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IMPROVING THE USE OF PLANT OPERATORS

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ABSTRACT

Every plant has operators. They may be an untapped resource to improve reliability at a marginally low cost. The operators believe it's their job is to make good product, do it safely, and prevent environmental excursions. It is. However, management also expects them to detect problems early, gather operating data and do troubleshooting.

INTRODUCTION

Every plant has operators. They may be an untapped resource to improve reliability at a marginally low cost. The operators believe it's his job is to make good product, do it safely, and prevent environmental excursions. It is. However, management also expects them to also detect problems early, gather operating data and do troubleshooting. Yet many operators are not taught how to gather data or troubleshoot. They are generally not given the training or tools that would allow them to perform these types of tasks. Training on how to interpret pump curves or to properly inspect and troubleshoot rotating equipment are not always provided; but this should be changed.

If training the operator to gather data and troubleshoot can eliminate or reduce the cost of maintenance by detecting a problem early that results in even 10% of repairs that could be avoided, or reducing chronic problems, the savings would be staggering. Many times, the method of troubleshooting for maintenance and operators is to change parts until the problem is eliminated. It works but is very expensive!

This tutorial is short and will primarily deal with pumps and seals. No matter how good your pump rebuilding capabilities are, nor how correctly the overhaul is done the operator, through lack of knowledge, can cause equipment to be damaged or fail prematurely. Several days of training, ideally on a mixture of seasoned and new operators would result in the maximum benefit to the plant.

The purpose of this tutorial is to suggest there are areas of training and utilization of operators that are not presently being taken advantage of. Everyone thinks operators are troubleshooting effectively and doing vigorous visual, audible, and tactile inspections of operating equipment in the plant. My experience and others who I have talked with indicate that this is not true. Many operators do not understand lubrication, or how their equipment operates. They do not understand the relationships of pressure, flow, NPSH or horsepower, in pumps.

This tutorial will suggest areas where operators can be taught to identify problems early and how to relate it to equipment failures. Examples will be given to illustrate the techniques and benefits presented here. It is essential to have everyone understand that the way business was done in the past is in the past. The new normal needs to be taught and then enforced to have the changes accepted.

Items that will be covered are:

- Look, listen and feel
- Applying look, listen, and feel to troubleshooting
- Why the operator is important to troubleshooting
- Operator tools
- Operator understanding of the equipment – pumps, seals and sealing support systems with examples
- A list of some equipment problems that overhauling a piece of equipment will not solve
- Operators should have input on capital projects
- Writing quality work requests

Look, listen and feel

It is believed that operators already practice this inspection technique during walk around readings and inspections. It is true that some are very good at inspections, but the majority are not. They tend to walk through the plant and see the same thing over and over. Many times, unless sparks are flying, or smoke gets out of the machine operators may not notice key inspection clues. If things are changing very slowly they may not notice it at all. (Boiled frog syndrome)

Apply look, listen, and feel to troubleshooting

The question seems never to be asked, “If you see something, as in 1a, what caused that and what would be the results if nothing was done?” In this example if an operator was walking by the tank would he notice the black mark on the tank, Fig 1a? If he did, would he look for the cause in 1b? It should be obvious that the hose was rubbing on the tank and eventually the hose would fail. The root cause is the hose is too long and rubbed the tank when pressured. The hose needed to be shorter to prevent the rubbing. If that is not possible because the equipment would have to be taken out of service, then perhaps the hose could be protected with an abradable wear cover to prevent failure. Remember it is not always possible to solve the root cause of a problem in which case acceptably treating the symptom is adequate.

Why the operator is important to troubleshooting

Operators can add information to the work request that will make it easier to troubleshoot the problem or know what to work on. For example, if a specific problem happens repeatedly to a piece of equipment after a plant upset, temperature excursion, wash down, or some other recurring activity, the operator is likely the only person to detect the relationship of plant occurrence and equipment failure, if he is attentive. Operators may gather valuable information that no one else has. For example, bearings may be installed in the pump correctly, but they are still failing after a wash down for a product change. The mechanic gets the “bad press” even if he has done everything correctly because he was the one who installed the bearings and they failed. The operator can help solve the problem by identifying this cause and effect relationship. An attentive operator will know what the noise, temperature, vibration, smell etc. was yesterday, last week, and last year so changes can be detected and investigated.

