

## Reliability Roadmap Web Workshop #1 17<sup>th</sup> February 2006

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### Presenters

- Terrence O'Hanlon – CMRP, Publisher, Reliabilityweb.com
- Jim Taylor – Machinery Centered Healthcare
- Vee Narayan – How to Determine Failure Finding Test Intervals

**Terrence O'Hanlon:** Alright, here we go. Welcome to the Reliability Roadmap Web Workshop produced by our Reliability Web and Uptime Magazine. We thank you for choosing to participate and we hope that the next hour provides you with useful information to help you in your work and your professional development. Today's event is being recorded for playback later on the web. Our audience is quite large, so you may have noticed we've muted your calls in order to avoid plant noise, music on hold and other telephone generated noise that could interfere with today's workshop. You can and are invited and encouraged to post questions for Jim and Vee at [maintenanceforums.com](http://maintenanceforums.com). We've setup a special area for them to take your questions. If you have other questions during this you are free to be able to chat with me, the organizer, Terrence O'Hanlon on this, on this call while this call is going.

I'd like to take this opportunity also to thank the sponsors of the Reliability Roadmap Workshop, as this educational project would not be possible without the support of Chevron, MRG who is the management Resources Group, DMSI (Design Maintenance Systems), Commtest Instruments, ALL-TEST Pro, Genesis Solutions, Micron Infrared and Lubrication Systems Company, the makers of the Thermal Jet Oil Purifier. Again the support provided by these fine companies allows us to bring you these non-commercial educational series which demonstrates their commitment to the maintenance and reliability community. Please consider them as you seek solutions because if this is the support they offer before you buy something, imagine the level of support each of these companies provides

their actual customers.

Our first workshop leader today is Jim Taylor, of Machinery Management Solutions. Jim has more than 40 years experience both as a wrench turner, analyst and manager of machinery maintenance and operations. Jim formed his company after his work with HSB Reliability Technologies, a subsidiary of Hartford Steam Boiler. His company is Machinery Management Solutions Inc. and it provides machinery condition monitoring services and mentoring, product management, technical quality and industrial maintenance related training to industry. Today he is going to cover a practical approach to determining what maintenance work you should be doing based on failure prevention. Does it sound like RCM? Kind of but a much kinder and simplified approach. We have just sent you a link to your email where you can post questions for the presenters during and after the presentations at [maintenanceforums.com](http://maintenanceforums.com). So without further ado I am honored to introduce you to Jim Taylor. Welcome Jim.

**Jim Taylor:** Morning Terrence and morning everybody. Thank you for having me on this morning. This morning I hope to give you folks a tool that you can use and find immediate use for in your day-to-day work. It's a way to decide how to maintain your machines. If we look at most condition assessment programs in industry today they concentrate on one or two technologies. The people, the procedures and the practices are tailored to those technologies. The application of the technology is optimized but the results aren't necessarily optimized. I advocate a machine centered, as opposed to a technology centered approach. Just as your physician uses a variety of tests to assess your state of health, we should do the same thing for our machines. To do any less means that we're making decisions based on incomplete information.

And Terry that should be the next slide.

**Terrence O'Hanlon:** Okay.

**Jim Taylor:** Many plants have a condition assessment program in place. Use of those programs though operate in relative isolation, they concentrate on only one or two technologies. The people responsible for them work to maximize the technology and not necessarily maximize the results. A machine centered as opposed to a technology centered approach will maximize your effectiveness in improving machine reliability. This

approach focuses on just those tests that are most cost effective when it comes to a particular machine's reliability.

Let's consider the typical vibration program. After some research a cost justification is approved to purchase vibration equipment and software. (Next slide)

Then one or two technicians are trained and designated to manage the program. They are told to make the vibration program run. They don't get any other measure of cost benefit so they make the decision to apply the vibration to as many pieces of equipment as they can. From their perspective that's a smart move. It spreads the cost of the equipment and the training over as many pieces of equipment as possible and it minimizes the cost per measurement. It provides a full workload for those guys to show to their supervisor and it keeps the equipment in use. They've optimized the individual technology program. (Next slide)

But is the best way to improve machine reliability. Would you be happy with your doctor if on your annual physical he only tested your pulse rate and then maybe he makes a decision to do surgery based on that test? Probably not! You'd like to see him make a number of tests, blood work, EKG, chest X-ray, any of a number of others. Then he'll get a complete picture of your health and be in a lot better position to make that decision on surgery. (Next slide)

