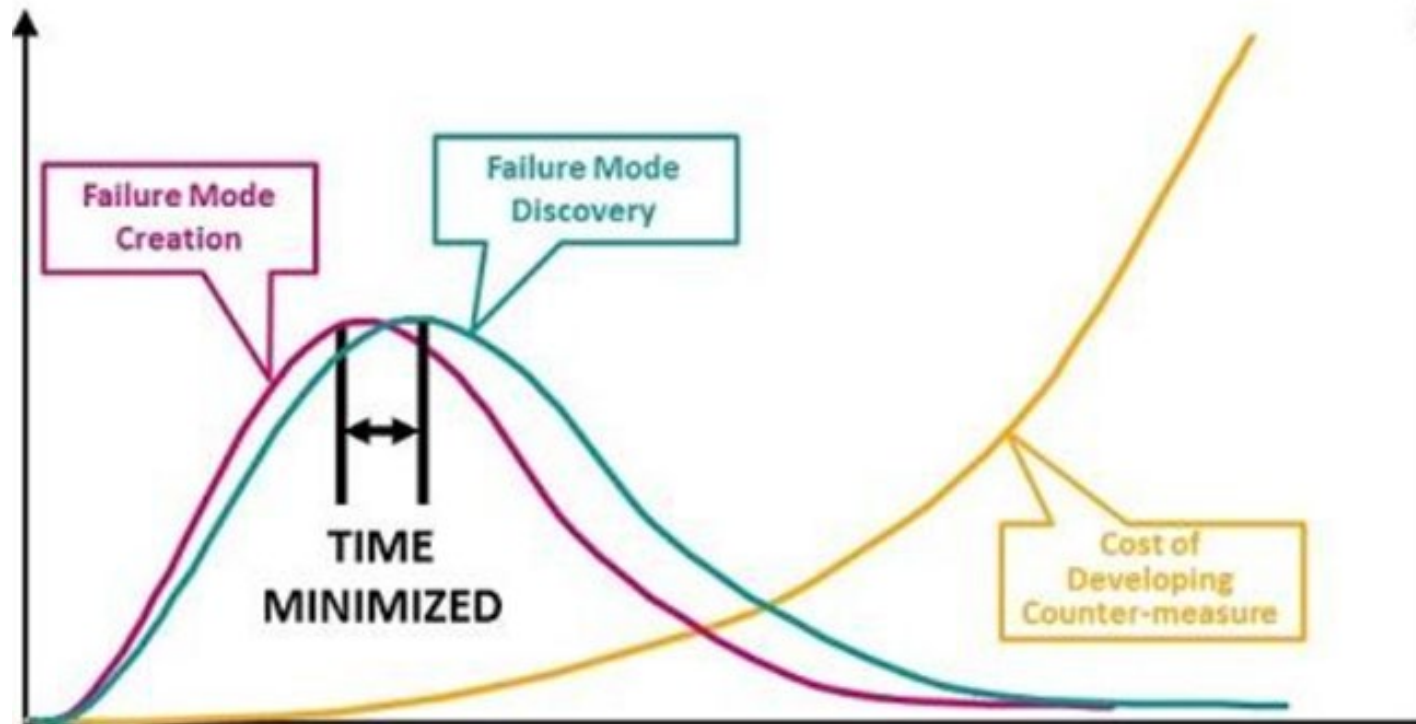
Detecting impending asset failure



By the time there is obvious overheating, noise, or vibration, it is often too late to prevent significant damage.

Example: A bearing fails in a pump motor. By the time it becomes obvious (because of vibration and noise), the casing and wiring are already damaged due to overheating. Therefore, the entire pump needs to be replaced.

Detecting impending asset failure



These are just two examples of how failure mode analysis can be used to mitigate potential failures for a multiple component asset. **What else could we do?**

For critical asset failure modes, sensors and inspection methods can be implemented for earlier detection and repair before damage occurs.

