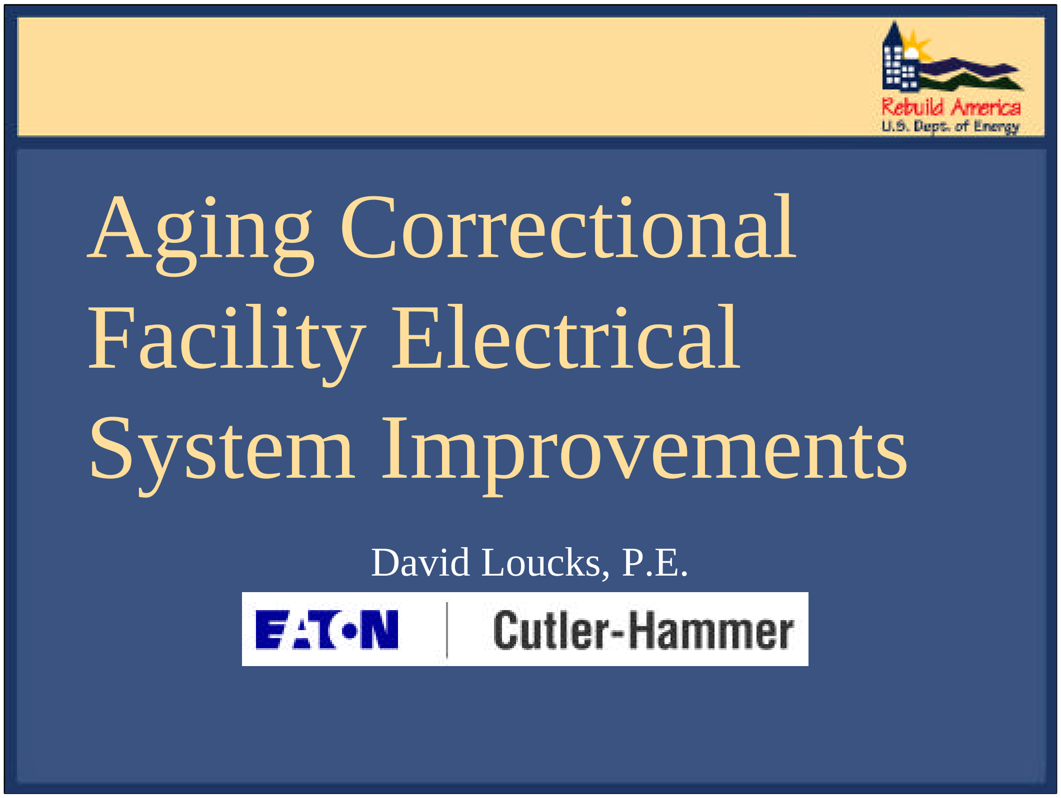

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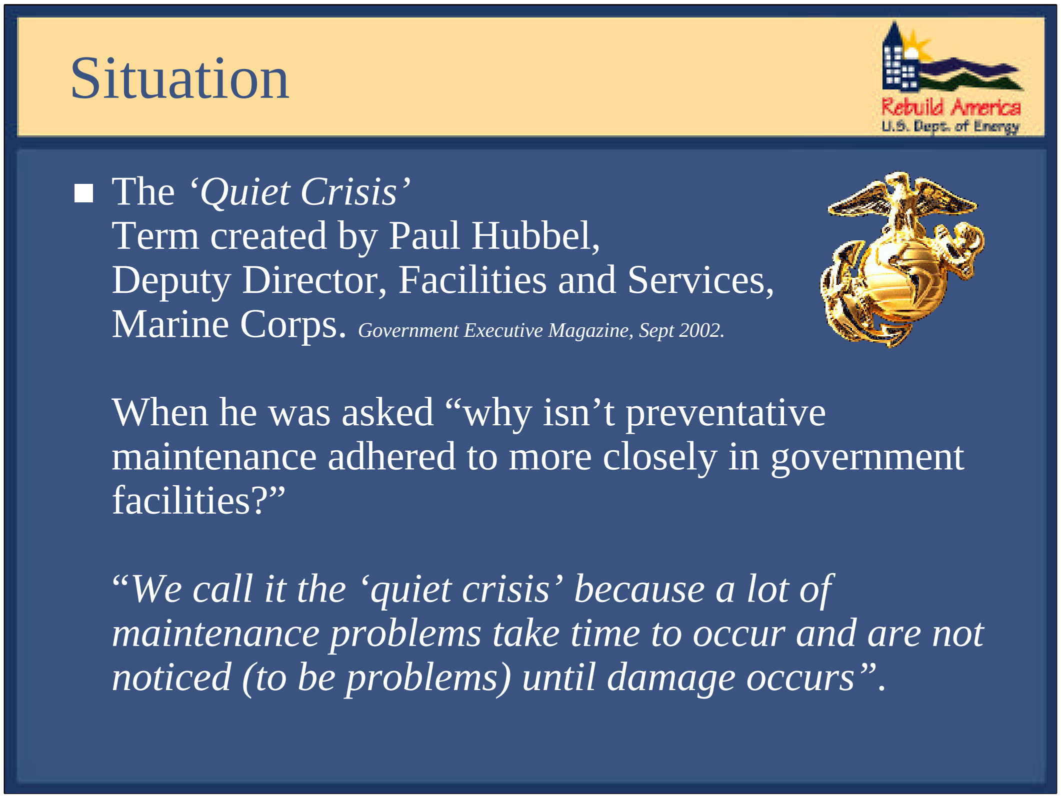
Aging Correctional Facility Electrical System Improvements