The same principle applies to machinery. To get a complete picture of machine health, you need to run a number of tests, then you'll have complete information to manage the machine and when that PM for overhaul comes up, you may decide to defer it rather than do it and don't forget, any kind of an overhaul where you break the system boundary on the machine, that's really surgery. (Next slide)

If you're going to have a technician go into the machine to collect data for one technology, say vibration, why not go ahead and collect all the data that you need instead of just vibration how about trending bearing temperatures and fluid pressures. You can also look at RPM and any number of other parameters all of which can contribute to a good picture of the machine's health. It means that more time is going to be spent at

each machine and you're probably going to be able to do fewer machines in a day but the information you gather is going to be a lot more valuable.

You'll also save transit time, prep time and administrative time that's associated with multiple trips to the machine. And you'll save some time also by applying the technology just to the machines for which it's cost effective. You haven't optimised the technology but you have optimised the machine's health care and that's what we really want. (Next one)

I want to propose an approach that's not new. Many maintenance people have been doing it for years, it's formalised by Reliability Centered Maintenance but I call it Machine Centered Healthcare. I do believe that Reliability Centered Maintenance is the best approach for critical machines but not every plant can afford to do Reliability Centered Maintenance, they may not be able to get approval or they just don't have the manpower for an RCM programme, it gets expensive in the short run. I'm proposing a thought process that will help you to decide how to maintain your machine in a less formal manner with less paperwork than Reliability Centered Maintenance requires. A machinery centered approach looks at the machine first and by asking a series of questions helps you decide how to maintain the machine's health. What tests should be done on that machine, what routine PM should be done on the machine, how can we make that overall/ no overhaul decision? (Next slide)

What we want to do is maximise the effectiveness in improving the machinery reliability. We need to assess the health of the machine based on several measures and we should only do those tests that are cost effective from the point of view of the machine itself. The question is, how do we decide what to do?

I propose that we follow a systematic step-by-step process to identify that. In summary, the process is: the first thing we're going to ask is, what are the possible failures? How has this machine failed to meet the reason it was put in the system in the first place? And once we've figured that out then we're going to ask, which one of these failures are significant, which one has a major impact, which one has a minor impact? Once we've figured that out and ranked our failures using that, then we're going to ask, how can we avoid the significant failures? How can we totally reduce the possibility that that failure will ever occur? And some failures we will be do

that, some we won't. For the ones that we can't avoid, we're going to ask, how can we get an early warning of this failure, what kind of symptoms will the failure present that we can detect? And once we've had that list, now we're in a position where we can tailor a suite of tests that we can apply to that machine to get those early warnings.

Now once we do that and we've started collecting data the final step is to bring all that information together at one point so that we have a single point of decision on decisions about the health care of that machine.

Let's take a look at this process in detail. (Next slide)

The first thing we want to ask is, what are the failures? But before we can do that we need to know what the machine is supposed to do. What's its primary function? At first glance you might say that a pump's primary function is to pump a liquid. In reality its primary function may be to keep a supply tank full, as the process draws liquid from the tank, the pump replaces it. If the pump can't pump at a sufficient rate, the supply tank will go empty. That minimum rate's going to vary from process to process.

You've also got to look beyond the obvious to find the real function of the machine and many machines will have multiple functions, for example, a pump, a secondary function of a pump is containment of the fluid that's inside so if you get a crack in a casing or a leak or something like that, it's failed to meet that function. Once you've decided what the machine's function is, we've got to ask, what can happen to prevent it from meeting that function? In the case of the pump, the answer might be that the impeller wearing out reduces the available head or maybe a bearing failure is caused on a low RPM or maybe we've got a crack in the casing or a worn out seal causing liquid loss which may reduce the flow. And there's a number of other possible failures for a pump. At this point you're just brain storming. Don't worry about whether the failure is likely or is going to have much impact. We'll do that in the next step. For now, just get a complete list of the possible failures. (Next slide)

This table is a partial list of possible failures for a motor-drive system. Your particular systems may not have all of these, they may have additional ones that I don't have on this list. Any machine's going to have primary and secondary functions, be sure you consider all of them. In this case, start motor, stop motor are obviously primary functions. Specified

speed ramp down or ramp up may be secondary functions in this particular case. You need to consider all. (Next slide)

