# CENTRIFUGAL PUMPS MAINTAINING THE INTEGRITY OF 3-A SSI STANDARDS FOR HYGIENIC EQUIPMENT

FAILURE ANALYSIS to FAILURE PREVENTION Jim McCormick

#### **IT BEGAN FOR ME IN 1986**

- COLIN ASKED ME, "WHAT DO YOU KNOW ABOUT PUMPS AND FILTERS"?
- "WHAT DO YOU KNOW ABOUT VALVES"?
- "TRY TO LEARN SOMETHING NEW EVERY DAY"
- CUSTOMERS DON'T OFTEN KNOW WHAT THEY WANT OR NEED. IT WILL BE MY JOB TO LEAD THEM TO THE END RESULT AND A SALE.
- ELBOWS
- WHAT ARE YOUR HOBBIES? IRISH DANCE



# THE ORIGINAL PUMP



#### WHAT HAPPENS WHEN THE PUMP STOPS PUMPING?

#### EVERYONE THINKS IT IS, BUT IT'S NOT ALWAYS THE PUMPS FAULT

- DESIGN FLAW
- WRONG SEAL FOR APPLICATION

"

"

- WRONG PUMP "
- WRONG MOTOR "
- OPERATOR ERROR
- INSTALLATION ERROR
- MOTOR FAILURE OR DAMAGE
- **DEFECTIVE COMPONENT(S)**
- IMPROPER TRAINING



### HOW MANY WAYS CAN A CENTRIFUGAL PUMP FAIL?

- When the Pump goes down, it all goes down.
- "We're out of business. Should I send my people home"?
- ROOT CAUSE
- EFFECT
- EVALUATION
- CORRECTION
- PREVENTION

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178



What Route did Failure Take in the Pump Set Cause and Effect Tree?

An Internet search by the Author for causes of centrifugal pump-set failures found 257 separate ways for the wetend to fail, 178 ways for a mechanical seal to fail, 52 ways for the shaft drive coupling to fail, 16 ways to fail the base, and 100 ways for the electric motor to fail.



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#### **ROOT CAUSE FAILURE ANALYSIS (RCFA)**

 Without having the failed item as evidence, it is a crazy and pointless task to investigate a failed pump because it could be anyone of 600+ causes. That is why the evidence is so vital in a root cause failure analysis (RCFA); only the evidence can confirm the actual route the failure took from cause to incident. Any RCFA done without the complete evidence is at risk of going off track and fixing a thing that did not cause the failure.

#### **MAINTENANCE STUDIES**

#### Key findings

- Respondents to the Plant Engineering 2016 Maintenance Study identified eight important, high-level findings impacting the manufacturing industries today:
- **Shutdown schedule:** Specialized production machinery and packaging systems are generally shutdown only once or twice each year for scheduled maintenance, while material handling equipment is typically shutdown four to six times each year.
- Maintenance support: Six in 10 survey respondents indicated that their facilities' rotating equipment receives the most maintenance support, followed by plant automation and fluid power systems.
- Unscheduled downtime: The most popular cause of unscheduled downtime within respondents' facilities remains aging equipment (50%), followed by operator error (15%) and lack of time (14%). Some facilities plan to upgrade their equipment and implement preventive maintenance strategies in an effort to decrease downtime.

#### **MAINTENANCE STUDIES P.2**

- **Training:** Three in five respondents indicated that their maintenance teams receive basic mechanical and electrical skills training. Other types of training include motors, gearboxes, bearings (54%) and lubrication (53%).
- **Technologies:** The top three types of technologies facilities use to monitor/manage maintenance are CMMS (*computerized maintenance management system*) (62%), inhouse spreadsheets/schedules (52%), and paper records of maintenance reports (39%), 1% noted on a cocktail napkin.
- **Outsourcing:** The average facility outsources 22% of their maintenance operations.

#### TROUBLESHOOTING GUIDELINES

pumps are relatively maintenance free with the exception of sanitizing. Like any piece of machinery, however, occasional problems can arise. This section provides a means of determining and correcting most of your pump problems. The motor manufacturer should be contacted for specific repair instructions on the motor.

