P (+61 8) 9457 6297 E info@plant-wellness-way.com

Did DuPont Chemicals Miss Something Important in their Turn-Around?

Let a Plant Wellness Way EAM System-of-Reliability End Your Business Risks Forever

Abstract:

Did DuPont Chemicals Miss Something Important in their Turn-Around? DuPont Chemicals credit Root Cause Failure Analysis (RCFA) as a key tool in improving their productivity during the late 1980s. But was it the best choice to make if they had known the reliability properties of series equipment arrangements as well as we do today? Questions over whether RCFA is a good choice for improving the reliability of existing operations are raised, along with identifying the most powerful reliability improvement property that exists. Many companies have spent much time and resources using RCFAs on equipment reliability problems, when they could have got the same outcome years sooner had they used system-wide reliability improvements across the whole plant.

Keywords: DuPont Chemicals, root cause failure analysis, defect elimination, failure prevention

Ever since I first heard the DuPont Chemicals turn-around story I have been inspired by it. If you do not know the DuPont Chemicals story here is a very quick summary.

Back in the early 1980's DuPont realised that though they were a big company, they were exposed to low-cost producers. They began investigating what opportunities they had to protect their world-wide business. What soon became clearly apparent was that they were not utilizing their capital plant and equipment well and were getting a poor return on investment. Compared to the best operators in their industry they were average performers. Their maintenance costs per unit of production were well above the top organizations and their plant availability well below. They decided that this had to change if they were to secure their future.

From the mid-1980's onward they initiated and used good asset management practices across their operations. They started challenging their business-unit managers to implement those practices that improved the utilisation and availability of their plants. Figure 1 is a graph from that period that shows how DuPont's cost of maintenance as a proportion of equipment replacement value (ERV) fell during the years following the introduction of those initiatives. It represents some 30% reduction in maintenance costs. But more importantly, it implies greater plant reliability as the need for repairs fell. For DuPont that translated into higher equipment availability and plant utilisation, which gave them more production for no extra capital cost. The return on investment skyrocketed!

Consequently, DuPont Chemicals became known as innovative pacesetters and a world-leader in industrial asset management. Along the way they developed or improved many of todays commonly used asset management practices and knowledge. It is a highly inspirational story to those of us who work in the field of industrial operations and maintenance.

There were many initiatives used by DuPont during that period. One that their people today claim was amongst the most important was the use of Root Cause Failure Analysis (RCFA) (A comment made by a DuPont presenter in a 2004 seminar heard by the Author.). They applied it to solve both sporadic failures and chronic process problems. As each RCFA improvement project was successfully completed their process plants' reliability and productivity rose higher and higher.

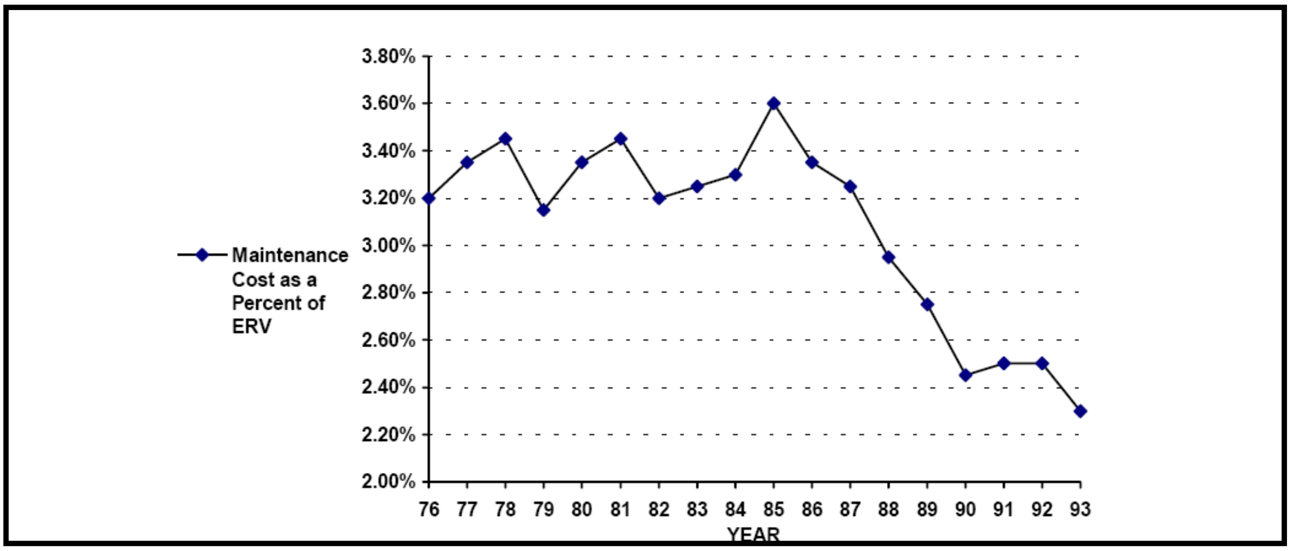

Figure 1: Sourced from: **Benchmarking Performance in the Mining Industry - Reliability and Maintenance as Strategy Components** by Edwin K. Jones PE, and William Holmes