This busy slide and it's kind of hard to read I know, is a partial list of the functions. It also shows functional failures and the failure modes associated with them. It's your starting point for looking at the symptoms or looking for the symptoms rather. But because it's so long we're going to need to make it a more manageable size and that's going to be our next step. But let's take a look at what we've got here. In this particular table we can look at the first function is, start the motor. One of the possible functional failures for that is the motor will not turn and then the failure mode lists a number of different reasons that the motor may not turn, winding failure, insulation failure and you can see the rest of them that are on the list there. (Next slide)

Now that you have a list of the possible failures, you want to decide which ones you are going to worry about. Some of these failures are so unlikely that you're not going to concern yourself with them. Others may have such a low impact that its effect on cost and production is minor. Now if we rank these, machinery history is your best way to determine how often it occurs and what its impact is. You can use the failure data and the cost data from the machinery history to rank these failure modes. But we can do without history too. I've had success in the past by using a subjective evaluation. What you do is you make a list of the failures and you ask two questions about each one, how often does this failure occur and what's the impact on production when it does and then you make this up as a questionnaire. (Next slide)

This table shows some possible answers to those questions. It looks pretty simplistic but it works. Now you're going to send the questionnaire out to a cross section of your people. You're going to send it to maintenance, you're going to send it to production and you're going to send it to management, to anybody that has some exposure to that machine and may have an idea of its reliability. And when you get the questionnaires back with their rankings, you're going to average the scores for each failure.

The significance of a failure is really a combination of two things, it's a combination of frequency and it's also a combination of the effect. You can have a failure that occurs infrequently but has a large cost when it

does or you can have a failure which occurs very often but has a minor impact and they both they can have the overall same impact on cost on annual basis.

So what we will do is we will take the score for frequency and the score for effect and we will multiply them together. And we will get a composite score in the range of 1 to 25 in this case and we will use that to rank the machines, the higher the composite score, the greater significance of the failure. (Next slide)

Starting at the top of the list, now we're going to ask how can we avoid this failure? Is there some action we can take that will keep the failure from occurring? Can we change the design, can we replace the part that has a predictable wear out period and can we adjust or lubricate to avoid the failure? This list you make here should be the start of your preventative maintenance programme for that particular machine. (Next slide)

But some of these failures we can avoid. For those we're going to ask, how can we detect the failure before it occurs? What are the symptoms of the failure? Most failures show symptoms before they happen. A pump may have to run faster because it's got a worn impeller, maybe a motor draws more amps because it is misaligned and because the supply voltage is low. A coupling may be hot because of misalignment or lack of lubrication. What you do is you make a list of all these possibilities for each failure. (Next slide)

Once we've got this list of symptoms, now we're going to go ahead and select the text that can detect the symptom and for each symptom you want to try to get as many independent tests as you can, the more information you have the more confident you will be in your call. You should have at least two tests for each failure that confirm each other and that will help you avoid false positives or false negatives in your calls. When you're considering tests don't limit yourself to high tech methods. Process parameters are particular valuable and one of the most valuable indicators is the operator and maintainer. If you have an experienced person who is familiar with the machine and he's been trained to consciously sense a particular effect he can be very effective in assessing the health care of that machine. (Next slide)

This table, even busier, shows some of the failure modes, it shows their causes and it shows the symptoms they might present for a motor. It also shows some of the possible tests that you might want to do for a motor, for example, the first line, the failure mode is winding failure in the stator. Two different causes might be conductor failure or excessive vibration, the symptoms, you can see the very symptoms there of the vibration, there's various electrical things you can measure on the motor to detect conductor failure. And you see some of the measurement technologies out there, vibration monitoring, motor current signature analysis or motor current evaluation. What you want to do is, you want to develop a similar table for each of your machines and after you've finished doing this you have a list of the tests you want to apply to that machine. (Next slide)

If we do the tests without putting all the information together it's not going to be as effective as it could be. I recommend that you designate one or two people who are assigned to monitor the health of each machine. They have to be trained in assessing all the information that is provided by the tests but note that I didn't say, trained to evaluate the data. They don't have to analyse the data, for example, the vibration spectrum. They just have to understand what the results of that analysis mean. They should get the results of all the tests along with any other pertinent information on a regular basis.

