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Reminiscences of the Evolution of Reliability in Manufacturing

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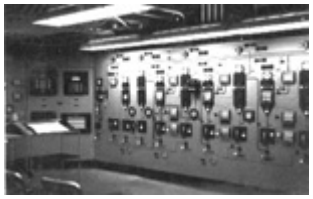
2000 Machinery Reliability Conference, April 2000





It was a dreary day outside when I got to work at a small Allied Chemical facility in Delaware in September 1951. My boss, the Chief Engineer called me into his office and told me I had a new assignment. I was to report to the head of maintenance. I had been at the facility for about three months. I was a new graduate Chemical Engineer. My first assignment was in industrial engineering. My next assignment will be in maintenance. Go figure.

My new boss assigned me as a shop supervisor in the facilities central shop. In this shop we performed machining operations, grinding, welding, pipefitting, carpentry, lead burning and assembling operations. Job tickets were all hand written and assigned by the maintenance manager or his clerk. The clerk also filed the tickets away so that they could be retrieved if we needed to check equipment histories and if the clerk had time to do the search.

My desk was a standup type located on the shop floor in line with the radial arm wood cutting saw. One day a missile cut a hole in my desk when a piece of wood flew by. When I asked my boss for permission to move the desk he uttered something about the normal hazards of the job.

Our work on equipment was strictly breakdown maintenance. However, my boss had a good eye, good feel and ear for trouble and made frequent daily trips to the processing sites to gauge the health of the equipment. I am positive, although he never confided in me, that he also did a bit of planning and scheduling in his own head.

To give you an idea of what the environment was like in those days, I must also tell you that all pencils that were worn out had to be brought to the Assistant Plant Manager's office for inspection. If the stub passed the manager's critical examination, then we were awarded a new pencil. Also all nails that were recovered from shipping crates were collected and later straightened and reused. In today's modern version, these kinds of activities would be called cost control.

We manufactured some very corrosive acids including hydro fluoric acid. We had safety showers to bathe in if we were showered by a leak but safety was a weak issue. When someone was hurt, management ordered the gates closed to all reporters and information was tightly held. As a result the reporters would publish all the mishaps and accidents of the last thirty years making it look like they had happened recently in rapid succession.

It wasn't until 1956 at a new site in Hopewell, Virginia, that I had seen, and was able to purchase, an IRD vibration analyzer. This was a large awkward metal box of electronics. It was difficult to move around but I was able to solve some difficult machine problems with it such as soft foot and resonance problems.

In the fifties we came to appreciate the fact that we could not allow our large rotating equipment, as well as our critical stationary units, to fail so we began inspecting them periodically. We would open vessels and crawl in to

inspect. We would open heat exchangers and pressure test them and we would take compressors, turbines and large pumps apart replacing bearings and seals.

Interestingly only managers that had courage and foresight would go along with this at first. Looking at it from the managerial point of view, they were asked to shutdown equipment that was producing product for a substantial length of time on the promise everything would work without major problems until the next periodic overhaul. Incidentally, in the fifties the overhauls were yearly for most of the continuous process industry.

The fact of the matter was that sometimes we had awful times starting up after one of these preventive maintenance overhauls. And we did not always have a good run between overhauls. The less sightful managers were putting pressure on the need for something else that would provide better assurances. The forward-looking fellows fought the fight but without substantial successes, they were outgunned.

I believe this is what makes America great. Our freedom allows us to enter into debates that raise questions that must be analyzed. What generally results, are the means to propel us forward in the right directions.

We thought it out and decided that new non-destructive, non-invasive tools that were emerging in the marketplace could provide us an opportunity to lengthen the period between overhauls and also allow us the means to assure better performance between inspections.

So the new tools that were emerging in the fifties started to be employed by more progressive organizations in the sixties. In the sixties I was transferred to Allied's then largest plant and in a short time became the Head of Maintenance and shortly after that, the Head of Engineering and Utilities as well. I had a few technicians trained to take vibration readings and had every piece of equipment covered weekly. I had instant coverage of all rotating equipment. The technicians logged vibration readings and then submitted them to an engineer for analysis.

Within a short period of time, six months as I recall, we were able to sort out the proper inspection frequencies and adjusted the program. Today, many companies go into very long and arduous studies to set frequencies. I still believe that is best to get coverage as soon as possible.