Their approach was to first produce a Pareto chart of the 'bad actors' equipment in an operating plant. Equipment across an operation was charted in order of cost impact to the operation, with the worst cost plant items being clearly identified on the Pareto chart. The second step was to make another Pareto Chart for each of the worst equipment showing the cost of each problem on the equipment. Finally, RCFA was applied on the repetitive problems and their causes were either removed by redesign, or better procedures put into place to address the cause.

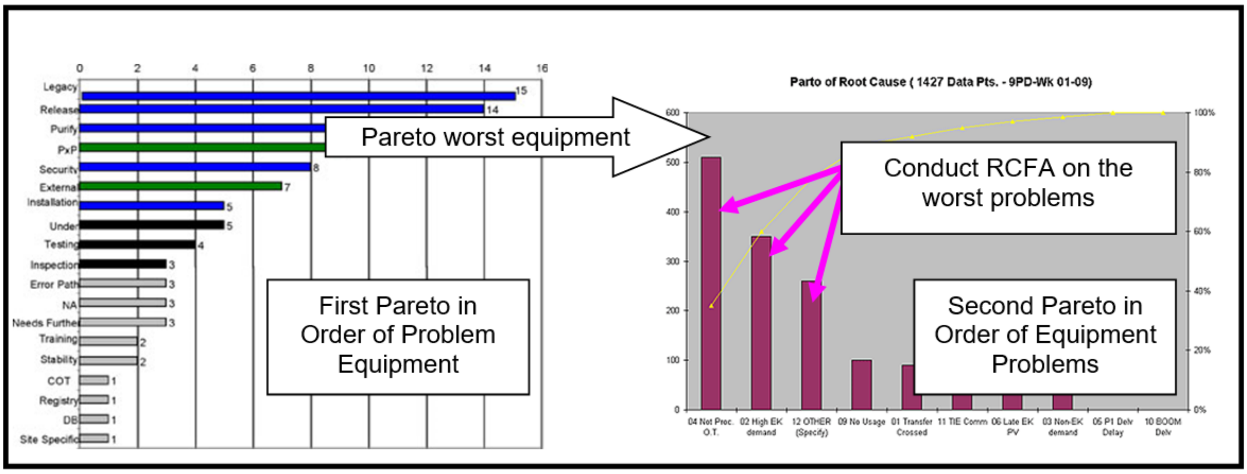

Figure 2: The Double Pareto Chart Method used to Identify Equipment and Problem Priorities for RCFA

Further credence that Root Cause Failure Analysis is a powerful tool for improving the reliability of industrial operations was given in 2007 when the Author heard a similar story about a New Zealand hydro-generator, Meridian Energy, who had used RCFA along with other reliability growth strategies, to vastly improve their operating performance. In the late 1990's Meridian Energy was experiencing high generation asset downtime due to equipment failures. The forced outages could not be tolerated as it exposed them to risks of financial penalty from Government Authorities. In Figure 3 the rising part of the red line is bad operating performance, and the falling part is good performance.

In 1999 they introduced the regular use of RCFA to find and correct failure causes. It combined with the other reliability initiatives underway and propelled the business to a dramatic turn-around in the operating performance of their equipment assets, gaining annual savings of NZ$975,000 by 2003. Figure 3 shows graphically how generating asset reliability began to accelerate when RCFA was instigated in mid-1999.