Other information they may be interested in is loads, product, product mix, run time, that sort of thing. Then they can use that information to manage the health of that machine. They can adjust lubrication intervals, they can decide when adjustments are needed, maybe when a part replacement is indicated and they may decide in the case of that overall that it's not really needed right now. I know of a case with pumps that they extended the overall interval on pumps from 5 years to 9 years strictly through this process. (Next slide)

So in summary what have we said here? We've got this thought process, the first thing we're going to ask is what are the possible failures? How can the machine fail to meet the function that it was put in the system in the first place. Then we have to ask, which of these failures are significant? And we don't want to ignore the small failures, they can add up and be just as costly as the major failures. Once we have the list of failures we ask how can we avoid these failures all together? And we can do design changes, part replacement, several other ways we can do that.

But some of the failures we can't avoid so for those failures we're going to ask how can we get an early warning? What's the symptom that the failure is going to present that we can measure? Once we have that list of symptoms we can tailor a suite of tests that detects those symptoms. And we're going to use both high-tech and low-tech methods to test this machine.

And finally, once we have this put together, we're going to gather all this information at one decision point so we can make a rational decision on how to manage the health of that machine. (Next slide)

Now if we do all that well we should be able to do this – to optimise the machine's health care. I thank you for your attention, I'll be happy to take any questions or listen to any comments.

**Terrence O'Hanlon:** Jim, thank you very much for that, that was absolutely excellent. I've been getting chats from a lot of the audience members and just so everybody knows we will make these slides available both in PDF format as well as this whole web workshop will be recorded for playback on the web hopefully within a couple of hours this afternoon and we'll send you a link on that.

Jim, I do have a question. You can see that you've gotten this approach as a basis in Reliability Centered Maintenance or RCM. How long have you been using this approach and how has it been working for you and your clients?

**Jim Taylor:** Oh I'd say this approach probably goes back 10, 20, 30 years. Maybe not in such a formal manner but as a thought process. I probably first saw this approach in the sixties when I was a reactor operator on nuke subs. And they were just installing the Navy's PMS system. At the time we were converting from an old card file system to the current PMS system and at the beginning of that we started using this same kind of thought process before we got totally into Reliability Centred Maintenance to do it.

**Terrence O'Hanlon:** Excellent. Now obviously we've invited people up to [maintenanceforums.com](http://maintenanceforums.com) to post follow-up questions, we have a link to your

recent article in Uptime Magazine. In the meantime, how can people find you, are you on the web? How can people learn more about you?

**Jim Taylor:** I am on the web. Our website is [machineryhealthcare.com](http://machineryhealthcare.com) and my email is [jim.taylor@machineryhealthcare.com](mailto:jim.taylor@machineryhealthcare.com) and 'machineryhealthcare' is all one word.

**Speaker:** Terrific I encourage everybody to go up and take a look. Thank you Jim, we hope to be reading a lot more articles from you, we've really enjoy working with you and we hope you will decide to lead many more workshops for us in the future.

**Jim Taylor:** My pleasure, I'd be glad to do it.

**Terrence O'Hanlon:** Thank you. Well great. That brings us to the second part of this Reliability Workshop. I'm very pleased at this point to introduce you to Vee Narayan. He is the author of Effective Maintenance Management: Risk and Reliability Strategies for Optimizing Performance which is published by Industrial Press. I've had the pleasure to work with Vee on prior occasions and I find his thought process and his knowledge to be extensive. He has a very practical way about him which allows those of use, and I included myself in there, who may not be as familiar with reliability engineering principles and concepts to more easily grasp them.

Vee has over 40 years experience in the oil, gas, pharmaceutical and engineering industries and he's worked in many countries. He's calling in from Scotland today and for those who may not realise it that's the UK's version of Florida.

Vee's workshop today will cover the concept of failure finding task intervals and as many of you on this call are directly involved with failure finding I hope you find today's workshop very valuable. Remember, you have an email with a link to [maintenanceforums.com](http://maintenanceforums.com) where you can post a question for Vee as well as getting links to some of his prior work. So again, without further ado, I am honoured to introduce Vee Narayan. Vee, welcome.

**Vee Narayan:** Thank you Terry and thank you Jim for leading on so beautifully. I enjoyed your talk and I found it fascinating. Excellent way to

start the subject of Failure Finding Task because failure finding is one of the many tasks that you will find when you do the kind of work that Jim was talking about earlier. I'm Vee Narayan. I live in Scotland, it's a beautiful country and as you know it's the home of scotch. So welcome, come over any time you like and I'm sure you'll find it a great place to be.

Okay, I guess we better get started then. (Next slide). Terry.