David Loucks, P.E.

EATON | Cutler-Hammer

This presentation is based on IEEE standard 493-1997, also known as the IEEE (Institute of Electrical and Electronic Engineers) Gold Book. Few have time to read the Gold Book's 503 pages. As a result, this presentation was developed to offer an overview of the methods discussed in IEEE 494, plus provide a simplified way of predicting the reliability of your system.



Situation

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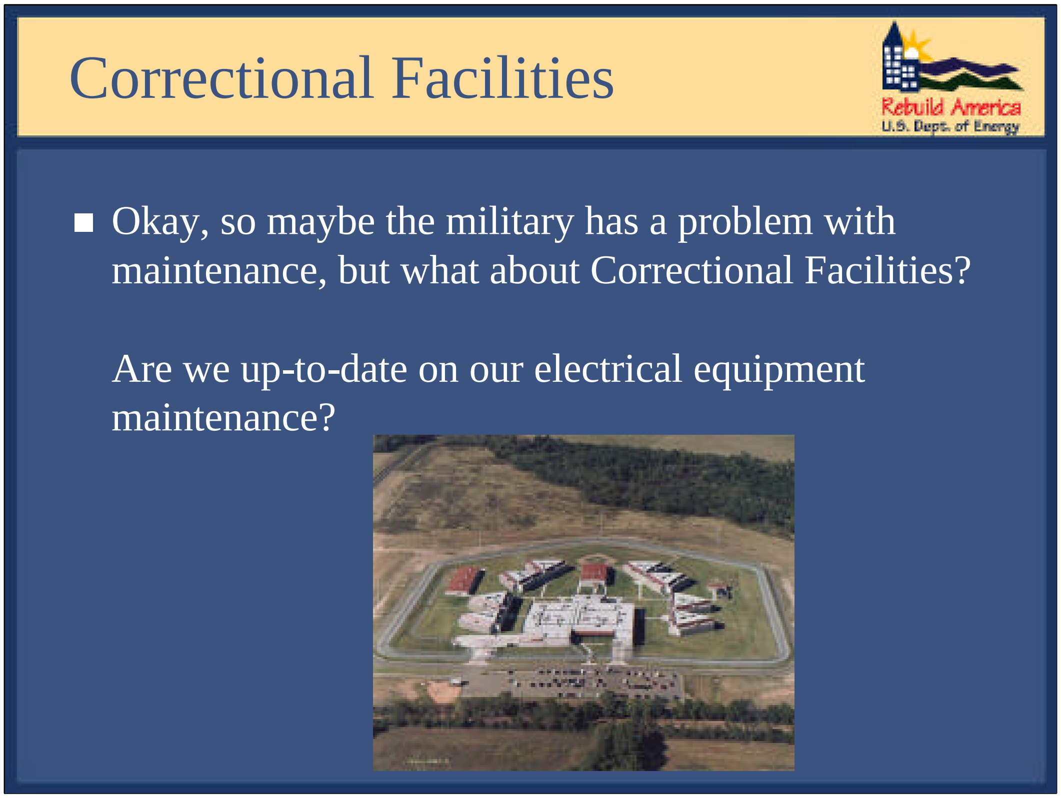
- The *'Quiet Crisis'*
  Term created by Paul Hubbel,
  Deputy Director, Facilities and Services,
  Marine Corps. *Government Executive Magazine, Sept 2002.*

  When he was asked "why isn't preventative maintenance adhered to more closely in government facilities?"

  "We call it the 'quiet crisis' because a lot of maintenance problems take time to occur and are not noticed (to be problems) until damage occurs".

We tend to react to crises, and why not? When something needs attention we attend to it. Unfortunately, if we use the crisis response method to dictate how we spend our time, you are insured that you won't know where the next problem will arise. If our facility is older, we may not be able to keep up with the problems. But if we did perform preventative maintenance, where would we even focus our efforts?