Of course, thickness testing of pipe, boiler tubes and some process tubing followed. Infrared Thermography entered during this period and we were able to measure and analyze insulation breakdowns, pluggages and process flows with this new tool. Many others followed and the better run plants put them to good use. We were finally able to monitor the health of equipment while it was running with a great deal more precision than my previous boss did when he walked his facility to look, feel, and smell potential trouble.

What was the benefit? We were able to identify component failures and take equipment off line in time to prevent more catastrophic machine failures. To most facilities this benefit was measured in millions of 1970 dollars. We were able to lengthen our turn-a-round cycles to two years and continue lengthening them, as inspection equipment improved, to the point that many facilities do not go down for five years today. The benefit --- also in the millions of dollars.

Interestingly, in the seventies, and perhaps before then, we were able to continuously monitor the bearings of our largest, high-speed turbines and compressors. It naturally followed that if we could monitor these bearings continuously then we should automatically take the equipment off line if the signals indicated trouble ahead. But, this did not work because of a human factor. Some equipment came off line when it was OK and managers were hard pressed to explain to their bosses why they allowed an expensive shutdown and subsequent startup to occur. Until voting logic was available and managerial fears were allayed, the compressors were not afforded automatic shutdowns in many facilities. As many of you are aware, a loss of a thrust bearing can wreck a machine before people have a chance to react manually.

So there we were with a whole array of reliability tools. We should have felt pretty good about ourselves. After all we were saving millions of dollars, the plants were running better or were they?

Even though we had the technology to predict a large number of machine failures, we still weren't preventing them. Now man has a natural tendency to want to know why he cannot control his environment. He or she has a natural desire to solve problems that affect them. In the fifties and the early sixties we would muse about such things. We learned to read the surfaces of failed components and took measures to prevent those failures.

Recognize that this was always done under pressure to get the equipment repaired and running. So, at best, our efforts were hit and miss. In the late sixties we began to add discipline to our efforts by employing logic trees introduced to us by fault tree analysis. Now fault tree analysis is an excellent prospective tool but since we already had failures we could be even more definitive.

We employed logic tree analyses to solve our most catastrophic failures. We found stress risers, misalignment, balance, resonance, poor metallurgy, speed, and equipment sizing were typical causes of machine breakdowns. Again we found ourselves adding more millions to the benefit pool. But a strange thing happened; many of the failures that we solved continued to reappear.

But if stress risers, misalignment, balance, resonance, poor metallurgy, speed and equipment sizing were typical causes isn't it logical to wonder how they happened. So we extended ourselves and defined the point of human intervention that caused these things to happen. But we fell into a trap. Humans do not find closure unless they associate another human to incidents that befall them. So punishment had to be dispensed. Solved failures disappeared for a time, but then most of them returned.

Some time in the 1970's, a researcher described to me the path of error. He pointed out that all things that go amiss are caused by a multiplicity of errors, that our environment is very forgiving. I later found that eleven to thirteen errors generally occur prior to the one that obviously caused major problems to happen. Now this put a new dimension on solving problems. Consider that when we discipline an employee for causing a mishap, we effectively cut off the lines of communication that could lead us to the other contributing errors.

In the 1980's we added this new dimension to failure analysis. We drove the logic tree further down into an area of latent causes. Interestingly this was the area that management exercised the most control. Now we asked why was this error made. And we found that employees make errors because they are poorly prepared for their tasks, procedures are flawed or do not exist, they have too little time to perform with precision, engineering errors make assembly and operating errors easy or poor communication exists. All of these base-line causes occur because of poor or lacking management systems.

Let me give you an example or two. When a piece of equipment fails and shuts down the productive capacity of a facility, often the plant or mill manager will only ask when will it be ready to run again. If he or she does this often enough they will instill a paradigm in the workforce that says that management is not interested in the quality of repairs, only in getting the process running again. Management has now laid the seed for poor quality work and they do not even know it.

One steel mill was having catastrophic, but chronic, failures that were physically caused by misalignment, lack of bolt torquing and lack of cleanliness during assemblies. Their latent issues were improper training and lack of procedures. Because the physical causes were easily overcome, the latent causes were not addressed. Were they surprised when the failure occurred again? This time they took care of the latent issues and the failures disappeared.