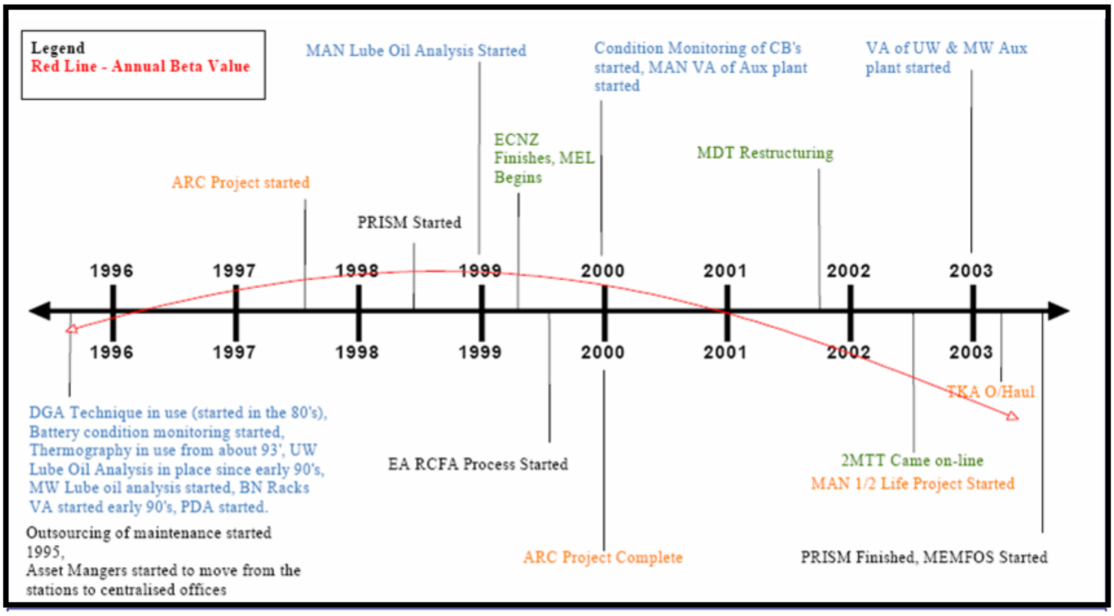

Figure 3: Extract from a presentation '**Crow/AMSAA Reliability Growth Modelling**' by Nigel Comerford given at the November 2007 MESA technical seminar, Perth, Western Australia

Now you have clear evidence from two organizations that vastly improved their businesses by vigorously using RCFA. RCFA works. It will let you find and fix your problems one-by-one if you faithfully use it and persevere with it. Both DuPont and the Meridian Energy are proof of that.

DuPont and Meridian Energy used RCFA in a suite of reliability improvement tools to tackle reliability problems in their plants. However, the entire reliability improvement process required four years of consistently applying reliability growth methods to make significant improvements at Meridian Energy, and about six years at DuPont Chemicals. One wonders if there was an alternative method to achieve the same results in less time.

There is, but in order to explore how that can be done it is necessary to understand the reliability properties of series processes.

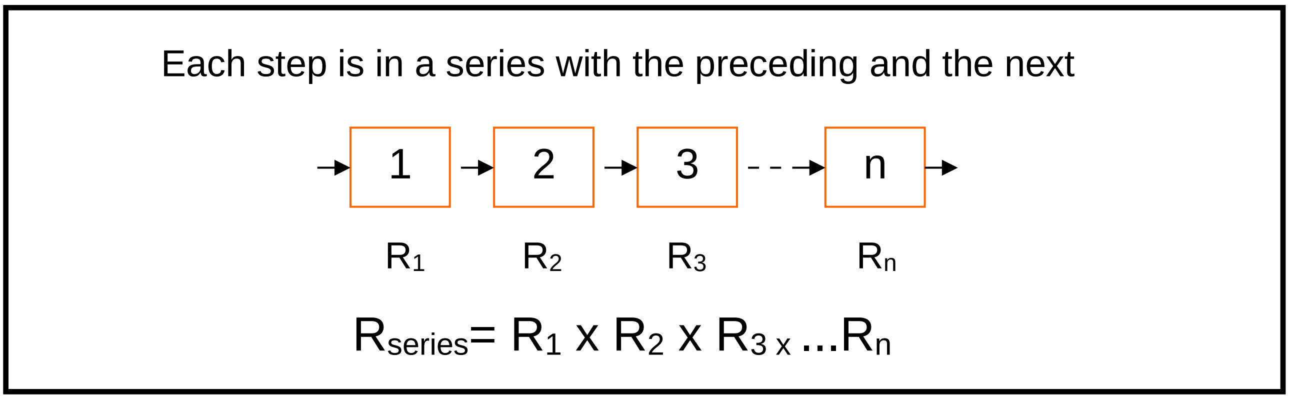

Figure 4: Reliability Block Diagram of a Series Arrangement

Most of our industrial plant and equipment, all our production processes and all our work procedures are a series configuration—one thing sequentially comes after another. Figure 4 shows what a series layout looks like. It is any situation or circumstance where each sequential step is done one after the other.

