

LOW COST RELIABILITY THROUGH OPERATOR INVOLVEMENT

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ABSTRACT

At most industrial facilities, the engineering, maintenance, and operation groups are under great pressure to increase reliability and also reduce costs. This paper discusses the role of operators in achieving low cost reliability. Although operators can have a dramatic impact on both reliability and costs, there has been very little focus on understanding or utilizing the potential of the people that are closest to the machinery, 24 hours a day. This paper discusses both the reliability that can be achieved if a culture of operator ownership is developed and the conditions necessary to develop this ownership.

INTRODUCTION

A major challenge facing those responsible for machinery in process industries is to support high plant stream factors by maintaining sufficient machinery reliability—yet at the lowest possible cost. Many plants endeavor to achieve reliability by a variety of methods including the following: sophisticated vibration

analysis and lube oil analysis; oil mist systems and automated greasing systems; quality initiatives; defect elimination programs; hardware upgrades such as cartridge seals, bearing isolators, pump upgrades/replacements; root cause analysis; total productive equipment management (TPEM); etc.

However, possibly the most important factor in achieving low cost machinery reliability is mostly ignored—developing operators who properly care for their machinery. To put it very simply, operators can break equipment very easily. Good engineers and craftsmen are no match for poor operators. On the other hand, good operators can run somewhat marginal equipment very reliably and they can also help the engineers and craftsmen troubleshoot equipment. Even though many acknowledge the important role operators have in the reliability of the machinery, there is very little thought or effort in defining the proper role of operators or in encouraging the proper operation of equipment. While technical solutions to reliability problems will always have their place, a majority of (but not all) reliability problems can be addressed with little or no technical involvement. A diligent, well trained operator can run some fairly marginal equipment very reliably. The foundation of any reliability program should be the individuals whose responsibility it is to run the plant. If a plant's operators can be engaged to take ownership of the equipment in the plant, the battle for reliability is mostly won. However, in spite of the importance of good operators, machinery experts often spend the majority of our time developing technical solutions to reliability issues, rather than cultivating a culture of operator involvement.

The purpose of this paper is to discuss both what operation's role in plant reliability should be and also what is necessary for this operator ownership to occur. This paper is written with the perspective of over 10 years at a refinery where very low cost reliability has been achieved, primarily through engaging operators as owners of the equipment. A major focus at this refinery has been making the operation's group most responsible for equipment reliability, rather than engineering or maintenance. The refinery's equipment reliability has progressed to the point where there have been no refinery production curtailments (shutdowns or slowdowns) due to rotating machinery in over four years. The average pump life exceeds seven years and the direct pump maintenance costs are less than \$400/installed pump/year. These reliability results were achieved using very little of the costly technical/hardware fixes that are generally considered necessary to achieve good reliability. Instead, the reliability of the refinery is largely based on the efforts of the operators who simply run their equipment properly.

Although this paper focuses on the role of operators in achieving low cost reliability, it does not mean that engineering and maintenance groups are insignificant. At the Anacortes refinery these other groups certainly play a crucial part in achieving low

cost reliability. However, since a significant amount has already been written on how engineering and maintenance best practices can enhance machinery reliability, the authors have focused on a concept of operator ownership.

ANACORTES REFINERY BACKGROUND

The Anacortes refinery is located in the northwest corner of the U.S., about 60 miles (100 km) south of the Canadian border. The refinery is capable of 115,000 barrels a day (5.3 million tons per year) crude intake and contains the following units: crude, vacuum flasher, distillate hydrotreater (DHT), catfeed hydrotreater (CFH), naptha hydrotreater (NHT), cat reformer, cat cracker, alkylation, de-asphalter, butamer, effluent, tank farm, wharf, etc. The crude diet changes based on price versus quality issues. The refinery processes crude between 14 to 45 degrees API and up to one percent sulfur.

Anacortes refinery has experienced no machinery related equivalent distillation capacity (EDC) losses in the last four years, meaning that no machinery failure has resulted in either a production slowdown or shutdown.

The total direct pump repair costs averaged less than \$400 per installed pump in 1997, decreasing from over \$900 per pump in 1995, and the mean time between repair (MTBR) averaged over seven years in 1997, increasing from four years in 1992. The average direct cost of a pump repair was \$2800 in 1997.

General purpose turbines average over 15 years between overhauls, while special purpose turbines and compressors average over 10 years between overhauls. The cat cracker slurry pumps are running in excess of 10 years since the last overhaul.

In addition to the reliability of the machinery, the overall refinery is also very reliable, consistently placing in the top five refineries in the U.S., according to industry wide benchmarking. Staffing levels and maintenance costs are also very low, according to internal and external benchmarking.

Much of the plant machinery is over 40 years old, with minimal upgrades. In addition, the Anacortes refinery's reliability and cost performance has been achieved without using, on a widespread basis:

- Oil mist or bearing housing isolators (<5 percent of pumps).
- Cartridge seals (except on between bearing pumps).
- Comprehensive repair procedures.
- Mechanical seal testing.
- Pump replacements or pump upgrades.
- Periodic vibration monitoring of general purpose equipment.
- Lubrication analysis of general purpose equipment.
- Root cause analysis/preventive maintenance optimization programs.
- Automatic greasing systems.