First of all, why do we need Failure Finding Task? Among the many things that Jim mentioned earlier, when we look at functions we will find that there are some hidden functions, now what do we mean by hidden functions? Hidden functions are those that the operator does not know in the normal day-to-day duties. For example, a warehouse operator may not know, or cannot know, whether the sprinkler that is there to douse any fire that may occur will actually work. Or you may not know whether the standby pump will start. These functions are said to be hidden because the operator cannot know whether or not the item will work when required.

Now most items, especially complicated machinery, have protected devices. These protective devices almost always have hidden functions. Now, when something does not work it might matter but when something that is hidden and does not work, at the point when it fails it does not actually matter. For example if your smoke detector does not work, at this point in time it may not matter. But down the line, a week or a month or a year later if there's a real fire in the place, the lack of the smoke detector might burn you to a crisp. So, hidden functions or protective devices and their hidden functions can cause serious trouble affecting safety and perhaps environment and sometimes production.

So how will we know if we can trust these items to work? Next one. Okay. Because these hidden functions are not obvious to the operator a second event or a failure is required. For example, the standby pump is normally not water. Now, if the duty pump fails then the standby will start up or rather, should start up. If there's a smoke detector in your room you will know whether it will work if there's a real fire, but then it's too late. Whether your pressure relief valve will work you don't know. But if there's an over pressure in the pressure vessel and if the relief valve works you're okay, if it doesn't work because it has failed a few weeks ago, then you may have an explosion and a fire. A fighter pilot will not know whether his ejector seat will work if there's a real need for it. And so on. (Next slide)

Now protective devices have only one job which is to protect something else. So on rotating machinery an expensive, high speed, high cost rotating machine we may have things like over-speed trips, you may have axial displacement trips. On a process plant you may have relief and blowdown systems to protect the plant in the event there's an emergency. There may be depressurizing systems, shutdown systems, there may be water or other release systems. Tankers which are being moored at dock may need emergency releases. All of these devices can fail in one of two ways. They can either fail to protect when they're required or they may operate when they're not required. Now the latter is called a Spurious failure or a Spurious trip and they are a major source of production loss. (Next slide)

How do we know what a hidden failure is or a hidden function is? There is always some confusion about, for example, the time of failure. The time of failure doesn't matter. If a smoke detector fails today and you detect it only ten days later the failure has been taken place. So, the test that we use is did the consequence take place at the same time as the failure? For example, if a pump seal leaks then you will see some evidence, it could well be a pool of oil or water or water or whatever the process fluid is, on the pump bed. But if a relief valve fails and fails to open on overpressure we will not know, in other words if it has got blocked or jammed in a place, we will not know until something else happens. So in this case the consequence does not take place at the same time as the failure. So, for hidden functions the test is if the consequence does not take place at the same time as the failure it's a hidden function. (Next slide)

As machinery becomes more complex and costly, the drive for productivity and quality is what makes them complex and costly, there can be large damage caused by the failure of these protective devices. They have protective devices, if they fail the damage can be very high. So such the protection it will provide is either from maloperation, unbalanced, loose bolts, worn bearings, reverse current and such like. Also for maintenance incidentally. Protective devices have hidden functions and if the protection is lost and the protected equipment needs it, so there are two requirements, one is the protective device has failed, the second is the protective function which may be the pressure vessel actually needs it. So there's a multiple failure, two things have failed, then serious damage can take place. You can burn the whole factory down or you can melt down a

large compressor. That sort of serious damage can take place. So we have to find these hidden functions and find out what condition they are in.

Now we use the term technical integrity to say that the plant or the equipment is safe. So the absence of a threat to safety or environment or production, we call that as technical integrity. Now, hidden functions are not like baby cub tigers as I've shown but sleeping tigers. They are waiting to bite. And if we don't know the condition we may well have a big tiger bite. (Next slide)

A feature of hidden functions is that we will only if an item is working or not when we don't want it to be. We either use it, for example, the duty pumps stops for some reason and the standby has got to come on so we have actually used it. Although alternatively if we do a test, we actually simulate the conditions so obviously the equipment thinks that there is a demand and it starts or it works. (Next slide)