Correctional Facilities

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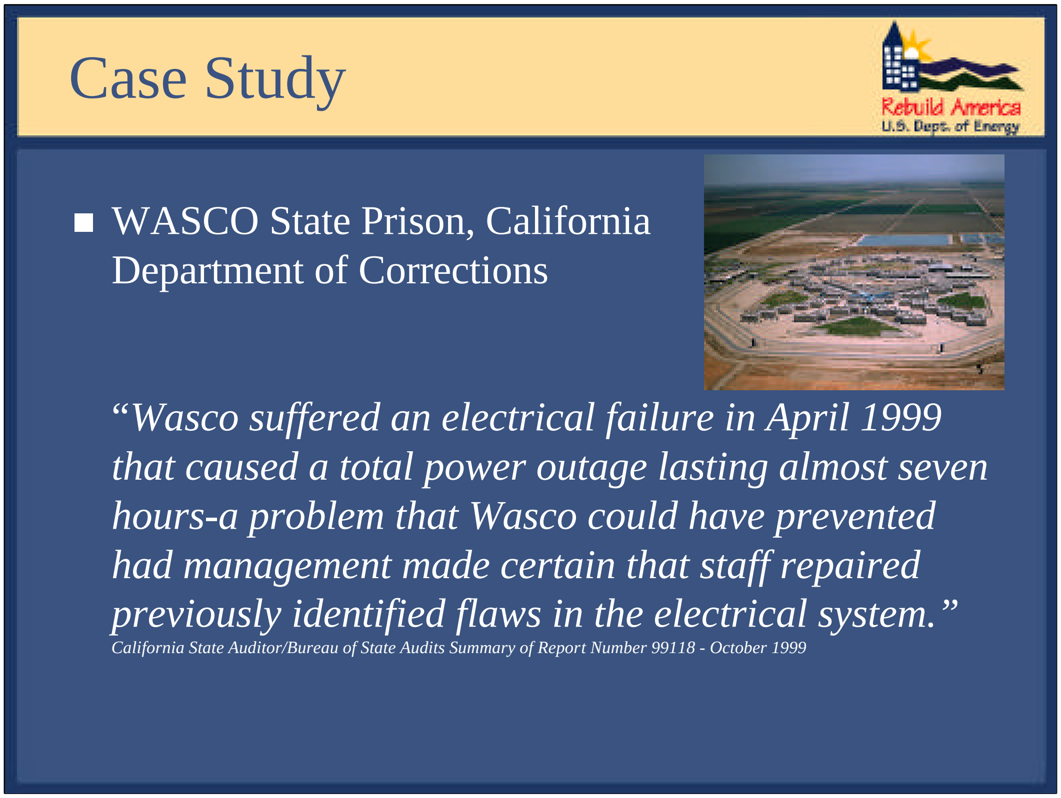
- Okay, so maybe the military has a problem with maintenance, but what about Correctional Facilities?

  Are we up-to-date on our electrical equipment maintenance?

We probably won't know how serious or when they will occur, but we know we will have problems with our electrical equipment. And we realize that the older the equipment, the more likely there will be a problem. But can we justify spending money to solve a problem that hasn't resulted in any downtime, fire or other hazard? Wouldn't saving that money and waiting for the problem to occur be more prudent? After all, we may spend money on the wrong thing and still have a problem.