Instead of achieving reliability through the above methods, the operation's group (the hourly employees are represented by Oil, Chemical, and Atomic Workers International Union, OCAW) at Anacortes has taken a great deal of responsibility for reliability and maintenance costs of the machinery. This operation's involvement has enabled the refinery to run very reliably with a minimal expenditure of both capital and maintenance dollars. Operators at Anacortes consistently run the processing units very smoothly, thus placing minimal stress on machinery. The operators are also diligent in making sure the equipment is properly lubricated and they closely watch the machinery and shut down equipment in a timely manner before small failures become big failures. This operator ownership results from both placing high expectations on the operators as well as providing the necessary training, information, and other resources.

OPERATORS AS OWNERS OF EQUIPMENT

At many facilities the operators of the equipment have only a very narrow approach to their job. They simply operate the equipment without much understanding or concern. If a piece of machinery is in distress, operators often ignore the problem until it becomes pressing and then call in maintenance or engineering to fix the machine. They do not try to understand why the problem is occurring or what they may be able to do to prevent the failure. Operators often have a very limited knowledge of their plant's machinery. They do not understand how their equipment works, how the plant process can affect it, what the machines basic lubrication needs are, etc. Often, engineers and maintenance personnel respond to machinery problems by either fixing the same problem repeatedly or by attempting to "bullet proof" the equipment—both expensive propositions. Maintenance personnel and engineers generally make very little effort to understand or correct the human issues that lurk behind many problems; even though achieving low cost reliability without good operators is, at best, difficult.

However; if a plant can successfully deal with the human issues surrounding machinery operation, many of the reliability issues can be corrected with surprisingly little input of either technical resources or capital spent on equipment upgrades. A model for this proper operation of equipment might be called "operator ownership." The Anacortes refinery has effectively transformed operators into the primary "owners" of the equipment. This ownership means that the operations group is the primary focal point for most problems and issues related to their machinery, rather than the engineering or maintenance group. The operations group also has significant input in new equipment installations, assuring they are installed in a manner that enhances low cost, reliable operation. Finally, each individual operator is treated with respect, basically as "owners" of their processing unit. Anyone wishing to enter an operating area must first receive an operator's permission after explaining what they plan on doing.

OPERATORS AS PROBLEM SOLVERS

Operators should, in general, try to determine the cause of problems and try to correct problems before they ask for help. For example, if a pump is apparently performing below expectations, the operator, at a minimum, should be expected to check basic possible causes, such as determining if suction screens are plugged, checking to see if the spare pump check valve is leaking through, or putting the spare pump online to see if it performs poorly as well. All these checks should be made before the operator solicits help. Often the operator can solve problems without any outside assistance. However, even if the problem is difficult and requires technical assistance, the operator still has a very important role to play. That role is to both quickly identify that there is a problem (hopefully while the consequences are still small) and then to begin the process of describing the problem. If a problem is identified and described well (tasks an operator can generally do), then the actual root cause determination is much easier than having an engineer or inspector gather all the information himself.

The following is a verbatim example of an Anacortes operator describing a pump problem that he was not able to solve on his own. The machinery engineer received this unsolicited information the following morning when we were first informed there was a problem. "Started P-736 at 00:01 with discharge valve 100 percent open and the recycle valve 100 percent closed. The amp gauge pegged for about one second as pump started, then fell back to about 20 to 25 amps with no unusual vibration. Vibration started about three to four minutes after start when flow dropped below 4.0 chart reading. I pinched the discharge to 50 percent, then 40 percent, 30 percent, 20 percent open with no change in sound or vibration. At this point, I gave up on closing discharge, opened it 100 percent open again and pump came around on its own. As it

has in the past without pinching discharge. Vibration went away somewhere between 4.4 and 5.0 flow (about 15 minutes after start).” The chart shown in Table 1 was also included by the operator.

Table 1. Operator's Pump Problem Chart.

Minutes after start	0	2	4	6	8	10	12	14	16	18	20	24
Discharge % open	100	100	100	50	40	30	20	100	100	100	100	100
Recycle % open	0	0	0	0	0	0	0	0	0	0	0	0
Flow on chart	13	8.5	3.8	1.7	1.3	2.4	2.9	4.4	5.0	6.4	7.6	8.9
Amps on pump	26	32	30	33	37	33	30	31	32	32	31	30
Vibration	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N

The above example is based on a large vertical propeller pump that had excessive vibration and noise on startup. The determination of the cause still took some technical effort after receiving this information, but the above information was a good start toward solving the problem and lessened the need for technical resources. Another interesting aspect about the above information is that the gathering of this kind of information does not take technical skill, but instead an inquisitive mind and good observation skills.

OPERATOR SURVEILLANCE

Surveillance of equipment is possibly the most critical activity of an operator. It is important to be able to detect machines in distress at the earliest possible moment. Then either correct the problem causing the distress or at least remove the machinery from service at the earliest opportunity, thus minimizing damage to the equipment. At the Anacortes refinery, there is no periodic vibration monitoring or lube oil analysis of general-purpose equipment—yet catastrophic failures are extremely rare, because, in general, operators carefully watch their equipment.

Good equipment surveillance involves uses of four senses: sight, hearing, feel, and smell. Also, good surveillance requires that the operator spend significant time in the unit to both check the equipment often, as well as to get a feel for what sounds, feels, looks, and smells normal. Within a fairly short amount of time, most operators gain a sense of what is normal and can therefore detect even slight variations in noise level, gauge readings, vibration, or temperature. When the operator senses that something changes, he should then try to determine what precisely has changed; why it has changed; and is the change important, asking for additional assistance as necessary. For example, an operator will notice that the temperature of a pump bearing housing seems warmer than normal (usually he will sense this by touch rather than using a surface temperature probe). The operator may then contact a machinist to get his opinion.