Shift mechanics in an East Coast chemical plant all carried chains and chain links in their toolboxes because they knew that a feeder under a rotating horizontal dryer would either have the drive chain break or fall off. This was one of the invisible failures. It happened once or twice a shift. The mechanics were experts at reinstalling the chain in about ½ hour.

Consider that this facility was losing about 6% of their production because of these failures. In today's dollars that would amount to about $175,000 per year. Think about how many of these sleepers exist in a plant. Incidentally, when the new young Superintendent of Maintenance perused a year of shift notes he noticed this failure and several others. He performed root cause analysis on the chain problem and found that the original Design Engineer had misplaced a decimal point causing the feeder to operate ten times faster than it should have been. A simple sprocket change was made and the problem went away.

We concluded the 1980's with smaller boxes to do vibration analysis, more sophisticated and smaller equipment to do infrared scans, better means and equipment for acoustical studies and a host of new ways to gather information. Unfortunately, although we had improved our design technology, we were still lagging in our ability to help employees to motivate themselves, to transfer knowledge from the training room to the field and support proactive activities such as Root Cause Analysis.

So our challenge for the nineties was to educate management that it is possible to establish a culture where proaction leads and reaction lags. But we ran into awesome obstacles. Hammer and Champy ushered in the concept of re-engineering in the work place. It caught on and a $4.7 billion dollar business emerged. However, many of these applications eventually failed. When questioned about these failures by a Wall Street Journal reporter in 1996 Hammer said, "I wasn't smart enough about that. I was reflecting my engineering background and was insufficiently appreciative of the human dimensions." I hope you see the obstacles. Re-engineering has propelled us forward but at a cost. Certainly a loss of a lot of company expertise, certainly a loss of morale at least for a time, and certainly by increasing anxiety in the work place.

Please understand that I personally believe that re-engineering was a proactive step forward. And proactive moves will increase anxiety. In fact, if there is no anxiety, then expect that there is no culture change. The obstacle was in the intensity. In America we lost loyalty to a company. Now people work for the benefits and the pay, very few work for the joy.

In an effort to link maintenance and reliability, people like John Moubray brought Reliability Centered Maintenance (RCM) out of the aircraft industry and offered it to the continuous process industries through his book Reliability Centered Maintenance published in 1992. RCM is a very thorough audit of equipment and process functionality with the end result usually being a program of non-destructive testing and usually some procedure changes to avoid catastrophic failure. First let me say that I see no harm to equipment or processes by using RCM. I personally believe that it is a long and arduous way of developing an effective non-destructive testing plan.

I am also amazed at the following that this method got in the continuous process industry. During the Kosovo bombing, stealth bombers were flown from bases in the United States. These airplanes had to stay in the air for thirty hours which some felt a remarkable feat. In contrast, in the continuous process industry equipment runs for years without shutting down. They do this twenty-four hours a day without the redundancy that exists on those bombers. I wonder who should have been teaching whom.

In the 1990's Six Sigma was also introduced. This is a very expensive training exercise in statistical approaches to achieving excellent performance. Here again I have no quarrel with people that want to use their financial assets in this manner. I personally know that the results can be greater and achieved in less time by other means.

In 1993 Noel M. Tichy quoted Jack Welsh as saying, “I made my share of mistakes – plenty of them – but my biggest mistake by far was not moving faster.” No one can challenge General Electric’s performance during the Jack Welsh tenure. I am certainly impressed. However, Six Sigma is not simple or fast although it does get results. I believe there are faster and more powerful means.

To appreciate this fascinating appreciation of fads, we have to understand that it is restraining paradigms that are preventing us from achieving much grander production and much higher profits.

For example, most businesses employ people to deal with problems. In fact, when one considers that anything that is repetitive can be automated we begin to realize that many, if not most, of the people that we employ are there to solve problems. In deed, in most cases, the problems that they solve are the same problems that they solved yesterday, last week or last month. Many, if not most, of these problems are so commonplace they tend to be invisible. Correcting stock deficiencies, misaligned machinery, balancing rotating machinery components, misplacing x-rays, dispensing medicines to the wrong patients are examples.