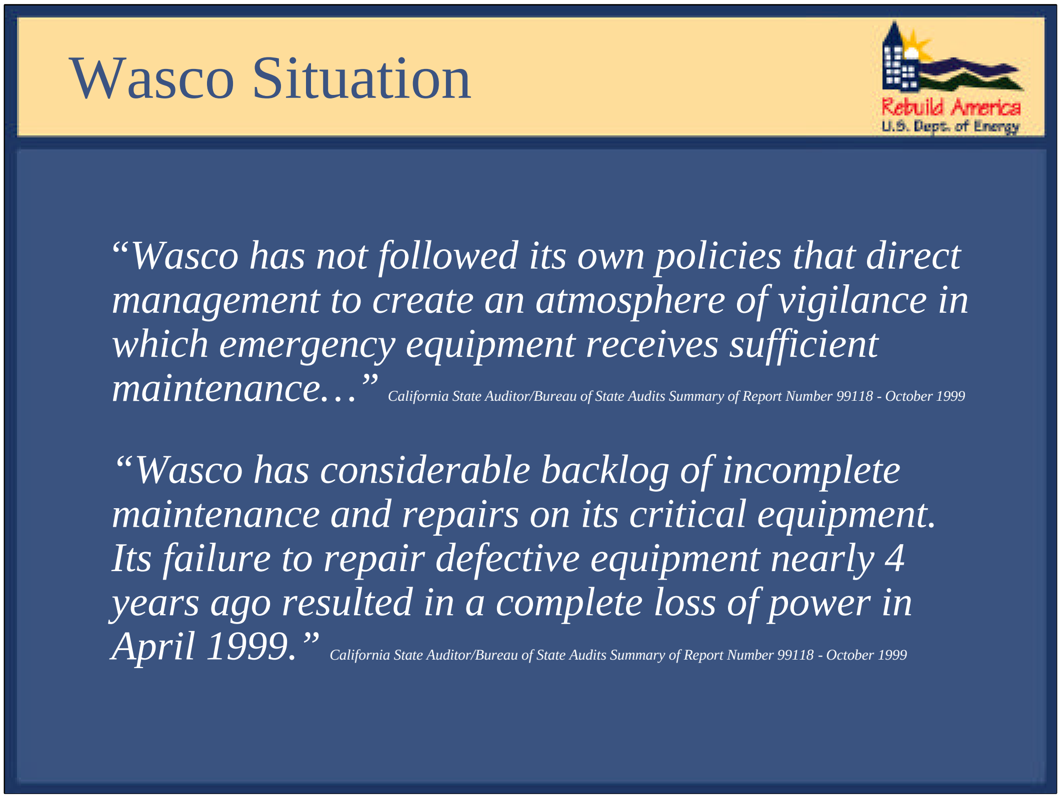
Case Study

- WASCO State Prison, California Department of Corrections

“Wasco suffered an electrical failure in April 1999 that caused a total power outage lasting almost seven hours-a problem that Wasco could have prevented had management made certain that staff repaired previously identified flaws in the electrical system.”

California State Auditor/Bureau of State Audits Summary of Report Number 99118 - October 1999

Here is the problem. If we ignore the wrong piece of equipment and that piece of equipment causes a major problem and that problem results in a complete interruption of operations, it is likely that our cost of the problem will increase by an order of magnitude. The more complete the interruption, the more attention it receives. Sometimes the attention is from internal sources. Even it the facility isn’t managed by an oversight committee, as occurred in this correctional facility outage, any interruption will affect the people that expect a facility to perform a function. Whether that is customers or bosses, we are held accountable. We are judged.



Wasco Situation

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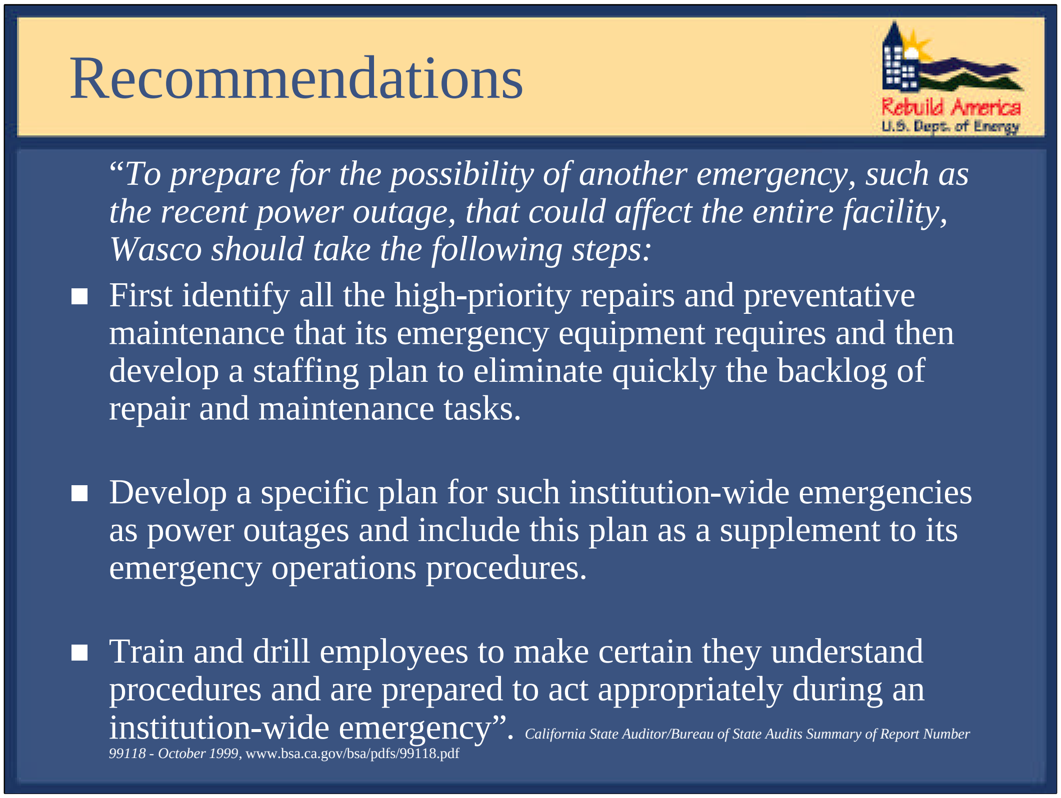
“Wasco has not followed its own policies that direct management to create an atmosphere of vigilance in which emergency equipment receives sufficient maintenance…” *California State Auditor/Bureau of State Audits Summary of Report Number 99118 - October 1999*

“Wasco has considerable backlog of incomplete maintenance and repairs on its critical equipment. Its failure to repair defective equipment nearly 4 years ago resulted in a complete loss of power in April 1999.” *California State Auditor/Bureau of State Audits Summary of Report Number 99118 - October 1999*

For example, it appears in this case, a problem was noted, but the recommendation to repair was ignored. The problem, apparently, didn’t cause any problems until 4 years later. When the dust had settled and the analysis identified the root cause of the outage, this 4-year old need became the crucial issue. What if you were responsible for this maintenance that didn’t get done. We all have our reasons, but the fingers still point to us.