Several times per shift the operators should check all pumps for the following:

- Bearing housing and seal gland temperatures
- Seal flush operation
- Unusual noise or vibration
- Discharge pressure
- Proper lubrication
- Cooling water flows
- Proper line-up of spares
- Leaks

Coffee Cup Oil Analysis

A powerful method of “oil analysis” is the use of a paper coffee cup to sample oil from the bearing housings of general purpose

equipment. Most of the machinery at Anacortes is equipped with snap drains on the bearing housings. The operator periodically drains a small amount of oil from each bearing housing into a paper coffee cup—checking for discoloration, water, or metal particles. This crude analysis is a very effective way to detect most lubrication problems. The results of this sampling have been successful. There are very few bearing failures (about 13 percent of all pump failures) at the Anacortes refinery.

Pump Switches

Another way operators check the condition of their equipment is through routine pump switches between the main and spare pump. These switches should generally take place on a weekly basis and the spare pumps are run long enough to assure stable operation (approximately one hour); or if there is no economic reason to run the spare versus the main pump, the “spare” pump is allowed to run until the next pump switch. Most pumps should be switched on a weekly basis. However, there are a very few exceptions to the weekly pump switch requirement, in cases where the stress on the pump is felt to be so high as to make the pump switches problematic. Boiler circulation pumps are the major exception to weekly pump switches at the Anacortes refinery. The purpose of the regular pump switches is threefold. First, the present ability of the pump to be a suitable spare is confirmed on a regular basis. It is important that each operator have confidence in the equipment that he is assigned to operate. Second, the operators take the pump switch opportunities to drain some oil from each bearing housing to check the condition of the lubricant. Finally, switching pumps once per week allows each operator to get experience starting any particular pump about once per month (with four rotating shifts). This once per month opportunity for each operator is sufficient to allow all operators to keep current on the critical skill of starting a particular pump.

Many refineries and chemical plants feel that switching pumps on a weekly basis is actually a detriment to reliability. One argument, heard often throughout industry, is that frequent pump switches place too much stress on pumps and actually decrease reliability. This has simply proven not to be the case at either the Anacortes refinery or at several other refineries that have followed this frequent pump switching philosophy. Frequent pump switches may, at the beginning, cause some defects to be revealed (one defect probably being that operators are not very well trained on how to properly put pumps in service) and possibly cause some failures. However, these defects can usually be corrected by minor hardware changes, procedural changes, or additional training, resulting in better overall machinery reliability.

OEM RELATIONSHIPS

For the purpose of this paper, OEM refers to operations, engineering, and maintenance. Cooperative relationships between operations, maintenance, and engineering are critical to achieving low cost reliability. Most complicated machinery problems are best attacked in a team manner, with input and ideas from the different groups. However, in many plants the OEM groups do not work well together. Instead, “silos” are present, where problems are not addressed cooperatively and even worse, much energy is wasted in assigning blame for the reliability problems.

In order to achieve low cost solutions to reliability problems, the OEM group must be able to work effectively together as a closely-knit team. Working effectively together requires trust and honesty, a willingness for all groups to keep an open mind, and a commitment to finding solutions rather than placing blame. As an illustration, at Anacortes, there have been several instances where a pump has failed, and before engineering/maintenance started analyzing the failure, the operations group told us not to bother doing any failure analysis. Instead, they admitted making an operating error that allowed the pump to run dry. This kind of honesty saves an extraordinary amount of time, but requires trust

and a discipline system that can allow honest mistakes, but still provide discipline in the case of negligence.

At Anacortes, the operations group generally assumes the central role in the OEM relationship. The operations group takes responsibility to oversee the entire reliability effort in a particular area of the plant. They track individual reliability issues, and make sure that proper priorities and resources are brought to bear on any particular reliability issues. Even though, operations should generally have the lead role. They must be critically aware of the need for input and help from the maintenance and engineering groups that support them, and treat them as valued partners. On the other hand, the engineering group is responsible for plant-wide reliability tracking and measurement systems as well as developing many of the strategic plans. Also, an effective OEM team can better determine the true root cause of failures. They can assure that the response to human system problems is not a technical fix, but instead a procedural change, additional training, or possibly even discipline.

CREATING OPERATOR OWNERSHIP

There are four critical components in creating operator ownership: encouragement, fair expectations, adequate training, and accountability. Not only do all these components have to take place to allow operator ownership, but expectations, training, and accountability must be in proportion to one another and all should gradually increase over time (Figure 1).

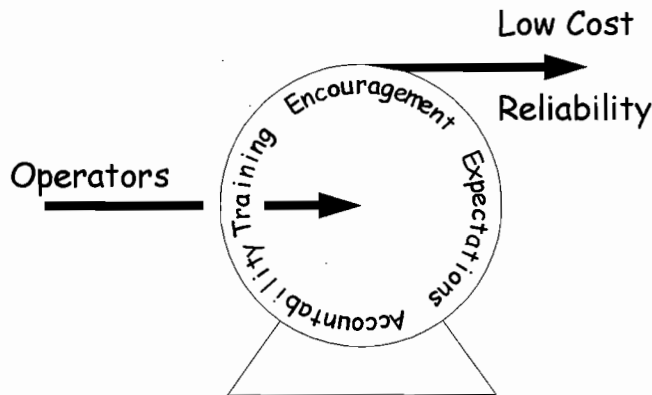


Figure 1. Creating Operator Ownership.