Now one of the things we need to identify is how good is the standby equipment or protective device? In other words what is its availability on demand? Will it actually come to work when we want it? Now at any given time the expected value of it being in a working state, and what I mean by expected value is we know that when an item is new it's 100% available but after a few weeks, months or years it may not be that high and that value is what we call the expected value and that value is equal to its reliability at that point, its survival probability at that point. Now in the case of hidden functions, the item is either working or not working. So at any point in time, its survival probability – in other words whatever we calculate is its probability of survival is the same thing as its availability on demand. In other words whatever be it its survival probability is the same number as the availability on demand. For a hidden function therefore, we say that the availability is equal to its reliability. (Next slide)

The availability; in the case of hidden functions remains a couple of assumptions. The first is that any failed item is replaced as soon as we know of it, with an item in perfect condition. The second assumption we make is that failures are exponentially distributed. You don't need to worry about what this means and the maths mumbo jumbo is not really what we need to think about. There is a certain distribution which is fairly easy to manipulate and we assume that these failures are exponentially

distributed partly because we use mean time to failure. Now the availability on next slide sorry.

Let's take this small exercise for you to think about. You have an automobile, a car and it's got a couple of brake lights. Now on average the life of these bulbs is five years, its mean time between failures is five years. Unfortunately you have a Friday afternoon job on your car and after you've done the annual inspection at which point in time everything was working perfectly, just half a month after that one of these Friday afternoon jobs fails. So one light bulb has failed. What is the availability of the light? Just think about it. If you test the brake light after six months instead of a year, or after three months or after two months what is the availability? Is it any different from the answer to the first question? (Next slide)

Okay we can look at this pictorially with this little picture. Let's say the first bulb, we are testing it every year so every twelve months. Now in our case the Friday afternoon bulb has failed after half a month, there are twelve months; the next test will be at the end of twelve months. So for eleven and a half months that bulb is not working. So the availability is half a month on twelve which is 4.2%. If we tested after six months, we know that the bulb has failed so we will replace it immediately. These bulbs last on average five years and therefore we can expect that it will be in working condition for the remaining six months so the availability of that brake light will be half a month plus six months which is 54.2%. Similarly if we do it after three months and after two months it will be 79% and 87%, 87.5%. So what do we see now? The same bulb has failed after the same half a month but the availability has moved from 4.2% to 87.5% merely by changing one thing which is how often do we test? So the availability, the test frequency and the mean time between failures are all related and this picture should help you to understand why that is so. (Next slide)

We make a few assumptions; first that the reliability of the item is a 100% when it is newly installed. It's as good as new. The second assumption we make is that the test interval is much smaller than the mean time between failures. For example for the light bulb that we were talking about five years MTBF, we will test it probably every year; at the worst case maybe every six months. In general the value of the test interval divided

by the mean time between failures should be less than five. Usually it is much, much less than five. (Next slide)

Now we don't need to go in the math of this but it can be shown quite easily that the value of  $T/MTBF$  or  $-T/MTBF$  is equal to  $\log$  to the base  $n$  of an expression  $2^{\bar{A}-1}$ . That  $T$  is the failure finding task interval,  $MTBF$  is the  $MTBF$  of the item – the protective device – for example your brake light bulb or your pressure relief valve.  $\log$  to the base  $n$  is the napieran log – the natural log – and  $\bar{A}$  is the mean availability during the test interval. We take the mean because it's over a period of time so we take the average availability. We don't need to go into the actual derivation of the expression, all we need to know is what do we do. Now the ' $\bar{A}$ ' is an important item. (Next slide)

How do we know what ' $\bar{A}$ ' to use, what is the  $\bar{A}$  bar to use? We need to know the risk level and the demand rate. If we know the risk level that we are willing to tolerate or accept and how often this item is called upon to work then we can accept the mean availability for the certain function. Now there are quantitative methods called quantitative risk analysis which are used sometimes. You can do it qualitatively by talking to people. In general the more the exposure – for example if you've got 100 people exposed then you have a higher risk than if there is one person exposed. For example if you're talking about the glass carbon blade on a compressor where there are operators present, there's a danger that one or two or more operators may get killed if the glass carbon blade decides to fly out of the casing, but the same blade flying out of the casing of a jumbo jet may kill 300 people. So the risk levels are different depending on the exposure and the risk levels are different depending upon the demand – how often can this happen? The higher the risk, the higher availability we want. So in the case of the availability value that we talked about in the previous expression, in the case of an aircraft glass carbon blade we may expect an availability of 99% or better, whereas in the case of a process plant we might be willing to go with 97%. (Next slide)

In summary a hidden function is important for health, safety and environmental management. It's also important for profitability. So we need to make sure that these hidden functions are identified, that we know what the risk levels are and what sort of damage they can do when things go wrong. Protective devices and systems have hidden functions and for these high-risk situations we need high availability protective systems.