Recommendations

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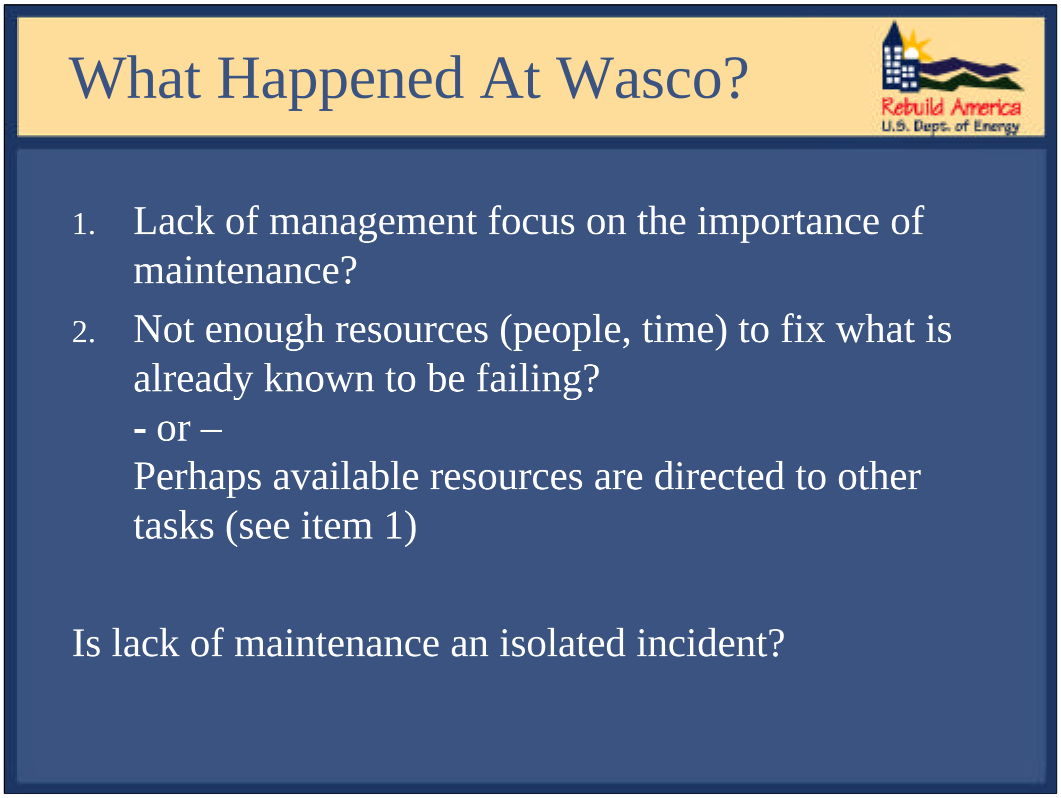
"To prepare for the possibility of another emergency, such as the recent power outage, that could affect the entire facility, Wasco should take the following steps:

- First identify all the high-priority repairs and preventative maintenance that its emergency equipment requires and then develop a staffing plan to eliminate quickly the backlog of repair and maintenance tasks.
- Develop a specific plan for such institution-wide emergencies as power outages and include this plan as a supplement to its emergency operations procedures.
- Train and drill employees to make certain they understand procedures and are prepared to act appropriately during an institution-wide emergency". *California State Auditor/Bureau of State Audits Summary of Report Number 99118 - October 1999*, www.bsa.ca.gov/bsa/pdfs/99118.pdf

This problem caused new scrutiny to be placed on maintenance procedures. In other words, they reacted to the crisis.