Encouragement

The basis of encouragement is to simply treat the operators with dignity and respect—recognizing in various ways that how they operate and care for their machinery is crucial for the success of the plant. There are many ways this encouragement can take place, but the important consideration is that the encouragement be sincere and reflect a plant-wide understanding of the value of good operators.

One way this encouragement takes place is by senior plant management spending time out in the plant, simply stopping to talk with the operators, thus showing concern for their contribution to the success of the facility. To have the leaders of the plant spending time out in the field showing their concern and thanks for operator’s efforts related to machinery reliability is crucial. A few personal words of thanks or questions about reliability issues from senior management will have a very strong impact on most operators.

Another way operators are encouraged is to receive timely support from other groups (particularly engineering and maintenance). When an operator calls an engineer with a question or concern with the machinery, the engineer needs to make the request of the operator a high priority and then follow up on their concerns or questions. At Anacortes, many operators feel that the

main reason the rest of the plant’s staff exists is to support the efforts of the operators in maximizing the production of their units (Figure 2).

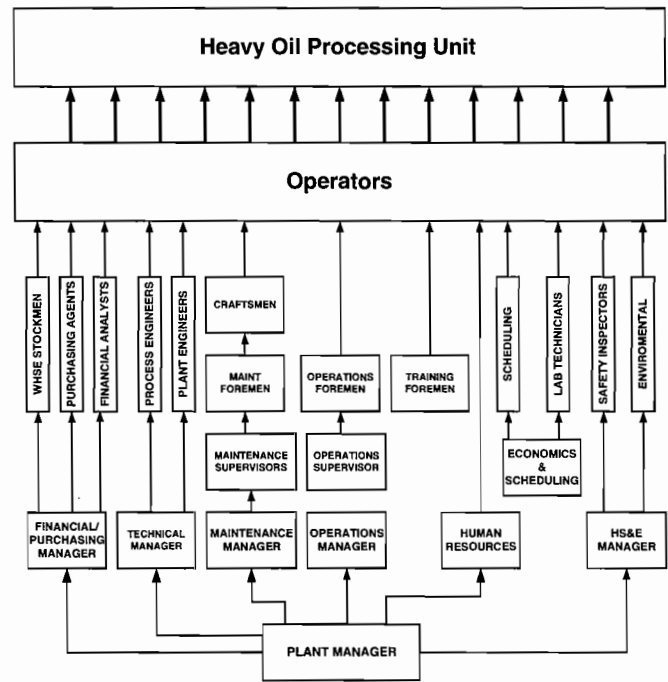


Figure 2. Upside-Down Organization Chart.

As an operator’s sense of ownership of their units increases, they will become more aware of defects, and they will desire to have the defects (bad pressure gauges, oil leaks, steam leaks) corrected or eliminated. In order to be credible with the operators, management should be willing to commit to making progress on the elimination of these defects or else the operator’s response will be “if management does not care, why should we?” Therefore, defects should be prioritized and tracked, and reasonable progress should be made on their elimination. The elimination of defects will help the reliability of the plant in its own right as well as encourage the ownership of the operators.

Encouragement of operators also takes place through recognition of their efforts. For the most part, this recognition takes place in the form of personal thanks from someone in a leadership position and/or a peer. These small personal expressions of thanks should happen as often as the opportunity allows. For more significant efforts of operators, there should be other levels of recognition ranging from letters, to gift certificates, to even cash awards.

A final way of encouraging operators is to find a measurement of their progress that can be compared with other units in their plant and also other plants, thus kindling their competitive spirit. These comparisons should generally be “low-key,” rather than using the measurement as a club to beat them. Simply providing the operators the information rather than making a formal competition will invoke the competitive spirit in most people. If too much emphasis is placed on the competition, often people will either find a way to “make the numbers look good” without really impacting reliability or else they spend their energy developing excuses (such as their unit is too old) why their reliability numbers are not very good (sometimes there are perfectly valid reasons why one part of a plant has more reliability problems).

Proper Expectations of Operators

Expectations and followthrough are a difficult area for many plants and many plant leaders. It is often difficult, yet absolutely

critical, to properly assess what effort should reasonably be expected from operators and then to followthrough and make sure that the operators make the effort they should. The responsibility for establishing expectations and the subsequent followthrough lies with the operations leadership—in particular, the first and second line supervision. Without the total commitment and significant involvement of this leadership group over several years, operator ownership of the equipment will simply not occur.

The two key concepts when determining expectations of operators are “reasonable” and “increasing.” The expectations of the operators should be reasonable based on their background, present plant culture, and their training. The expectations should also increase, at a reasonable pace, over time as the operators develop a better understanding of their equipment.

Housekeeping

A most basic expectation is that a plant’s housekeeping should be excellent and the operators should be responsible for assuring that their units are clean. The processing unit should be kept clean of lube oil leaks, product spillage, and general debris, and all equipment such as valve wrenches, hoses, lubrication cans, and drums should be stowed properly. For example, drums of lubricant or other materials that are stored outside in the vertical position should be tilted at an angle of about 10 degrees, with the bungs at three o’clock and nine o’clock to keep water from pooling around the openings and seeping into the drums as they breathe. Good housekeeping has two benefits: pride of ownership increases and defects are more easily spotted. Unfortunately, many plants fail miserably at even this most basic activity. Poor housekeeping is a strong indication that management is not setting or enforcing basic expectations.