An example would be a foaming oil reservoir. The operator may ask an “expert” is that OK? If it was like that yesterday, last month, last year and we are having no issues with the piece of equipment then yes, the foam in this case is acceptable. However, that does not mean that this would be OK in every piece of equipment all over the plant. It means in this piece of equipment, in this service in this part of the plant it is acceptable.

Operator tools

Operators should be given some tools to help quantify the inspection results they find. For example, touch will tell you something is hot, but that measurement is very subjective. How hot is it? Everyone may not feel the same "hot". Many companies give their operators an infrared temperature sensing device in the form of a small hand-held tool as in figure 2. They do not teach the operator its limitations, so many times the readings are suspect or even useless. For example, these devices read averaged temperatures in a cone. That is the further away from what you are measuring the more area is averaged into your reading. Most have a laser dot to help aim the measuring device. The laser dot is the center of the cone of measurement, not the spot being measured. As an example, there was a supervisor that wanted temperature measurements taken on conveyer bearings near the ceiling, about 20 feet in the air. He did not want his employees standing on ladders or scaffolding to take the measurements. He never detected a failure because at 20 feet, there was so many things being averaged in, the hot bearing was never detected.

The devices measure the first object closest to the infrared gun. If there is glass between the gun and what you want measured on the other side of the glass only the glass will be measured, even if the laser spot is on the item on the other side of the glass. There was another supervisor that wanted temperature measurements on equipment protected by Plexiglas. He did not want his employees' hands near the operating equipment. He purchased IR guns and asked his employees to take measurements. They put the laser dot on what was to be measured but never detected a problem.

The use of this type of temperature measuring device requires four things:

1. Measure as close to the measuring point as you can.
2. Have nothing between the measuring point and the IR gun.
3. The measuring point should be flat black in color for the most accurate readings. Ideally a flat black paint spot should be sprayed on the equipment as the measuring point. That also means everyone will take the measurements in the same place.
4. Use a piece of black or dark paper in the area of where the measurements are being taken to get an "ambient" temperature reading. You will be able to see how hot the equipment is compared to its surroundings, otherwise you are recording changes to the equipment itself. If the readings are taken one time in the dead of winter and then in summer, there will be differences in the temperatures measured but it may not indicate an equipment problem.

Many operators are not taught limitations of temperature for lube oil. The same situation exists with vibration pens or vibration limits. No matter how simple the tool is for operators, it must be explained, demonstrated and limits must be given for the tool, along with acceptable limits for the equipment.

One company started using a data gathering tool to collect data on equipment. One of the data measured was vibration. The data gathering device had alert settings programed into it. Plant procedure required a call to the vibration department for a second reading, data gathering, and analysis when the alerts were reached. The vibration department was getting many calls at all hours because of the many alerts. The problem was found to be inadequate training of the operators in the use of the tool. They were not told to place the probe on the equipment to be measured and let it settle, then push the button to take readings. When the button is pushed early and then the probe put on the equipment there was a large spike that resulted in the above normal vibration readings. After training, the number of calls for additional vibration data to be taken fell dramatically and there were usually problems found when the additional data was required.

These devices, in conjunction with logic diagrams can reduce overtime substantially. With a temperature detecting device, vibration detecting device, and a strobe, quality decisions can be made, and quantitative data can be obtained.