For example if you are running a petroleum refinery and you've got a fire protection system, then the fire protection system had better be darn good. If on the other hand you are packaging toothpaste and you have a fire protection system, yes it's still important but probably not quite that important. So we need to assess the risk level in each case and assign the availability to suit. The most important point is for – irrespective of the mean time between failures of the protective device we can always find the right availability by selecting the right testing to do, as I tried to show you with the car brake light example and by using the formula we showed you subsequently.

Thank you. I think that's about all that we want to say about Failure Finding Tests. They are important and your ability to sleep safely at night depends upon how well you catch them and how well you catch them depends on how well you test them, and that's why Failure Finding Tests are important. Thank you and have a good day.

**Terrence O'Hanlon:** Vee, thank you very much for that informative presentation. That was absolutely fantastic and I have a question for you: what advice would you give some of our members, some of the listeners of this web workshop who are just beginning their journey to improve maintenance. So what would you – what kind of advice would you give people who are just starting on their journey?

**Vee Narayan:** One of the things that I'd like to suggest is that people think of maintenance as you know "turning wrenches" but what we need to – we need to step back a bit and think what are we really doing here? We are managing risk and one of the major risks facing any plant, whether it is a toothpaste packing plant or whether it is a nuclear facility, there are risks involved and these risks, some of them are related to the fact that there are protective devices that are there. Now they need to think about it and decide what to do. Now in this presentation we've talked about what to do with them. Now for those who are in their early stages of their career in reliability engineering, get hold of a good book, read it and see what you can understand of it and if you attend conferences like ours in 2006, I'm sure you will meet a lot of knowledgeable people, listen to a lot of interesting presentations, from it you can pick up information and grow with it. But don't think of maintenance as "turning wrenches", that's the key thing. Think about it as protecting your plant from danger and the danger is not of people tripping over loose wires in the floor, which is an

important item to worry about, but there are things like releasers not working or your fire pump not starting. Those are the things we need to worry about.

**Terrence O'Hanlon:** Excellent, thank you. Vee. Lee, Ron, [Dossad] or [Dusai] and Kevin White both have question for you. I'm going to encourage them to move those questions over to your posting at [maintenanceforums.com](http://maintenanceforums.com). Because they're very good questions and I don't think we're going to have time to cover them on this. But I do have time to embarrass you because I want to tell everybody to run out and get Vee's book, Effective Maintenance Management: Risk and Reliability Strategies for Optimizing Performance. That book is available at [Amazon.com](http://Amazon.com) it's also available directly from the publisher at [industrialpress.com](http://industrialpress.com) and it is a very, very good read. We do also, as Vee mentioned we have the privilege of hosting Vee in the United States here for a one-day workshop at the Reliability Centered Maintenance Managers' Forum, March 8<sup>th</sup> through the 10<sup>th</sup> in Las Vegas, there are just a few seats left for that. If you are interested logon to [www.maintenanceconference.com](http://www.maintenanceconference.com).

We are going to request from the conference participants here today that they participate in a five question survey. We're going to send you a link and we would very much appreciate your feedback on the value of this workshop and what we can do in the future to make it better for you. We also want to thank our sponsors and Uptime Magazine for their work and support. Please support them if you're in the market for their solutions. Uptime Magazine subscriptions are free online it's [www.uptimemagazine.com](http://www.uptimemagazine.com). We will also send you a link for the recorded webinar and the PDF of these slides that people have been requesting and especially a giant thank you to Vee Narayan and Jim Taylor for sharing that knowledge today, both on behalf of Reliability Web and Uptime and all the attendees we would very much like to thank you for your participation and please stayed tuned, we're going to be hosting these at a minimum of about every two months so watch for the announcement for the next one coming up and again we appreciate you all being here as part of this. And go on over to the forums at [maintenanceforums.com](http://maintenanceforums.com) and Jim and Vee will both be hosting questions there in the maintenance connection section. Hope to see you then and thank you very much.

**Vee Narayan:** Thank you Terry for the opportunity.

**Terrence O'Hanlon:** Thank you.

**Jim Taylor:** Thank you Terry.

**Terrence O'Hanlon:** Thank you Jim.