The most important expectation of an operator is ensuring the reliability of his equipment, in particular rotating machinery. At Anacortes, there are separate “inside” and “outside” operating jobs. The primary job of the inside operator is the control of the equipment, while the primary job of the outside operator is simply the reliable operation of the equipment. All other work should be secondary to maintaining reliability of the equipment. Recently, during the end of run at our catalytic cracking unit, the seal eductors on the wet gas compressor were plugging frequently, and required the operator to dump a small amount of solvent down a vent line on an hourly basis to keep the eductor passages clear. Engineering volunteered to automate this effort. They were turned down by operations who maintained that the operators knew that the cat cracking unit wet gas compressor was the most critical piece of equipment in the unit and would be able to perform the task on an hourly basis.

Key and Critical Variables

Any operator should have process parameters for safe and reliable operation of his equipment. At the Anacortes refinery, these parameters are called key and critical variables. These key and critical parameters should include minimum flow requirements on most pumps as well as alarm and shutdown settings. A major function and high priority of the technical engineers is to assure that the operators have correct and up-to-date operating parameters.

Accountability

A plant can spend a great deal of money on training and effort on setting expectations, but will still fail to achieve reliability without adequate followup to assure that proper operator surveillance is occurring. Ensuring adequate, yet fair, accountability is the most difficult aspect of creating operator ownership. Ensuring accountability requires very frequent coaching and at times, formal discipline. Unfortunately, many persons, even in leadership positions, avoid this type of work. Many leaders choose to ignore “small” personnel problems, either hoping they go away by

themselves or else ignoring the small problems until they become so compelling that dramatic action must be taken. A good accountability system is created by the leadership striving to deal firmly but gently with discipline issues while the issue is still small. Also, it is critically important for leadership to be able to discern the difference between negligence and an honest mistake. Operators make many decisions and sometimes a diligent operator will make a mistake. These mistakes can serve a powerful learning experience if handled properly, or if handled poorly with excessive discipline, can lead to poor morale. On the other hand, negligence should be dealt with very strongly. Discerning the difference between honest mistakes and negligence requires both an awareness of what is reasonably expected and also the underlying reasons (extenuating circumstances) why the individual chose to act as they did.

Operator Logs and Checklists

A log is a record of particular process readings (temperature, pressure, flow, vibration, etc.), while a checklist is a record of specific actions. Accurate, meaningful operator logs or checklists are a necessary component of machinery reliability. The checklists and logs must be kept current and be purged of outdated or marginally necessary material. This updating/purging of these logs and checklists is a good team activity between operations and engineering to ensure that all necessary readings are taken, and all necessary checks are documented. Engineering should be able to clearly justify all items on the log sheets or checklists, and operations leadership should insist that operators actually fill out the log sheets and checklists with real information.

Checklists will run the range from very general to very specific, depending on two factors: the criticality of the task and the competency/knowledge of the operators. If the task is critical, then the checklists should be comprehensive and detailed enough to provide a high degree of assurance that the task is completed correctly. Also, the lower the knowledge/skill level of the operators, the more specific the checklists will need to be (the APPENDIX shows an example of a weekly pump switch checklist).

Formal Audits

Formal audits are one method to help assure that the reliability activities are actually being done. With a formal audit, compliance with certain expectations is checked and then a compliance report can be developed. The following are some areas that should be included in a formal audit:

- Housekeeping
- Oil levels
- Lubricant handling and storage
- Pressure gauge condition
- Seal flushes
- Vibration levels

Informal Audits

The term “informal audit” refers to operation’s leadership, engineers, inspectors, and craftsmen spending time in the field and being on the lookout for any problems or deficiencies in the unit, then giving the operator direct feedback. This type of “auditing” is probably more helpful and positive than the use of formal audits. It also reinforces the message that management really cares about machinery reliability. The disadvantage is that this kind of effort too often becomes secondary to more urgent, but less important, work and therefore may not get done.

Measurements

A critical factor in providing accountability for reliability and costs is developing decent measurements that provide an understanding of progress and opportunities for improvement. In

general, the most critical measurements should be focused on reducing or eliminating loss of production (plant reliability). Therefore, the measurements should be able, in a simple way, to show how much production is being lost and what units or equipment are causing the loss. Measurements of the costs associated with maintaining or upgrading machinery should also be tracked, with the goal to be both high plant reliability and low costs. The reliability of individual equipment or groups of equipment may also be worth tracking, particularly if the machinery is unspared and its loss results in a loss of production. A popular measurement in the refining industry is "average pump life" resulting from dividing the total number of pumps (or types of pumps) by the total number of pump failures per year.

Training and Procedures

There are two types of training: formal and informal. Two important keys to effective training are:

- Necessary skills and job knowledge are presented to the operators.
- Skills and knowledge are actually retained by the operators.

There should be a system that requires the operators to actually demonstrate the necessary skills and knowledge, ideally, by hands-on demonstration of competency. In addition, training should focus on more than memorizing numerous procedures. Instead, training should focus on the operators developing a deep understanding of the process and how the various systems and equipment are interdependent.