Most operators do not want to make the decision to leave a recently failed piece of equipment waiting for service during the off hours, i.e. 6 pm to 6 am, weekends or holidays. Even if the spare is performing perfectly with no indication of a problem. The result is an "emergency" work order written to have a failed piece of equipment fixed immediately. Most operators are not aware that management is willing to accept some level of risk for the second piece of equipment failing during this time. The result is that operators make "very safe" decisions so they are not "second guessed" on Monday for what happened over the off hours. This is very expensive. One company instituted a plan where decision trees were generated regarding centrifugal pumps. A contact pyrometer, vibration detection device, and limits were given and explained. The operators were trained on the tools use and told to follow the decision tree or be able to explain why it was not followed. This change made making a “good” decision easy. Two months after the implementation, the overtime dropped by 30%---very significant. Figure 5 is an example of a decision tree matrix that was used to achieve these results.

A strobe light is an excellent tool for doing field inspections while the equipment is running. Many problems such as broken fan blades on motors and finding impending coupling failures have been detected in this way. The source of seal leaks can be determined to be from the sleeve or the seal using this device.

Understand the equipment – pumps, seals and sealing support systems

Operators need to understand centrifugal and positive displacement pumps and their curves. Without the relationships demonstrated in the curves, it is not possible to adequately troubleshoot the equipment. For example, if the discharge pressure in a centrifugal pump is increasing, the flow will likely be decreasing. That does not mean the pump must be overhauled, but it does mean there is likely a blockage downstream as one example.

Figure 3 is an example of what can be taught to operators to explain the centrifugal pump curve in the simplest of terms.

In a hypothetical world, if the pump puts out 100 feet of head, and a hole was drilled at 100 feet, there would be liquid but no flow. If a hole was drilled down the pipe toward the pump 10 feet, there would be some flow, but 10 feet of head was lost. If holes were drilled every 10 feet down the pipe more flow would result, but continued loss of head. This shows the relationship between head and flow in a centrifugal pump in the simplest terms. Figure 4 shows all the interacting parts of the centrifugal pump curve. This information will help operators be part of the solution instead of handing the problem off to the engineering department or someone else.

Centrifugal pump Relationships to remember

Relationship of viscosity and head

- Viscosity up = Head down
- Viscosity down = Head up

Relationship of viscosity and horsepower

- Viscosity up = horsepower required for pumping up
- Viscosity down = Horsepower required for pumping down

Relationship of flow and head

- Flow up = head down,
- Head up = flow down

Relationship of flow and horsepower

- Flow up = HP required up,
- Flow down = HP required down

Relationship of flow and NPSHR

- Flow up = NPSHR up,
- Flow down = NPSHR down

Positive displacement pump relationships to remember

Viscosity to horsepower

- Viscosity up = HP required up,
- Viscosity down = HP required down

Flow and pump speed

- Speed up = flow up,

- Speed down = flow down

Speed and horsepower
- Speed up = HP up,
- Speed down = HP down

Speed and NPSHR
- Speed up = NPSHR up,
- Speed down = NPSHR down

Pressure and horsepower
- Pressure up = HP up,
- Pressure down = HP down

Many pieces of equipment get repaired when it is not necessary because little to no troubleshooting is taught or done, here is a list of some items that can affect a pumps performance that overhauling the pump will not fix.

- Plugged suction strainers
  Indication: Pump cavitates, sounds like gravel/marbles in the casing/ discharge gauges fluctuates and power draw is low. If there is a suction strainer there should be a way to know when it is filling.
- Closed valves
  Improper valve position or blocked piping with valve parts.
- Sediment in bottom of vessel blocking suction line
  Indication is the same as plugged suction
- Vortex breaker failed, covering part of the suction line in the vessel.
  Indication is the same as plugged suction.
- Not enough suction pressure
  Indicated by suction tank level low, or unusually high product temperature which causes pump to cavitate. If tank is pressurized to meet NPSHr requirements, is it at the correct pressure.
- Product too cold or too viscous
  Causes lower than design flow into the pump, which may not be enough to provide NPSHr. Too low a suction pressure for the pumps design causing the pump to cavitate
- Product too hot
  Causes the product to flash at suction pressure in the pump, causing pump cavitation or seal to run hot & fail)
- Air leaking into suction
  Can be caused by a flange leak, a drain valve on suction not closed completely, plug not installed in a valve on the suction line, opening somewhere on suction side of the pump if suction below atmospheric pressure. Will cause the pump to cavitate or will not prime or pickup suction.
- Check valve on standby pump leaking
  Indication is not enough flow or pressure from the pump. An indication might be the spare pump may be turning backwards.
- Pump turning backward (wrong rotation)
  Low flow and discharge pressure. Suspect any time the electrical system has been worked on or the motor changed.
- Wrong Pump Speed
  May be the result of the wrong motor speed being installed or if pulley driven the pulleys are on the wrong shaft.
- High discharge pressure and little or no flow.
  Blockage downstream of the pump. Indication would be no difference in discharge pressure with discharge block valve open or closed. If the stand by pump is started there is no change in operating conditions. There would be low power draw and if there was a discharge strainer installed they should be checked.
- Low discharge pressure