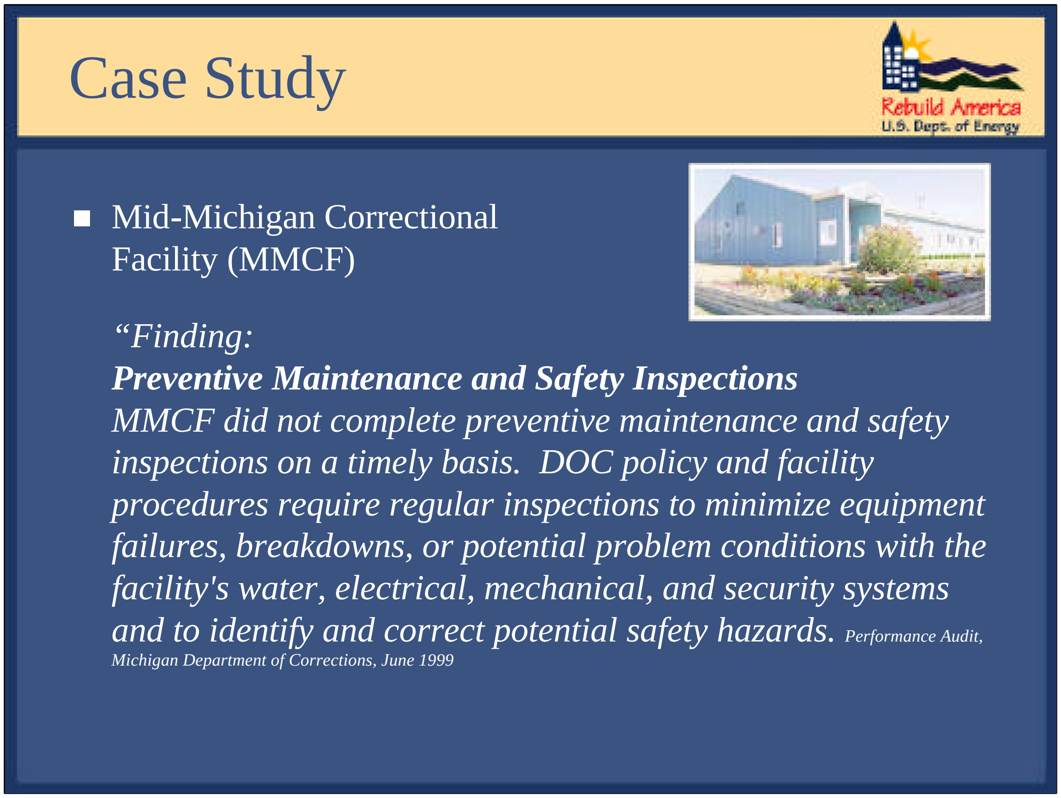


What Happened At Wasco?

1. Lack of management focus on the importance of maintenance?
2. Not enough resources (people, time) to fix what is already known to be failing?
   - or –
   Perhaps available resources are directed to other tasks (see item 1)

Is lack of maintenance an isolated incident?

Why do we insist on operating in the high stress “crisis” mode? Remember the comment made by the Marine Corps’ Paul Hubbel “*maintenance problems take time to occur and are not noticed (to be problems) until damage occurs”.* If you woke up today and said “I want to perform preventive maintenance, but where do I start? I don’t have the resources to do a top-to-bottom analysis of my system. Without a definitive method of identifying where the next problem will occur, transferring resources from fighting fires to items that “aren’t broken yet”, is difficult.



Case Study

- Mid-Michigan Correctional Facility (MMCF)

"Finding:
Preventive Maintenance and Safety Inspections
MMCF did not complete preventive maintenance and safety inspections on a timely basis. DOC policy and facility procedures require regular inspections to minimize equipment failures, breakdowns, or potential problem conditions with the facility's water, electrical, mechanical, and security systems and to identify and correct potential safety hazards. *Performance Audit, Michigan Department of Corrections, June 1999*

But the fact remains, that over and over we find examples of departments that failed to perform the necessary preventative maintenance and the result were problems that required substantially more resources to correct after the fact than if they were fixed before an catastrophic failure occurred. The collateral damage from the failure would have been avoided, saving the money.

Recommendations

Our review disclosed:

a. Nine (56%) of 16 items analyzed did not have at least one completed preventive maintenance inspection.

b. Nine (23%) of 40 monthly preventive maintenance inspections were not completed or were completed with the next month's inspection.