Formal training comprises new hire indoctrination, process unit specific training, and any other classes or computer based training. These are all opportunities to emphasize the operator's responsibility for equipment reliability, and that the operator's safety and the safety of his coworkers are dependent on understanding and properly operating the equipment. The new-hire training should include the basics of how machinery works and the operator's responsibility to run the machinery reliably. It may be helpful to have maintenance and engineering personnel provide some of the equipment training using cutaway pumps and other hands-on material—to both explain how the equipment functions and what work is necessary to assure that the equipment runs reliably. Having engineers and maintenance personnel involved in training helps to break down communication barriers. The new operators should be able to demonstrate actual field ability to perform the necessary equipment related tasks. The training and procedures should not be limited to simply how to accomplish particular tasks, but again should emphasize "how things work."

For one gas compressor train at Anacortes, there are over 100 "test" questions that an operator must answer, and an additional 300 questions for the rest of that particular operating job. Following are some examples of actual questions:

- Explain the purpose and operation of the turbine trip/throttle valve.
- Explain the importance of the trip/throttle valve "below seat" bleedoff.
- Show and explain the operation of the turbine extraction valves.
- Tell the causes of a high level in the surface condenser, why the high level must be avoided, and what can be done to correct a high level.
- Explain the purpose and operation and show the line-up of the gland seal system.
- What adjustments must be made (and why) to the gland seal system when the turbine stops rotating.
- Tell the common causes of poor surface condenser vacuum and explain possible corrective actions.

- Show all instruments that can shutdown the compressor and how to determine which initiated a shutdown.

Procedures

Procedures should provide all the information (in a clear, concise way) that is necessary to properly operate the unit, and the procedures should be kept up-to-date through a "management of change" system. The person (ideally an operator or an ex-operator) who writes procedures needs to have good writing and graphics skills and should be tenacious—willing to ferret out information on the equipment by asking for an engineer's help or by searching through equipment files. Following are some sample graphics that are intended to simplify the understanding of some machinery systems (Figures 3, 4, and 5).

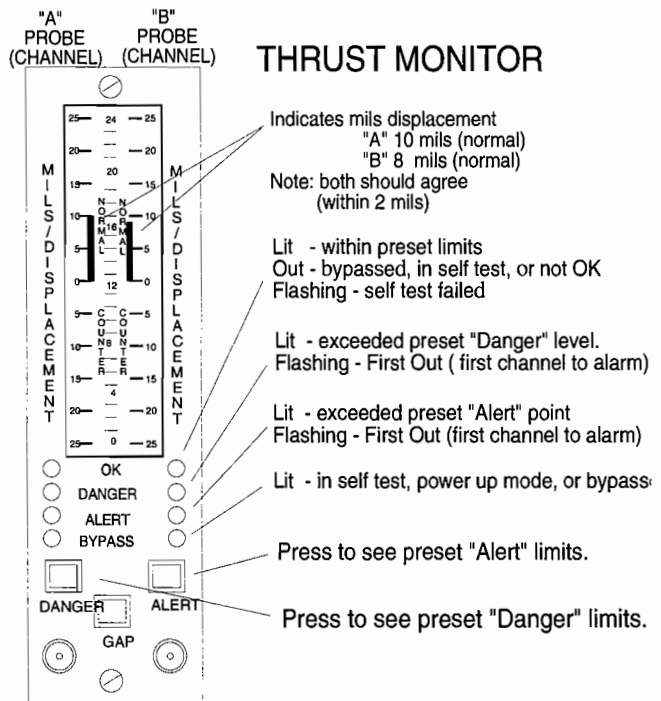


Figure 3. Thrust Monitor.

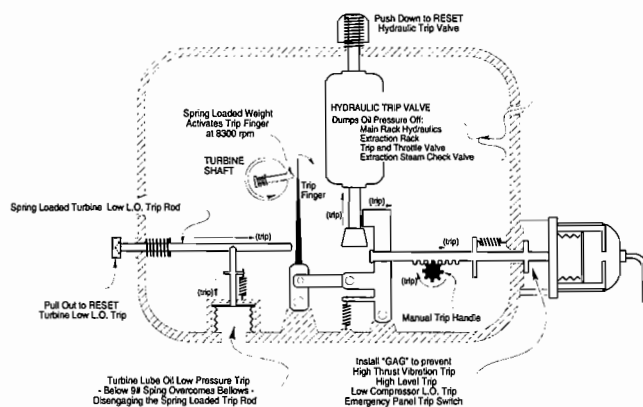


Figure 4. Turbine Internal Trip Linkages.

Informal Training

Even excellent formal training programs and procedures cannot provide all the information necessary for an operator to understand and properly run their equipment. There will still be an ongoing