Too much flow being required from the pump. The flow rates required from the pump have been increased from the original design or maybe a bypass flow has been installed. The discharge pressure would be very low, and amps or power draw will be very high.

- Too little flow being required from the pump
  Pump may be too large, and the indication would be the pump casing may become very hot
- Piping and or Structural Resonance showing as high vibration at the equipment but originating somewhere else.
- Product vaporization point too close to suction pressure---This will cause cavitation, low, or no flow. These conditions may be most pronounced during an upset of the plant or perhaps a hot restart of the plant.

All of these should be checked before condemning & overhauling equipment. Some will require more than just an operator's inspection to find.

Mechanical seals

Operators need to be taught that seals have the same requirements as bearings in your car. If they do not get cooling and lubrication, they will fail quickly. The support system, weather product or a complete separate system to supply cooled liquid to the seals is required to keep the seal functioning. The support system is like the radiator and lubricating oil in our vehicle. If either is stopped for long a failure will result. The operator needs to be taught how to detect problems while equipment is running. They should check differential temperatures on barrier fluid systems with a tool or touch. The upper line out of the seal chamber should be warmer than the lower line. If there is no differential, then likely there is no heat exchange and ultimately a seal failure will result.

Most operators do not know ALL seals leak. If there is only one seal it will always be the product leaked. If there are two seals, the barrier fluid pressure will determine what leaks. If the barrier fluid pressure is above stuffing box pressure the barrier fluid will leak into the process and to the outside. If the barrier fluid pressure is below stuffing box pressure eventually the pumped fluid will leak into the barrier fluid reservoir and eventually to the air side. Most operators do not know how expensive seals are and may pay more attention to them if they did.

An example of what lack of understanding and knowledge can cause is cited in the example below.

There was an operator working in the tank farm area of a plant. He needed to transfer the contents of one of the tanks to another tank for blending. The road to the tank the operator used to feed the pump's suction was about a quarter mile from the pump. The pump was on the road to the tank. The operator stopped the truck, got out and started the pump then got back into the truck and drove to the tank supplying suction to the pump and opened the valve suppling liquid to the pump previously started. The seal faces were hot from running dry and when hit with the relatively cool liquid caused them to fail. The hot seal faces was caused by the lack of lubrication and cooling because the pump had no liquid to pump when it was started. This pump had many seal failures because of something the operator did not understand. If only the seal and its installation were investigated the lack of operator knowledge would never have been addressed or the root cause of the problem solved.

Capital projects.

Invite operators to provide input on how new equipment can be efficiently decontaminated and vented. They can have a meaningful impact or how and where new valves can safely be accessed. This will also get agreement from the operators because their concerns are being addressed. It will also keep them informed on new installations before they see it in the plant for the first time. It is a good practice to include a maintenance representative during at least some of these meetings as well.

Writing quality work request

Most operators do not understand that work requests are one-way communications so as much detail as can be observed is required to properly asses the problem and plan the job. They do not know that the closed work order goes to the equipment history and will be used to solve a persistent problem. If all the work request says is "change pump, replace pump, fix pump" there is little value added to the equipment history. It is only known that the equipment was worked on. If the work request clearly describes the symptom or the reason the equipment was removed it would be more beneficial to anyone investigating the equipment history to solve a chronic problem. For example: If the work request read “too low a flow, broken coupling, vibrating, tripping off line” etc. this would help identify the reoccurring problem. It would make tracking the real reason for the failures easier to identify. This might also increase the cooperation between operators and craftsmen. In many plants, operators think their job is only to identify that the equipment has a problem. They don’t gather data or investigate the issue. Partly because they have not been taught to troubleshoot and partly because it has always been acceptable to identify there is a problem and write a work request making the problem someone else’s.