Using the centrifugal pump set in Figure 5 as an example: an electric motor turns a shaft connected by a coupling to the pump shaft on which is mounted an impeller. For the pump impeller to spin and pump liquid, the pump shaft must rotate, as must the coupling, as must the motor shaft, as must the magnetic field in the motor. All these requirements for the impeller to turn form a series arrangement. If anyone requirement is missing the impeller cannot turn and liquid cannot flow.

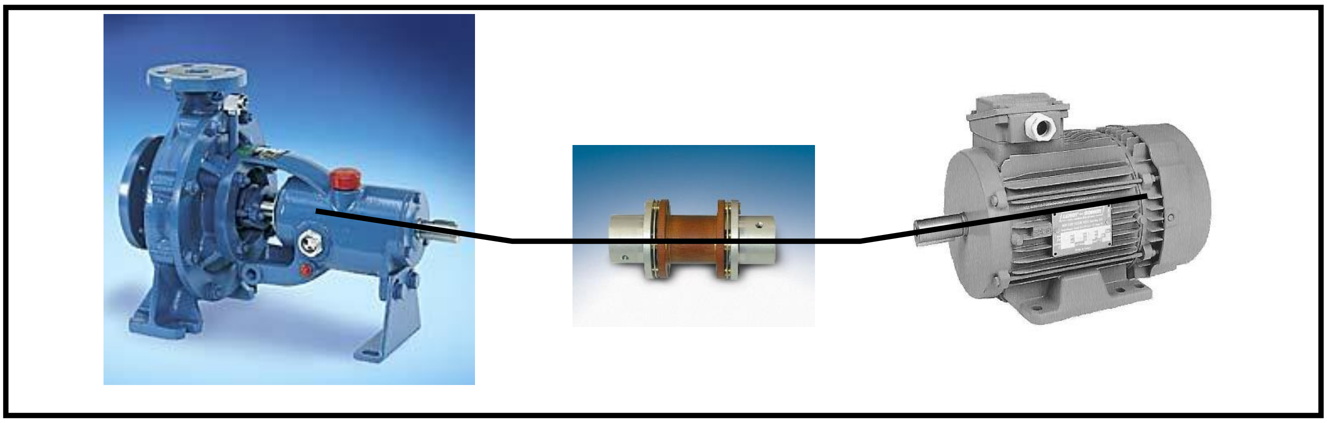

Figure 5: Series arrangement of parts on a Centrifugal Pump Set

The reliability of a series arrangement is calculated by multiplying together the reliability of each step in the arrangement. The equation to use is shown as ‘$R_{series}= R_1 \text{ x } R_2 \text{ x } R_{3\text{ x}} ...R_n$’ in Figure 3. As soon as any single step in the series drops to zero (0), the whole series becomes zero and this means the system stops working. If the coupling should fail on our pump set, the impeller mounted on the pump shaft cannot turn because the coupling joining the pump to the motor cannot transmit motor rotation, and no liquid will flow from the pump. The pump set would be considered failed.

A series arrangement has the three very important series reliability properties described below.

1. **The reliability of a series system is no more reliable than its least reliable component.**

   The reliability of a series of parts (this is a machine – a series of parts working together) cannot be higher than the reliability of its least reliable part. Say the reliability of each part in a two-component system was 0.9 and 0.8. The series reliability would be 0.9 x 0.8 = 0.72, which is less than the reliability of the least reliable item. Even if work was done to lift the 0.8 reliability up to 0.9, the best the system reliability can then be is 0.9 x 0.9 = 0.81.

2. **Add ‘k’ items into a series system of items, and the probability of failure of all items in the series must fall an equal proportion to maintain the original system reliability.**

   Say one item is added to a system of two. Each part is of reliability 0.9. The reliability with two components was originally 0.9 x 0.9 = 0.81, and with three it is 0.9 x 0.9 x 0.9 = 0.729. To return the new series to 0.81 reliability requires that all three items have a higher reliability, i.e. 0.932 x 0.932 x 0.932 = 0.81. Each item’s reliability must now rise 3.6 % for the system to be as reliable as it was with only two components.

3. **An equal rise in reliability of all items in a series causes a larger rise in system reliability.**

Say a system-wide change was made to a three-item system such that reliability of each item rose from 0.932 to 0.95. This is a 1.9% individual improvement. The system reliability raises from 0.932 x 0.932 x 0.932 = 0.81, to 0.95 x 0.95 x 0.95 = 0.86, a 5.8% improvement. For a 1.9% effort there was a gain of 5.8% from the system. This is a 300% return on investment. Series Reliability Property 3 seemingly gives substantial system reliability growth for free.