The chart below has been prepared on the basis that the pump is properly suited to its application. Should problems arise where the remedies listed below chart do not cure the situation, pump cavitation may be the problem. Symptoms of pump cavitation, such as noisy operation, insufficient discharge and vibration, can result when a pump is not properly applied. If these conditions are present, check the system and re-evaluate the application. If assistance is required, contact

	PROBLEM	PROBABLE CAUSE	REMEDY
1.	No discharge.	<ul> <li>a. Pump speed too low.</li> <li>b. Wrong direction of rotation.</li> <li>c. Closed valve; obstruction in discharge piping.</li> </ul>	<ul> <li>a. Correct wrong or poor electrical connections.</li> <li>b. Reverse a three-phase motor by switching any two of the three power leads at the motor controller; reverse a single phase motor per motor manufacturer's instructions.</li> <li>c. Open gate valve; clear obstruction.</li> </ul>
2.	Insufficient discharge.	<ul> <li>a. Pump speed too low.</li> <li>b. Wrong direction of rotation.</li> <li>c. Valve partially closed; obstruction in discharge piping.</li> <li>d. Impeller damaged.</li> </ul>	<ul><li>a. See 1a above.</li><li>b. See 1b above.</li><li>c. See 1c above.</li><li>d. Replace impeller.</li></ul>
3.	Excessive power consumption.	<ul><li>a. Motor speed too high.</li><li>b. Impeller is binding.</li><li>c. Motor shaft is bent or worn.</li></ul>	a. Internal motor wiring is incorrect; replac motor.     b. Relieve strain on casing replace defective impeller.     c. Replace shaft.
4.	Pump is noisy.	<ul> <li>a. Magnetic hum in motor.</li> <li>b. Motor bearings are worn.</li> <li>c. Foreign matter is rotating with impeller.</li> <li>d. Impeller is binding.</li> <li>e. Cavitation</li> </ul>	<ul> <li>a. Consult motor manufacturer.</li> <li>b. Replace bearings.</li> <li>c. Remove casing and remove foreign matter.</li> <li>d. See 3b above.</li> <li>e. Improper sizing or piping, etc.</li> </ul>
5.	Excessive vibration.	<ul> <li>a. Pump is not leveled properly.</li> <li>b. Impeller is damaged.</li> <li>c. Piping is not supported.</li> <li>d. Cavitation</li> </ul>	<ul> <li>a. Level pump.</li> <li>b. Replace impeller.</li> <li>c. Support discharge and suction piping.</li> <li>d. Improper sizing or piping, etc.</li> </ul>
6.	Pump leaks.	a. O-ring seal is worn or defective. b. Carbon seal is worn. c. Insufficient compression on seal assembly. d. Damaged inlet or outlet. e. Backplate gasket is worn. f. Clamp is loose.	a. Replace o-ring seal. b. Replace carbon seal. c. Replace spring. d. Replace casing. e. Replace gasket. f. Tighten clamp.

#### THE MANY CAUSES OF PUMP (and MOTOR) FAILURE

#### **Mechanical Failures Due to Design Flaws**

- Shaft misalignment, coupling imbalance, and impeller imbalance can all contribute to mechanical seal failures. In addition, after the pump is installed, if you have misaligned pipes bolted to it, you will impart a lot of strain on the pump. You also need to avoid a bad base: Is the base secure? Is it Level? Is it grouted properly? Is it bolted correctly? Keeping the rotational parts aligned is paramount to minimizing pump failure. Check rotation with a Dial Indicator when servicing the pump.
- Other causes include high viscosity media, operating too far from the BEP. will shorten motor life, misapplied seals and/or elastomers.

# "WHY SO MANY QUESTIONS? ALL I WANT IS A PUMP"

- The first task in sizing the proper pump is to obtain as much information about the client's application as possible. Let's review some of the data we request and why it's important.
- Flow Rate Usually one of the first and most important required data, because in certain environments like breweries, for example, there may be a need to run the pump at a lower speed to prevent damage to the product, but require a high speed for CIP. This is accomplished with the use of an AC inverter, a.k.a. a VFD.
- **Discharge and Suction Pressures** must be calculated to get proper performance. This is the reason we ask questions like line size, vertical and horizontal feet of pipe run, number of elbows, tees and reducers, presence of spray balls, filters, heat exchangers, etc. All of these factors combined tell us the friction loss in the application and is calculated and converted into TDH, or total head-in-feet. The source of the liquid entering the pump inlet, like from an open tank, is critical to ensure it will be adequately feed to the pump.