Procedures (procedures and decision trees)

The use of procedures for startup and shut down of equipment is essential. These can be helpful on common equipment just as they are for large specialized equipment. Some companies use decision trees for common problems on equipment to make it easy for the operator to make the correct decision. See figure 5. If they follow the procedure or decision tree they will not be “second guessed” later. If they choose not to follow the decision, then there should be some sort of consequence for that choice if it is found to be a bad decision. I will discuss that more in “Discipline” section. These can be beneficial for mechanics and engineers as well.

Many operators do not know acceptable limits on oil temperature, bearing temperatures, or vibration levels. It is impossible for them to make informed decisions without having been taught what these are and have the correct tools to gather this information in a quantitative method. Many operators don’t understand the differences and results of high vibration and of high thrust. The severity of the damage that can be done by excessive thrust is far worse that that done by excessive vibration. Many operators treat them as the same and they are not.

Must give operators feedback

The single largest complaint I hear in the plant is “I am asked to give input but none of my suggestions go anywhere. I never hear what happened to my idea”. Often the idea is used, but it is part of a capital project, or it may not be used for a specific reason. The operator’s problem is the reasons for non-use are never explained to him, so from his perspective, he is asked for something, he complies, but never hears anymore about it. This is not conducive to getting any other information from an operator.

One meeting concerning operators involved operator making many work request a “safety” request because the operator knew it would be investigated and followed up. He wanted at least feedback as to why his observations were not being acted upon. His observation dealt with a steam trap leaking and blowing steam, water, and debris in a walkway in the plant. It also caused safety glasses to fog making vision poor and the area slippery. The operator said he complained months ago but nothing was done. The maintenance manager had a good reason for not acting, but it was never communicated to the operator. The reason, for lack of action, was there was limited resources and either customers would be deprived of their order (force majeure) or the steam leak fixed. When this was explained the operator was still not happy about the steam trap but did understand. With further talks the operator offered to “rope off” the area and direct the steam spray to a safer direction.

Must be required to use their training

Many companies have in-house and external training for the operators and other crafts. Someone from management should attend to know what is being delivered. They can then help insure that the training is being utilized. Most consultants and trainers are happy to take your money, but for you to get the benefit of the training they offer, the concepts and methodologies must be used. The example used about centrifugal pump pressure rising thus, the flow falling, should prompt the operator to look for a blockage downstream, not have the pump overhauled. If instead the operator is allowed to do what he usually does, write a work request, and make the problem someone else’s, it is possible that the pump may get overhauled only to find out there was a blockage downstream. Identifying the problem and working on the root cause is the best way to increasing reliability.

Point out the benefits to the operator of using the training. The root cause of the problem with the collaboration of the operator and others and the problem eliminated. It could save the operator the trouble of having the equipment tagged and locked out and decontaminated only to have all that undone to “see it run” and part of the troubleshooting.

While speaking of training it is a good choice to hire some outside training for the plant. Some plants that have trainers resist hiring someone from outside of the organization for various reasons. I suggest that like maintenance organizations it is a good thing to look at these temporary outside trainers as consultants for a specific purpose. Maintenance hires consultants for their expertise in specific areas and training departments would do well to consider doing the same.

Discipline

I am not in favor of firings or time off as a discipline except in the most serious circumstances. You could lose a trained employee and perhaps someone that "won't make that mistake again". You may be giving a person time off to go hunting or fishing which may not seem like discipline to him. I have found that if someone is made to give a formal presentation on how their decision was made, it usually results in better decisions. Additionally, by the time the information about having to explain a faulty decision is passed around the plant people making decisions will make better ones. Most would not like to explain, in a formal presentation, why or how they made a particular decision. Decision making will improve quickly and dramatically.