These three reliability properties are the key to maintenance management success.

- Series Reliability Property 1 means that anyone who wants high series process reliability must ensure every step in the series is exceptionally reliable.

- Series Reliability Property 2 means that if you want reliable series processes you must remove as many steps from the process as possible – simplify, simplify, simplify!

- Series Reliability Property 3 means that system-wide reliability improvements pay-off far more that making individual reliability improvements.

When RCFA is used to address equipment reliability in order of problem size then Series Reliability Property No. 1 is being applied, starting with the least reliable equipment items in a process, one after the other, to gradually improve the whole system reliability.

But take a look at Series Reliability Property No. 3. This property says that if you introduce a system-wide reliability improvement, you improve the reliability of all equipment **and** you get a correspondingly greater proportionate rise in the system reliability for that effort. Series Reliability Property No. 3 produces a multiplier effect over the use of Series Reliability Property No. 1. A small improvement in system-wide practices, methods or technology leads to magnified system reliability. Small cause… big effect!

Sure, Series Reliability Property No. 1 works. An RCFA done to improve equipment reliability does work. And if you RCFA each subsequent poor performer in a series of equipment you will eventually get high system reliability as predicted by Series Reliability Property No. 1. But if you use Series Reliability Property No. 3 and introduce one change that goes system-wide, you not only improve each item in the system, but you also get 'free' added system reliability through the multiplier effect. High system reliability is achieved faster using Series Reliability Property No. 3 methods than by devotedly applying Series Reliability Property No. 1 methods, such as RCFA one problem at a time.

So, what sort of single system-wide enhancement will produce magnified improvements in whole-of-system reliability? One way is to do what DuPont and Meridian Energy did with RCFA. They used RCFA to identify and eliminate the 'show-stoppers' and the lessons learned were cascaded through-out the remaining fleet of identical assets. They used Series Reliability Property No. 3 to take each improvement across all their operations. RCFA by RCFA they corrected not only the problem(s) that the RCFA was concerned about, but also every other situation where the problem could occur. They made system-wide changes with each RCFA. But that is slow, and it uses Series Reliability Property No. 3 in a limited way. Do not get me wrong, it is still an effective approach. The improved performance at both DuPont Chemicals and Meridian Energy testify to the value of the approach. But it takes a long time to improve your business because it does not use the full power of Series Reliability Property No. 3: nowhere near the full power.

The power in Series Reliability Property No. 3 is greatest when a system-wide change improves the reliability of every item in the system simultaneously. We do not fix one problem at a time in one type of machine; rather we fix all problems in all machines in one stroke. That is where the speed and big profits comes from when using Series Reliability Property No. 3 to its fullest capacity. What are these single-stroke, profit-rocketing, over-night business success-making changes?

How about instigating precision maintenance throughout your operation? By teaching all your maintainers to work to precision standards on your equipment, you have, in one stroke, instigated a system-wide improvement that benefits every piece of plant. Series Reliability Property No. 3 says that you will get a multiplier effects across your whole business by doing so. The way it works is that when you teach all your maintainers precision skills, then everywhere they work in future they will apply those skills. As they get more masterly, so too will reliability improve even further. First the precision skills are learnt and then that single 'system-wide improvement' makes every item of plant in your operation better each time it is worked on. The one system-wide change – the precision skills training – simultaneously improves every equipment item throughout the business.

Other examples of single-stroke, system-wide changes that multiply reliability improvements are:

- **teaching all your operators to be TPM masters,**
- teach your operators precision operation skills,
- **introducing lubrication and wear particle management for all lubricants,**
- teaching machine engineering design and equipment care best practices,
- **the introduction of parts standardisation,**
- using ACE 3T[1] quality control standards and procedures in the manufacture of your products,
- **using ACE 3T quality control standards and procedures when maintaining all equipment,**
- introducing risk identification and risk removal methods before all work is performed,
- **applying ACE 3T procedures to all engineering and management decisions, and**
- improving communication and accuracy of information exchange between people.

Even improving communication is a single-stroke, system-wide improvement. Figure 6 is a reliability improvement plot showing how the introduction of hand-held computers at a refinery (a single-stroke, system-wide change) brought reliability improvements to every piece of plant.