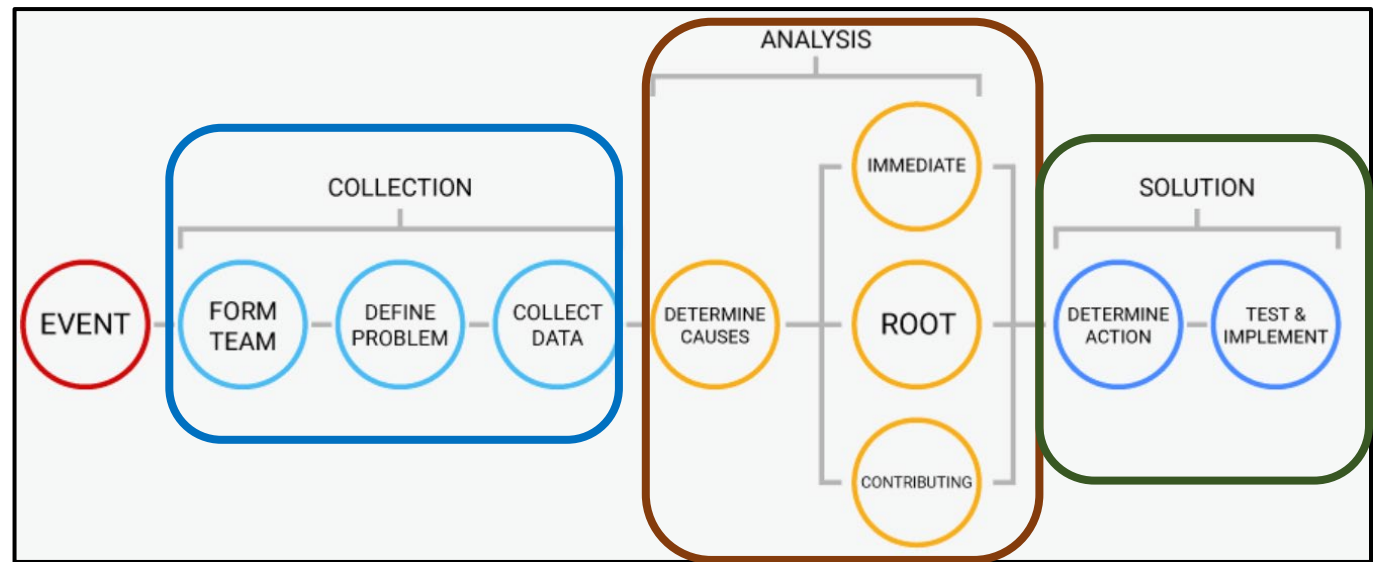
Example: For a lift station pump motor

- **Bearings** can be periodically assessed with ultrasound, vibration analysis, or infrared heat detection and replaced before they fail.
- A **motor protection relay** can be integrated to create an alarm when there is overheating or an over-amperage current draw.

Root cause analysis

A breakdown, outage, or other event occurs.

- Lift station pump fails and causes an SSO



The problem is investigated

- Operators pull the pump, check pump, motor, power, and control systems

The cause is determined

- **Voltage imbalance** led to motor overheating
- **Root Cause** was initiation of other nearby equipment on same circuit causing a voltage imbalance.
- **Factors:** Immediate factor - existing amperage imbalance and Contributing factor - failing motor bearing.

Poll #1

Solution(s)

1. Use a dedicated power source to operate lift pump
2. Routinely check and correct amperage imbalances
3. Routinely monitor bearing (ultrasound, vibration analysis, infrared heat sensing)

Regular processes for:

- Checking electrical input
- Monitoring amperage and voltages
- Assessing bearing condition

Change in culture

Condition assessment can help utilities make informed infrastructure decisions and prevent system problems

"We were just reading about a waterborne illness caused by a sanitary sewer overflow that occurred in a nearby town. A lift station motor malfunctioned. What can we do to prevent that from happening to us?"

"Perhaps the first step is to develop a condition assessment program so we can target resources toward prioritized maintenance & rehabilitation"

"Yes, I see here that there are several methods we can use to assess our pumps and motors"



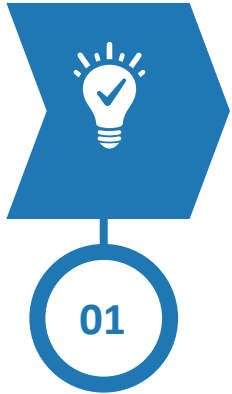
Our brains can only hold **3 to 5** things at once before they start tuning out.

So how do we get the important stuff to stick?

DISTILL IT DOWN to 3.

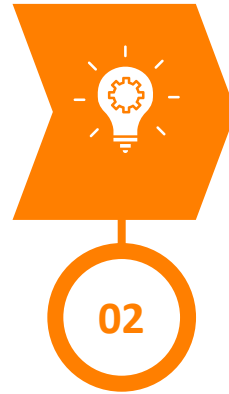
Main Takeaways

If you remember nothing else, remember these 3 key points...



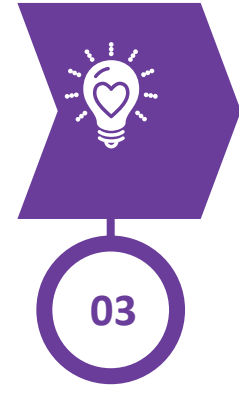
Asset Management

Condition assessment helps us gather information about maintenance, repair, or replacement needs of assets. It also provides data needed to prioritize resources.



Electrical Measurement

Amperage and Voltage imbalances help us gain insight into the operating conditions of pumps and motors. Megaohm readings provide information about the insulation integrity.



Analysis

Both Effect and Root cause analysis methods help us to develop a mitigation and monitoring plan to prevent asset failure

Thank you for participating!



Share in the chat, something you learned about today that you plan to put into practice at your utility

We're now open for questions!