CONCLUSIONS

As listed above, there are many opportunities to have the operator be an integral part of the plant's reliability program by being involved in the problem identification, data gathering, and troubleshooting processes. Many people do not take full advantage of what their operators have to offer, and their equipment reliability suffers for it. Most operators want to do a good job and take pride in their work but may not have been given the tools or training necessary to do their best work. I have never met an operator that gets up in the morning and says, "I can't wait to get to work and wreck something." They do wreck things, but it is usually due to lack of knowledge or training, not a conscious act. The equipment taken out of service usually means more work for them, with decon, tag and lock out etc. This does not include lost production, product or safety concerns.

NOMENCLATURE

NPSH = Net Positive Suction Head
NPSHr = Net Positive Suction Head required
NPSHA = Net Positive Suction Head available

FIGURES

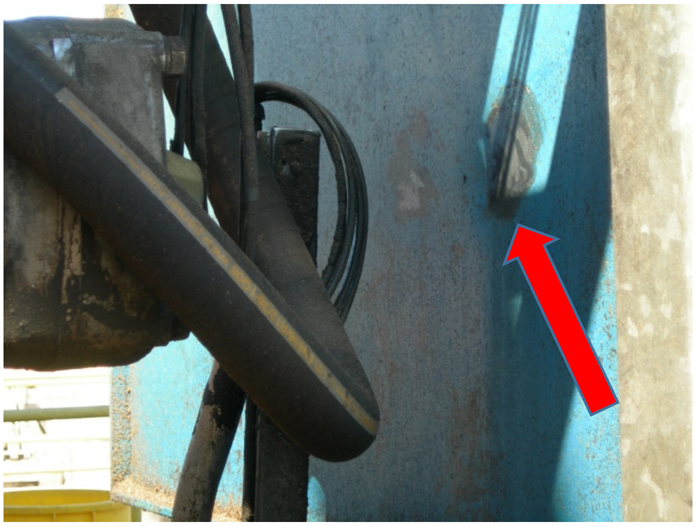

Figure 1a Mark seen on tank during operator rounds

Figure 1b Hose in operation causing wear.