#### ..... MORE QUESTIONS

- Fluid Information will assist us in selecting which pump is best suited, Rotary Lobe, Piston, or Centrifugal Pump.
- <u>Temperature</u> Selecting the right seals and elastomers for each application, will result in minimal maintenance and down time. In the case of Positive Displacement Pumps, it could also determine if the possibility of thermal expansion exists, in which case, undersized rotors would come into play.
- Seal Type is an important choice for the long-term performance and reliability of the pump selected for your application. Is the fluid abrasive or tacky? Does it "set-up" and crystalize when cooled? Single mechanical or double mechanical, carbon or silicon carbide material. FKM, EPDM or Buna? We will help you make the right selection. The primary reason seals fail is improper seal selection. Selecting a seal of improper geometrics can result in abnormally high friction and wear. In short, improper material selection can result in material failure or accelerated wear, causing costly down time and emergency parts purchases.

### ..... AND STILL MORE

- <u>Viscosity</u> is important information to the determination of what type of pump to use. Higher viscosity liquids won't move with a centrifugal pump and extremely high fluids may even cause suction problems which need to be considered.
- **Specific Gravity** is necessary in determining pump model selection as well as power required to run it.
- Solids, Sugars or Abrasives All have an effect a pump.
- **Power Requirement** accuracy is essential and we will determine the horsepower and speed requirements for you. What is often left unknown or unspecified is what type of motor enclosure is required. We offer Premium Efficient TEFC, wash down, stainless steel wash down, or explosion proof enclosures as well as special service motors like 575volt and 50Hz power.



#### **CAN PUMP FAILURES BE ELIMINATED?**

Absolutely NOT. It's Only a Matter of Time

70% of pump failures resulting in downtime are the result of seal malfunctions.

All Single Mechanical Seals leak—they have to in order to maintain a fluid film over the entire mechanical seal face. The leakage that comes out the atmospheric side is VERY low. The atmospheric side must not enter into the seal chamber.

Anyone who works with pump sales and engineering knows that when any kind of anomaly occurs anywhere in the system, it's got to be the pumps fault.

#### **DESIGN CONSIDERATIONS**

- You may need a proper seal flush arrangement, along with sufficient cooling. Dual systems have barrier fluids; the auxiliary seal pot needs to be in the right location, with the correct instrumentation and piping.
- You need to take the Length of Straight Pipe at Suction into account—some pump systems that often come as a packaged skid include a 90° elbow at suction right before the flow enters the impeller eye. They do this to make the skid more compact. The elbow causes a turbulent flow that creates friction in the suction line which can cause vibrations, cavitation, noise, poor performance, damage to equipment and/or product.
- All the suction/discharge and bypass piping needs to be engineered correctly as well, especially if some pipes have been repaired at some point over the years. All piping must be properly supported and drainable.
- For hot and or abrasive content fluids, seals may perform better and last longer with the use of a simple Water Cascade assembly.
- Elevation is to be considered regarding boiling point. At ) to 400 ft. BP is 212 (F). At 3,500 ft. BP is 205.6 (F), 7,000 ft BP is 198.2 (F). When water temperature exceeds boiling point, it turns to vapor. Vapor is a gas and cannot be pumped, thereby causing cavitation which can lead to catastrophic failure. As elevation rises, pressure decreases.