My point is that most of us will put up with enormous losses without finding the root causes of our problems and resolving them for good. In contrast, if we have a large loss such as a fire, explosion, babies switched in a hospital, large accounts that default in a bank we will do our best to find the roots of the problem. In economic terms these issues happen so infrequently their costs can usually be amortized over several years. I am not making a case for ignoring these large outlays but I will submit to you that the losses that you are incurring from chronic problems are much, much greater. So why do we put up with these drains upon our businesses?

Because of paradigms that can be stated as follows:

- Large losses raise the attention of top management so they must be studied down to their root causes.
- Chronic problems are small and of no interest to top management.
- Management wants to see us getting things back to normal instead of spending our time in long investigations.
- Finding and eliminating the causes of problems can reduce my job security.

I have discussed the past and tried to bring it up to the present. Before I close I would like to discuss the future in terms of the past. When I started working we did breakdown maintenance. When it broke, we fixed it. In the 1950’s we were also performing preventive maintenance which meant, in those days, that we took our critical equipment down, usually once a year, cleaned it, replaced worn parts and always replaced bearings and seals. Of course, as you know, these actions encouraged infant mortality failures.

In the late 1950’s and 1960’s, we introduced predictive maintenance. We used newly emerging non-destructive testing techniques to determine when machinery components started to fail so we could take action to prevent more catastrophic machine failure. We were looking for primary machine failures to prevent more expensive secondary failures.

Through the years we used new technology to perfect these approaches. We always had failure analysis because it is man’s nature to determine causes. Unfortunately, as we honed this technique we were able to find individuals that we could blame for the failures. When we punished these individuals, we rationalized it by believing that:

When a person is disciplined for making a mistake we are preventing future failures because that individual will never make that mistake again and his colleagues will observe his punishment and not make same mistake.

As I pointed out earlier, in our research over the years we found that when a deviation occurs, whether a failure of a machine or process or administering the wrong medicine to a patient there are multiple causes. When we examine the deviation and find the human error we make a grave mistake when we discipline individuals for the error. This is because that error represents only the last error before the deviation. Disciplining has the effect of closing off communications that help us identify the other eleven to thirteen errors. This is the reason why we were not successful in eliminating chronic problems.

Our research has also revealed that new initiatives cannot take hold if management is not willing to actively support them. What can management do? First they must realize that any change that they want to inculcate into the culture will usually be resisted. So they must appoint people to drive the change remembering that any change can ultimately be absorbed into the culture if it does not violate the deep seated values of the people that they are trying to change. I have found that in today's working environment it is best to also have a Champion, a member of management that can support the Drivers.

Beyond this, the introduction of a new way of doing things requires that management set up management support systems. For example, if we train employees to perform problem analysis they will need some way to tap experts. Since problems are resolved after the fact, that is, they are solved after an incident, the urgency to make changes passes. Our newly trained analysts need to have systems that will assure their recommendations are considered and implemented. I think you get the idea. Currently, some forward-looking companies are providing the needed support. In the near future many others will come on board.

This brings me to the last part of my address. What does the future hold? During the last term of the Eisenhower presidency, we had 35% of our work force engaged in manufacturing activities. Today we have 18%. Yet, we are producing three times more products. We are becoming more and more competitive. We are getting better at what we do. But more needs to be done if we are to remain the leaders in productivity.

I believe our next job will be to eliminate the need for predictive maintenance. We will do this by performing with much greater precision. To be proactive in the future will mean to be more precise. We will machine to exact dimensions not to tolerances. We will assemble our machinery in clean room environments, we will automate bearing assemblies, we will find new ways to fill prescriptions and dispense medicines and we will conduct meetings that get results.

When I started in 1951, our biggest chronic machine problems were poor lubrication, misalignment and balance. Today, in most facilities these are still the problems. But it is changing. Lubricants are more sophisticated and there are now more precise ways to deliver them. New computerized alignment methods make the job easier and more precise. The same is true of balancing equipment. We have a way to go but the path is clear and competitive forces are driving us.

I wish I could be around for the next fifty years because I believe it will be very exciting. I wish you courage to do the things that seem impossible, empathy and understanding of the human heart and the perseverance to stay the course.

Thank you for the opportunity to share with you my experiences and my vision of the future.

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