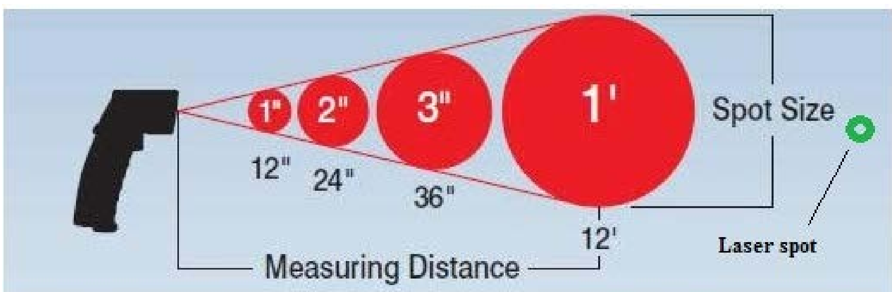

Figure 2 Infrared spot radiometer

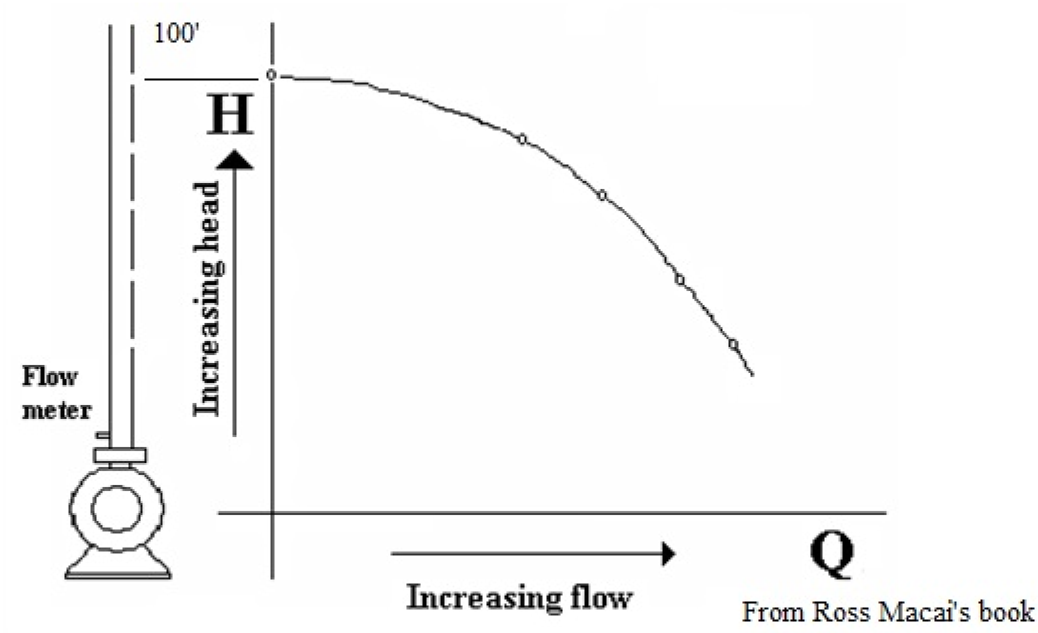

Figure 3 Pump curve generation from Ross Mackey's book

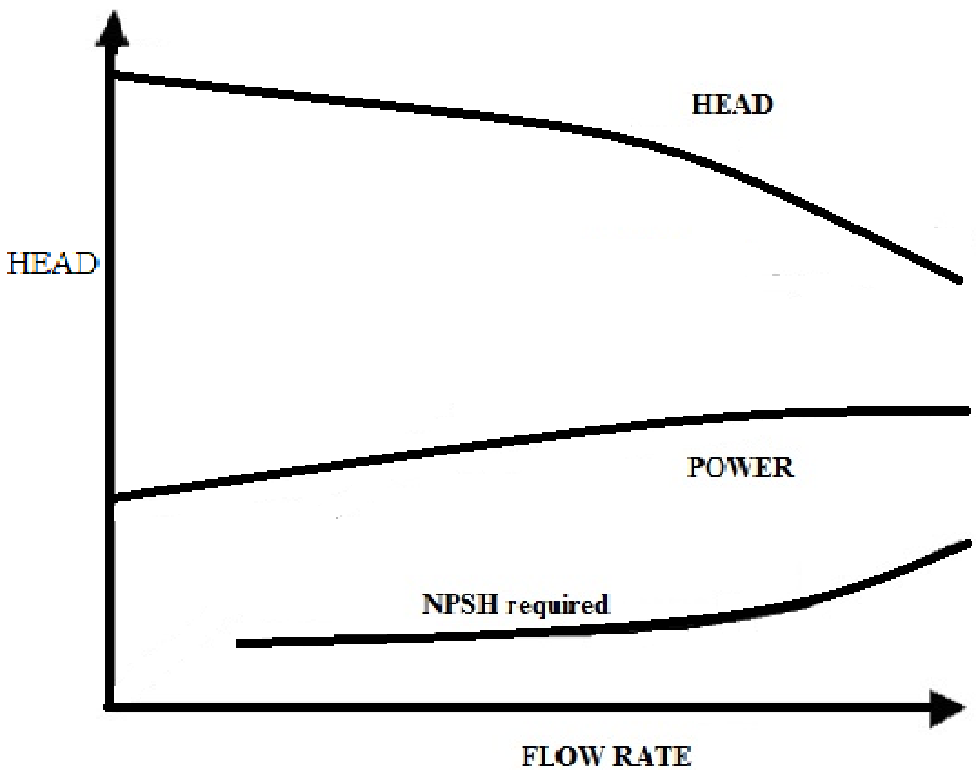

Figure 4 Generic centrifugal pump curve showing relationships of head, power, flow and NPSHr