#### **TYPICAL WATER CASCADE ASSEMBLY**



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### **SEAL FAILURES**

- A mechanical seal is a device that is used to control leakage between a rotating shaft and a liquid
- Before mechanical seals were developed, engineers typically sealed a pump with mechanical packing. Mechanical packing, a fibrous material usually impregnated with a lubricant such as graphite, was cut into sections and stuffed down what was called a "stuffing box." A packing gland was then added to the backside in order to pack everything down. Since the packing is in direct contact with the shaft, it requires lubrication, but will still rob horsepower.
- An eroded, worn, or fretted dynamic O-ring (or gasket) as the mechanical seal moves.
- Dirt or contamination in between the mechanical seals. Diatomaceous earth, silicon dioxide
- An off-design operation within the mechanical seals.
- If the centrifugal pump exhibits an uncontrolled leak, you must thoroughly check all potential causes to determine if you need repairs or a new installation. If this does not correct the leaking issue, call Jim McCormick and complain vehemently.
- Running a centrifugal pump dry, will result in cavitation and damage the pump. Starting with the seal.

#### **OPERATIONAL FAILURES**

- Neglecting the Best Efficiency Point: Are you operating the pump at the Best Efficiency Point (BEP) on a performance curve? Each pump is designed with a specific Efficiency Point. When you operate the pump outside that region, you create problems with the flow that cause the system to fail.
- Insufficient Net Positive Suction Head (NPSH): If you don't have enough suction head to your pump, the rotating assembly can become unstable, cause cavitation, and result in a seal failure.
- Operating Dead-Headed: If you set the control valve too low to throttle the pump, you can choke the flow. Choked flow causes recirculation within the pump, which generates heat and promotes a seal failure.
- Dry Running & Improper Venting of Seal: A vertical pump is the most susceptible since the mechanical seal is positioned on top. If you have improper venting, air can get trapped around the seal and won't be able to evacuate the stuffing box. The mechanical seal will soon fail if the pump continues to run in this condition.

#### **SOME FUN FACTS**

#### • 4,840,000 EVERY BUSINESS DAY

#### \$40 BILLION ANNUALLY

#### **FUN FACTS**

 4,840,000 PER DAY Is the estimated number of Next Day and Two day <u>packages</u> domestically combining FedEx, UPS and DHL. *Does not include envelopes*

• \$42 BILLION ANNUALLY The estimated amount spent on those shipments, domestic only. *Excluding envelopes* 

Source: Google Business and Money

What are your numbers?

# PREVENTIVE OR CORRECTIVE MAINTENANCE – HOW CAN WE MINIMIZE DOWN TIME?

- As stated earlier, there is no way to guarantee complete elimination of pump failure. It's only a matter of time.
- Ask your Pump provider for a detailed "Recommended Spare Parts" list.
- Keep your parts and supply room well stocked with the "Recommended Spare Parts"
- Keep a spare of any critical complete pump and motor. It could be new or reconditioned.
- Make sure your maintenance staff are well trained in the operation and maintenance of ALL PUMPS in your facility.
- Ask your Pump provider if they offer "On Site Maintenance Training" where a technical person comes to your facility. Very valuable tool. Make sure they bring pizza for staff.
- Keep records of ALL your pumps individually by Brand Name, Model Number or Serial Number, Location in the plant. These records can be kept on Excel spread sheets, computerized maintenance management software (CMMS), root cause failure analysis (RCFA) forms.
- Look for "trends" on each pump and motor. Log them, track them. This may bring to light an issue in the systems that needs to be addressed.
- Plantwide Preventive Maintenance programs can save tens of thousands of dollars annually in down time.
- For information and sources for CMMS, go to <a href="https://www.softwareadvice.com/cmms/">https://www.softwareadvice.com/cmms/</a>

#### **MECHANICAL SEAL FACES**

- Mechanical seal choices have become increasingly popular in the Pump industry. Many companies develop a set of pump seal specifications to make it easier for their people to select one or more seals for an application. The lack of a company specification can cause problems with inventory, installation and interchangeability of seals. Many plants are accepting seal components with unidentified and/or inferior materials, making troubleshooting a nearly impossible task for them.
- Carbon Carbon Graphite
- Carbon seals. The old standby. Carbon, or Carbon Graphite seals offer the greatest economy and lubricity for sealing non-abrasive products. It's good for clean, abrasive free materials. It self-lubricates to reduce heat and extend service life. It works great with all other seal materials.