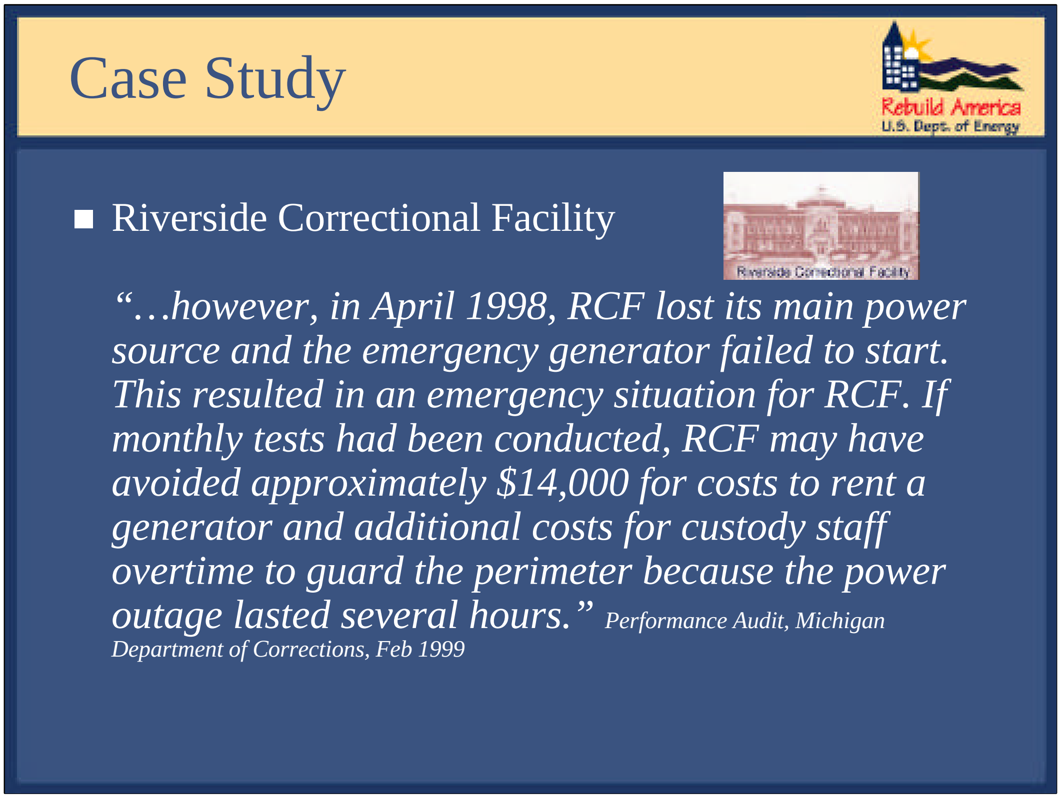
c. Twenty-nine (44%) of 66 weekly preventive maintenance inspections were not completed or were completed with subsequent inspections.

d. Fourteen (15%) of 93 weekly safety inspections were not documented as completed.

e. None of 6 monthly safety inspections were completed.

www.state.mi.us/audgen/comprpt/docs/r4727698.pdf

Why were these items not completed? Certainly qualified maintenance personnel recognize the importance of completing required maintenance on time.



Case Study

- Riverside Correctional Facility

"…however, in April 1998, RCF lost its main power source and the emergency generator failed to start. This resulted in an emergency situation for RCF. If monthly tests had been conducted, RCF may have avoided approximately $14,000 for costs to rent a generator and additional costs for custody staff overtime to guard the perimeter because the power outage lasted several hours." Performance Audit, Michigan Department of Corrections, Feb 1999

Here is yet another site that ignored previously identified needed maintenance and chose to wait with the result being an emergency situation. While the DOC audit didn't identify what was previously identified that required maintenance, by the tone of the report it appears to have been substantially less costly than the cost of the generator rental and guard overtime. Additionally, a case could be made that indirect costs increased since unexpected problems mean regular work is dropped and the emergency is dealt with. Depending on how many people were involved in this emergency, other needed work could not be done, resulting in "lost time" that can never be recovered.

Recommendations

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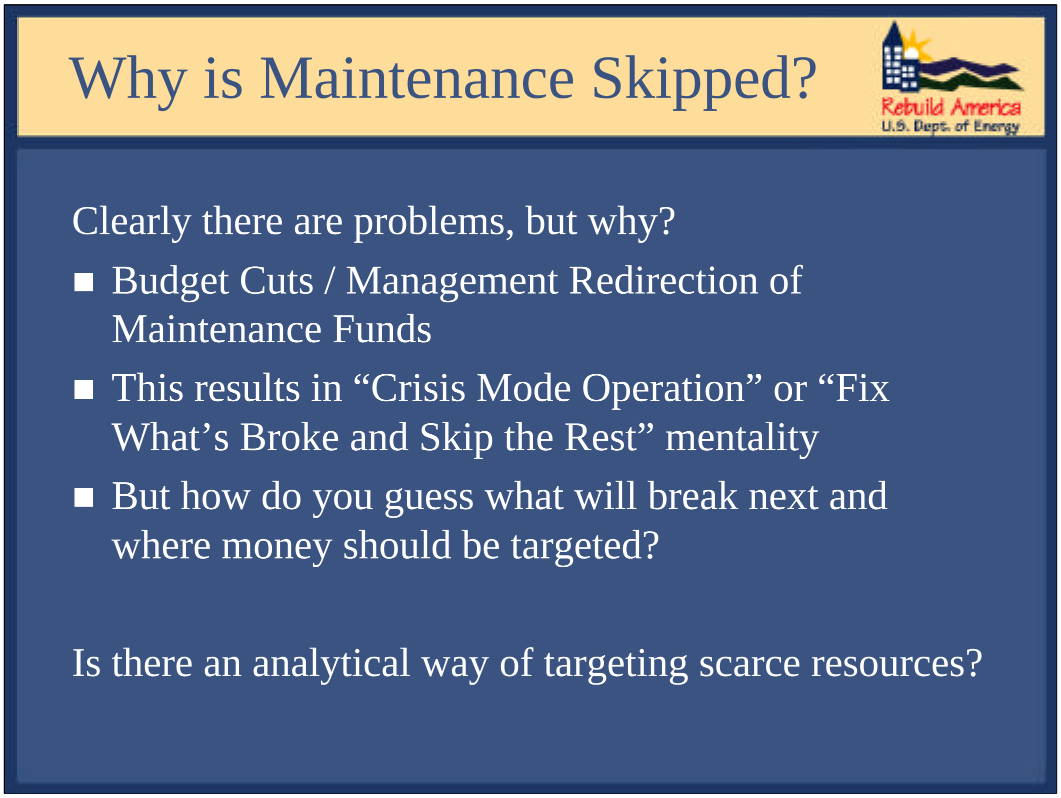
Findings:
“RCF had not developed a comprehensive preventive maintenance plan.