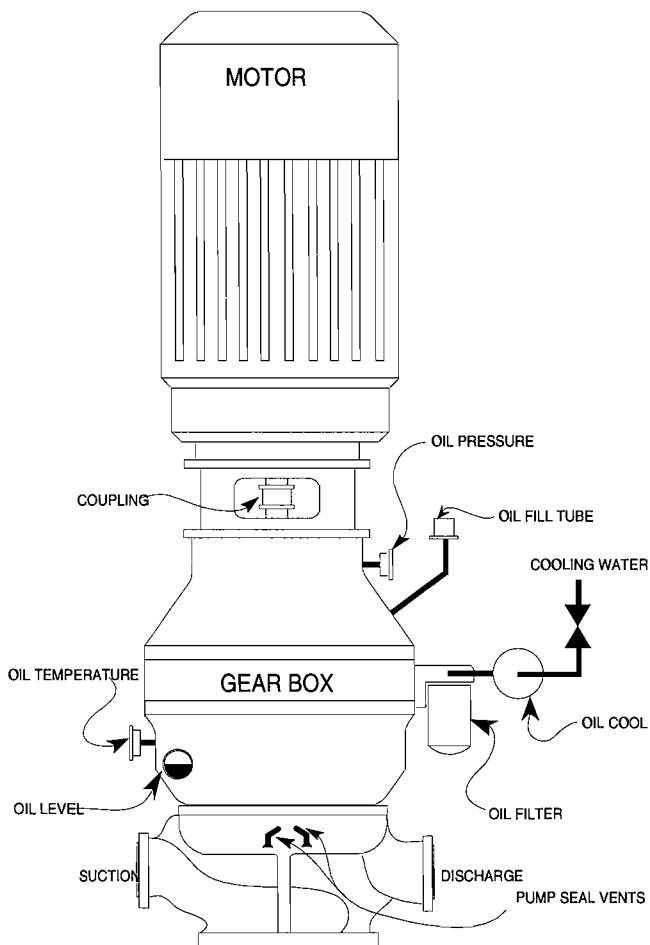


Figure 5. High Speed Pump.

need for operators to easily get answers to specific questions concerning their equipment. To provide this informal training, engineers and inspectors must see the training of operators as important, high priority work. As the level of operator ownership increases, operators become less shy about requesting help, and the technical focus shifts somewhat from the engineer doing the troubleshooting to the engineer providing information to operators. At Anacortes, this ongoing informal training of operators is deemed so important that there is a full time position (rover machinist) whose first priority is to be an information resource to operations.

The Rover Machinist

At the Anacortes refinery there is a full time machinist position called the rover machinist. This individual has been extremely important in developing operator ownership. The main role of the rover machinist is to informally train operators by simply being readily available to answer all their questions concerning rotating equipment. Even with a good formal training program, good procedures, and checklists, there is still significant additional knowledge that operators need. This additional knowledge is provided either directly or indirectly by the rover machinist. The rover machinist has no specific pump repair responsibilities. He is available to help with any of operations questions or problems on all normal maintenance day shifts. He carries a radio that allows him to be quickly contacted by any operator who may need some assistance with machinery. The operators also know that the rover's main job is to immediately respond to their requests for assistance. The rover answers questions such as:

- Is this bearing running too hot?
- Is this machine vibrating excessively?

- How does this equipment work?
- What is the correct type/amount of lubricant for this equipment?

Many operators are not comfortable directly contacting a machinery engineer or inspector to ask "a dumb question," but they will call the rover machinist. If the rover machinist cannot directly answer the question, he will then enlist the help of the machinery engineer or machinery inspector. The personality of the rover machinist is critical for his success. He must be able to have discussions with operators in an encouraging manner and he should be able to relate well.

The rover machinist also has several secondary, but still important roles in addition to being a training resource to the operators. The rover machinist also audits (usually in an informal way) the machinery reliability activities of the operators. If he finds any deficiencies, he will usually deal directly with the operators to encourage them to properly care for their equipment and rarely will need to escalate issues. The rover machinist is also the first line vibrations analyst. Although Anacortes does not routinely take vibration readings for general-purpose equipment, the rover will analyze vibration of machines that are suspected to have a problem. The rover machinist will also keep close watch on machines that are under some distress (frequently checking temperatures and vibration), until the problem can be corrected or the machine removed from service for repair. Finally, the rover machinist is available as an extra craftsman to help work on other machinery jobs of short duration.

Emergency Drills

Even the best operated plants still have process upsets. However, the ultimate consequences and cost of the upset depend to a large measure on the effectiveness of the operator's response. It is often possible to minimize the consequences and costs of process upsets with timely and correct responses. One way to enhance the operator's ability to respond properly is to conduct periodic (quarterly) emergency drills. These drills can be planned and led by trainers, operation's foremen, operators, or any subject matter experts. The goal of the drill is to allow a group of operators to think through their responses to various emergency situations. The outcome of the drill should be both learning by the operators as well as uncovering deficiencies in procedures or equipment.

The drills should vary from small and simple ones that focus on a single operator's response, to larger drills that require communications among separate operating areas throughout the plant. The emergency drills may be initiated by placing a "red tag" (an informational tag describing the mock problem) for an operator to find if he performs the checks he is supposed to. This is another method of auditing and encouraging proper surveillance activities.

CONCLUSION

It is possible to achieve high reliability at a low cost and with a minimal need for technical resources. But to achieve low cost reliability, it is crucial to have both operators who are highly engaged in properly running their equipment and a close partnership between operations, engineering, and maintenance. Operators who take ownership of their equipment can greatly increase the reliability of machinery (even marginal hardware) by keeping unit operation smooth, and closely watching and properly lubricating the machines. A culture of operator ownership can gradually be established by providing training and encouragement as well as establishing reasonable expectations and accountability.

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APPENDIX

PROCEDURE FOR WEEKLY PUMP SWITCHES

PURPOSE

This procedure provides guidelines and outlines steps used to perform weekly pump checks and pump switches. Due to equipment variation, some items may not pertain.

REQUIREMENTS

Unit operators are responsible for performing weekly pump checks and pump switches to ensure proper operation, reestablish internal lubrication, and reveal any limitations.