#### **MECHANICAL SEAL FACES**

- Ceramic –
- Generally, a 99.5% aluminum oxide offering excellent wear characteristics due to its hardness. It is chemically inert and can be applied to nearly any product. In the sanitary environment, Ceramic offers the best resistance to sticky liquids like syrups. <u>Ceramic cannot however handle the thermal shocks.</u> It has zero tolerance for thermal expansion and easily cracks or shatters. Like most other materials, it wants to expand with the heat, but it cannot. Ceramic is much more resistive to abrasive materials than carbon. It's wear resistant, corrosion resistant, and cheap. It is most commonly paired with carbon. It is limited only by extreme heat.

### **MECHANICAL SEAL FACES**

#### Silicon Carbide –

- Is a bluish-black material created by fusing silica and coke. It is in the same family as Ceramic (due to the Silica), but has much better lubrication qualities and is harder. It contains no silicon that can leach into the process, is excellent in an oxidizing environment, and has good thermal shock resistance due to low thermal expansion coefficient and high thermal conductivity.
- In summary, silicon carbide's combination of hardness, strength, and temperature resistance gives it excellent capabilities for services in a wide range of applications where high speeds, high pressures, and chemical and abrasion resistance are required.

#### **SEAL SELECTION**

- A good company specification for pump seals will include the following:
- -- Pump Seal materials with the widest range of chemical compatibility,
- -- Pump Seals that are easy to install,
- -- Pump Seals with features that make seal repair easy and low cost,
- -- Pump Seals that require the least amount of inventory and spare parts,
- -- Pump Seals that operate over a wide range of temperature, pressure and speed, and
- -- Pump Seal designs that allow the easiest conversion of packed pumps to pump seals

From an article from American Seal and Packing Co.

- WHAT IS THE LIFE CYCLE OF O-RINGS, GASKETS AND SEALS?
- WHO CAN CLAIM THAT ALL APPLICATIONS ARE THE SAME?
- IS 40 deg. RAW MILK GOING TO REQUIRE THE SAME SPECIFICATION CRITERIA AS 210 deg. ABRASIVE SLURRY OR SUGARY FLUID?

### SO, WHO IS RESPONSIBLE FOR MAINTAINING THE INTEGRITY OF 3-A SSI FOR PUBLIC HEALTH ASSURANCE?

ANSWER.....

# WE ALL ARE. THROUGH COMMUNICATION AND EDUCATION

- MANUFACTURERS / FABRICATORS EDUCATE AND TRAIN DISTRIBUTION BASE AND KEEP THEM INFORMED OF ANY AND ALL DESIGN CHANGES. OFFER IN HOUSE OR ON-SITE TRAINING OF DISTRIBUTORS AND END USERS.
- **SANITARIANS** COMMUNICATE CONCERNS AND MAKE RECOMMENDATIONS TO 3-A FOR REVIEW. CONTINUING EDUCATION.
- DISTRIBUTORS / DEALERS PROVIDE CONTINUING EDUCATION AND TRAINING FOR SALES, ENGINEERING, APPLICATIONS AND TECHNICAL STAFFS. PROVIDE ONSITE TRAINING FOR END USERS, ETC.
- END USERS MANAGEMENT SHOULD TRAIN MAINTENANCE TO LOOK FOR TRENDS AND CREATE A PREVENTIVE MAINTENANCE PROGRAM AND DON'T DEPEND ON "USE TO FAILURE" METHOD. ASK YOUR DISTRIBUTOR/DEALER TO PROVIDE A "RECOMMENDED SPARE PARTS" PROGRAM, BASED ON THE TOTAL NUMBER OF SPECIFIC EQUIPMENT.

#### **FINAL THOUGHTS**

- Mechanical seals are a major factor in rotating equipment reliability. They're responsible for leaks and failures of the system, but they also indicate problems that would eventually cause serious damage down the road. Seal reliability is greatly affected by the seal design and the operating environment.
- Implementing a preventive maintenance plan can be a daunting task if not approached the right way. Setup quick and easy tasks that can result in wins with a measurable ROI.

#### **CAN ANYONE TELL WHAT THIS PICTURE IS?**