Series Reliability Property No. 3 is a single-stroke reliability solution that protects against the 70% - 80% of equipment problems due to human error and failed business processes[2] by using accuracy-controlled procedures and training people to do them masterly. The Series Reliability Property No. 3 activity of writing quality assurance work procedures and training people to do them expertly introduces a standardised practice across an operation that greatly reduces variability – the cause of most operating and business problems[3].

The full power of Series Reliability Property No. 3 seems to have been missed by DuPont in the early 1980's and by Meridian Energy in the late 1990's. They undoubtedly improved their business by using the reliability strategies that they did use. But had they applied Series Reliability Property No. 3 in its most powerful version, it is likely that they would have got those reliability

[1] ACE – Accuracy Controlled Enterprise, 3T – Target, Tolerance, Test work accuracy improvement
[2] "Use Crow-AMSAA Reliability Growth Plots To Forecast Future System Failures", H. Paul Barringer, P.E.
[3] Deming, W. Edwards, 'Out of the Crisis', MIT Press, London, England, 2000 edition

benefits far quicker, instead of taking years to get there by progressively solving individual problems.

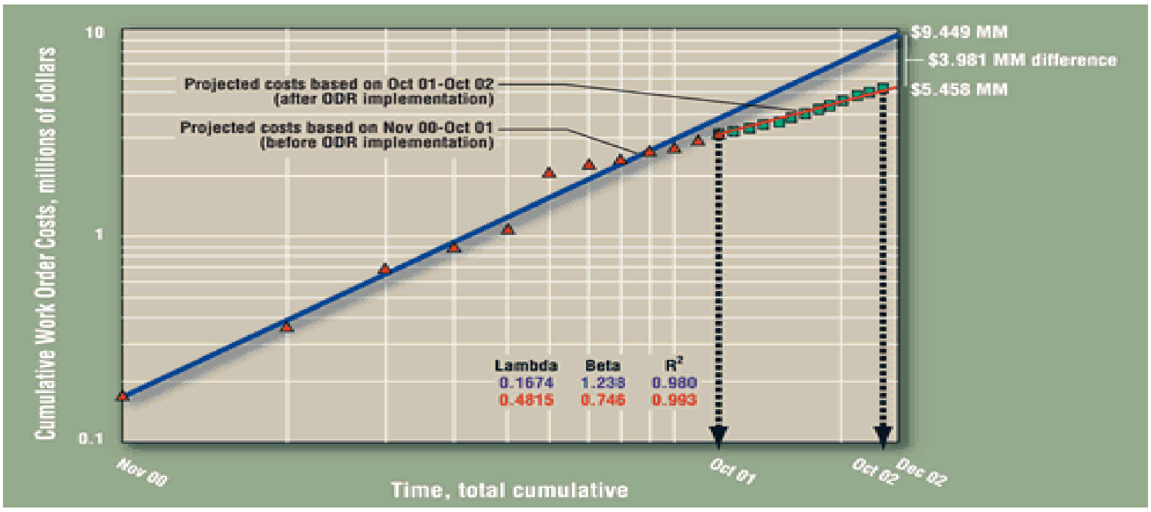

Figure 6: Monitoring effect on refinery reliability of hand-held computers to improve workflow

I am still inspired by what DuPont and Meridian Energy have done with their operations. But as useful as Pareto Charts and RCFA has been to them (and I still support the use of RCFA, because it does work), it now looks to me that if you want truly rapid reliability growth you ought to introduce single-stroke, system-wide improvements ahead of focusing on solving problems one at a time.

Series Reliability Property No. 3 methods involve reaching higher standards and using standardised methods of excellence applied across the whole business. Your managers and people are taught how to work to those higher standards and your business systems and processes are enhanced to support your people in achieving the higher standards. The 'secret' is that the reliability of every item of plant throughout the operation is improved by 'system reliability improvements' and not by equipment reliability improvements.

There is evidence available from many RCFA projects that use of Series Reliability Property No. 3 methods ahead of Series Reliability Property No. 1 methods does solve problems business-wide to lift reliability. In most cases an RCFA results in the writing of standard procedures to control equipment problems or business processes, followed by training people to the new procedure. You can use a Series Reliability Property No. 1 method to produce a Series Reliability Property No. 3 solution if the learning is used everywhere. But a Series Reliability Property No. 3 solution changes the system in which a piece of equipment is used and compared to the years it takes to improve system-wide reliability one problem at a time, the use of Series Reliability Property No. 3 methods would bring business-wide reliability growth seemingly overnight.

My best regards to you,

Mike Sondalini
www.plant-wellness-way.com