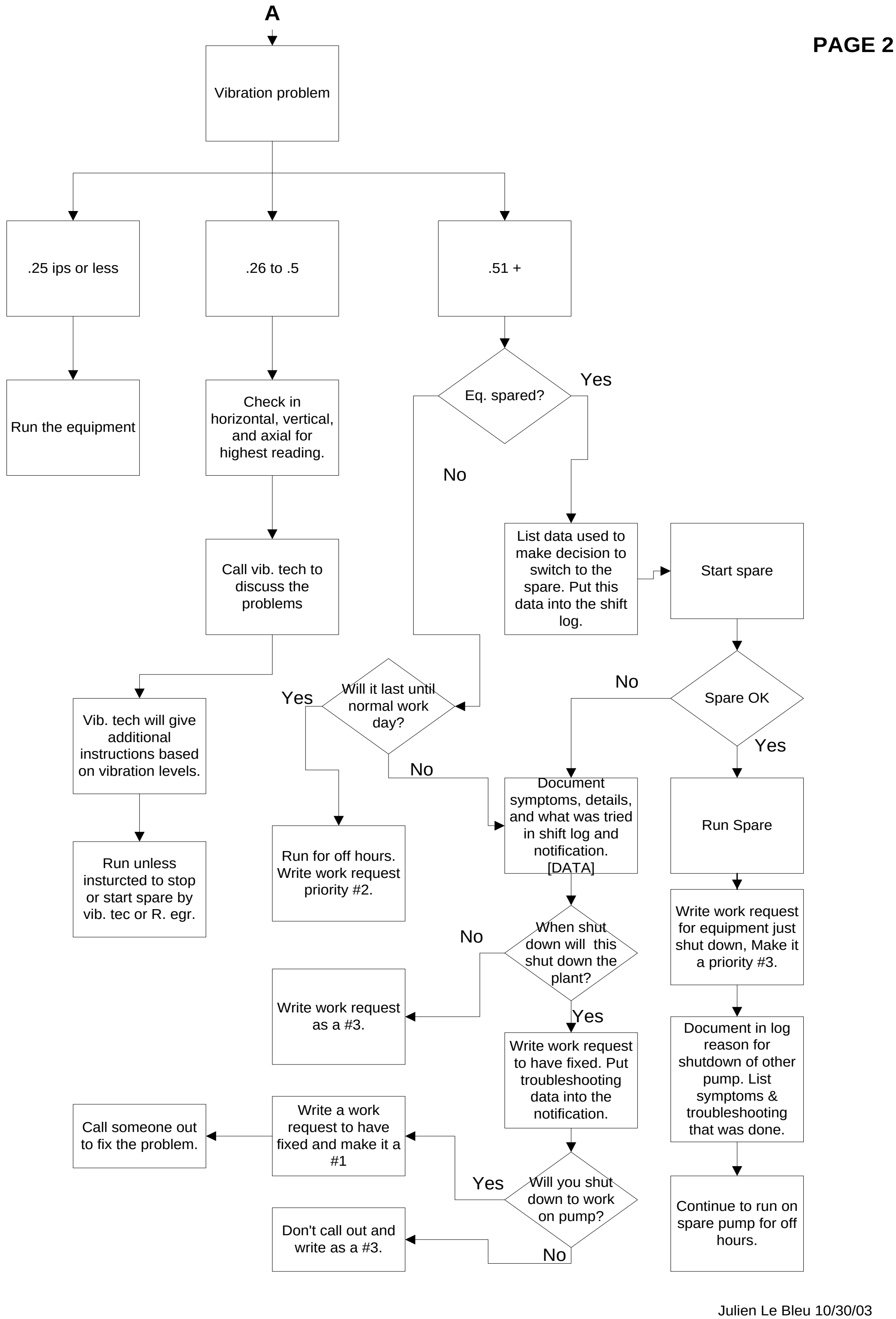

Figure 5 Example of a logic tree that could be used to make better decisions during weekends and holidays

APPENDIX A

REFERENCES

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ACKNOWLEDGEMENTS