HEALTH, SAFETY, AND ENVIRONMENT

Stay clear of moving parts at all times, while performing this procedure. Make sure that there are no hot work or automotive permits in the area before venting or draining pump cases or pressure taps.

REFERENCE MATERIAL

- Procedure for General Lubrication Instruction
Lubrication Manual
Mechanical Inspector Shop #1

QUALITY:

Unit operators must be attentive to pump operation at all times; small problems, if not detected and corrected in time, can lead to expensive repairs and possible loss of production.

REVIEWED BY: _____ (TSO) Date _____
REVIEWED BY: _____ (Training Foreman) Date _____
APPROVED BY: _____ (Dept. Supervisor) Date _____

- 1. Check the turbine and pump inboard and outboard bearings for water or sludge.
1.1 Drain a small amount of oil into a beaker or cup.
1.2 Any water or sludge found, note on the check sheet.
1.3 Drain water until good oil appears.
1.4 Change oil if contamination or discoloration is found.
2. Check the oil in the oiler bulb for discoloration, water, or sludge.
2.1 Make sure that the oiler bulb isn't cracked or leaking.
2.2 Rinse out and replace oil as needed.
2.3 Replace badly stained oiler bulbs.
2.4 Fill the oil bulb.
3. Make sure that the oil line is not plugged.
3.1 Drain a small amount of oil from reservoir into a beaker or cup.
3.2 Watch for bubbles to float upward in the oiler bulb.
3.3 If no bubbles appear, do not run the pump until the line is unplugged.
4. Make sure that the oil mist systems are operating (where provided).
5. Grease ball and roller bearings and other points (where provided) as recommended by lubrication manual.
5.1 Clean off grease fittings before applying fresh grease.
5.2 Avoid excessive grease injection.
6. Make sure that steam traps on the turbine supply and exhaust are working properly (where provided).
7. Make sure there is a flow through the CW jackets (where provided).
7.1 Backflush where possible.
7.2 Do not run the pump if plugged.
8. Make sure that the seal flush is lined up (where provided).
8.1 Adjust as needed.
8.2 Seal purge pressure should be at least 20 pounds over suction pressure.
9. Make sure that the steam seal purge (or quench) is properly adjusted.
9.1 Close purge supply.
9.2 Open supply until a wisp of steam can be seen coming out of seal.

Table with 2 columns: Initial, and a series of empty rows for initials.

NOTE: Do not bleed off pressure taps that are winterized.

- 17.4 Note the pressure to the PC when the output air drops to 15 psig.
17.5 The pressure noted should be 15-20% below normal pressure.
17.6 Return the auto-start system and turbine to normal standby condition.
17.7 Make sure that the trip and throttle mechanism appears to function properly.
18. Notify the unit Boardman that you will be switching pumps.
19. Test the motor auto-start (where provided). NOTE: This will start the pump.
19.1 Block in the pressure tap to the auto-start switch.
19.2 Slowly bleed-off the pressure to the auto-start until the motor starts.
19.3 Note the pressure at which the motor starts.
19.4 The pressure noted should be 15-20% below normal pressure.
19.5 Return the auto-start system to normal standby condition.
20. Pre-cool pumps in light hydrocarbon service by venting off some liquid to the atmosphere or flare.
21. Make sure that turbines and pumps in hot hydrocarbon service are preheated.
22. Start the pump and make sure that it is putting out discharge pressure.
23. Shutdown the pump that was running.
24. Run the pump for at least 15 minutes and monitor its operation.
24.1 Listen and feel for unusual noise or vibration.
24.2 Check for loss of product flow or difficulty with controllers.
24.3 Check for leaks.
24.4 Feel for overheating bearings.
24.5 Watch for oil consumption.
24.6 Check for a change in discharge pressure.

DEEPWELL PUMPS

- 25. Use Turbo 68 on all motors.
26. Only add oil when the pump is running.
27. Oil level should be maintained at the bottom of the "bullseye" sight glass. DO NOT OVER FILL. If the sight glass is dirty, then pull the plug using a wrench and look inside. The oil level should be approximately 1/8" below the plug threads. Plugs are usually kept hand tight.
Note: • P-8046 and P-8052 are sealed units and don't require adding oil or grease.
• P-929 and P-930 have vented plugs.
28. If the oil appears frothy, it indicates there might be water in the oil. Switch pumps and allow oil to settle. Restart pump, if froth reforms then switch again and write a maintenance work order.
29. All lower guide bearings on all deepwell pumps are sealed and don't require grease.

REFINERY WEEKLY PUMP CHECKS AND SWITCHING SCHEDULE

Table with 3 columns: DAY, ZONE, and REQUIREMENT. Rows include MON, TUES, WED, THUR, FRI, WEEK END SAT & SUN.

- NOTE: The steam purge should be left on even when the pump is shut down.
10. Inspect the pump for damaged or oil soaked insulation.
CAUTION: Oil soaked insulation can present a fire hazard.
11. Make sure that the discharge pressure gauge is lined up and appears be in working order.
12. Make sure that all guards are properly installed.
13. Check the suction and discharge lineups.
14. Make sure that all pump drains and vents are closed.
15. Drain water (or acid) from hydrocarbon pump cases.
16. Request permission from the Utilities Dept. to switch pumps.
17. Test the turbine Auto-Start system (where provided).
17.1 Prevent the pump from starting, using the trip/throttle or steam valve.
17.2 Block in the auto-start pressure tap.
17.3 Slowly bleed off the pressure tap while watching the PC output air.