DOC policy states that the warden shall develop a written preventative maintenance plan. The plan is to be designed to provide economical use of all facility equipment and to ensure that all equipment will operate effectively during emergency situations”.
www.state.mi.us/audgen/comprpt/docs/r4723098.pdf

As with other locations, the root cause was identified as not performing the needed work discovered during routine preventative maintenance or not performing preventative maintenance as frequently as needed. With this site, the auditors also criticized the site for *not even* developing any preventative maintenance plan!



Why is Maintenance Skipped?

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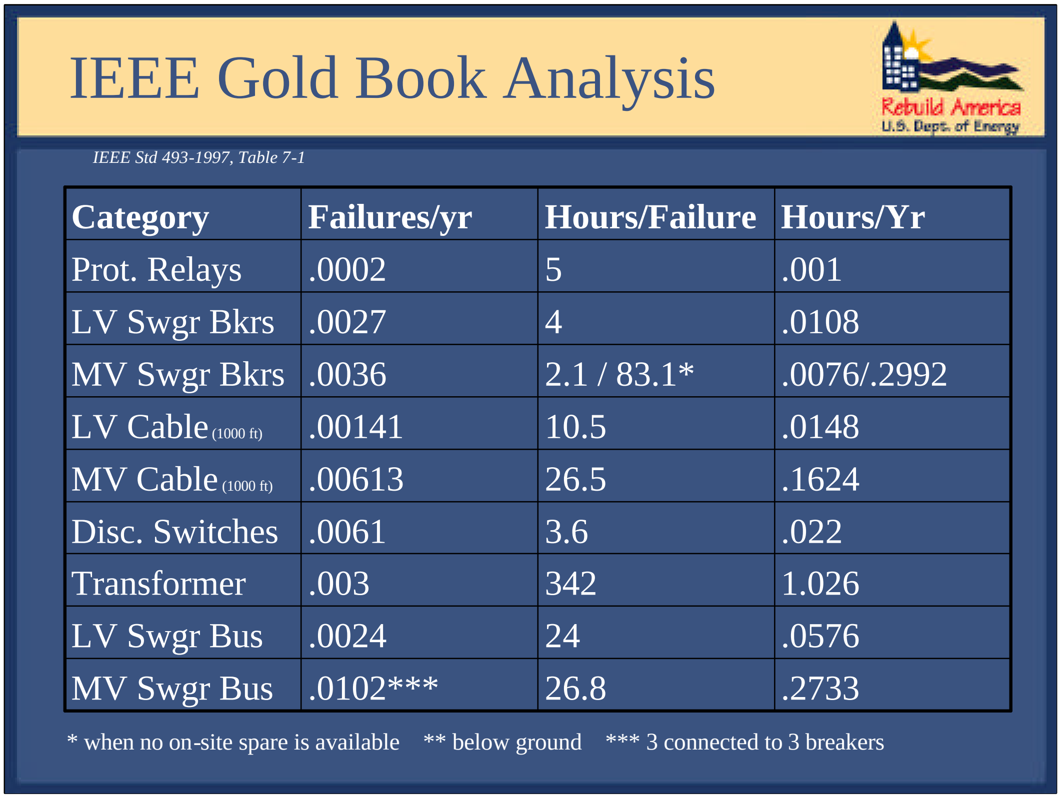
Clearly there are problems, but why?

- Budget Cuts / Management Redirection of Maintenance Funds
- This results in “Crisis Mode Operation” or “Fix What’s Broke and Skip the Rest” mentality
- But how do you guess what will break next and where money should be targeted?

Is there an analytical way of targeting scarce resources?

So how are we going to help fix this problem? We all are being asked to reduce costs. We don’t have the time or resources to “manage by wandering around”. We must be more selective. The 503 page IEEE Gold Book gives some detailed equations, but do you have time to develop such a detailed plan? Can we do something that will point out likely problem area without resorting to extensive text reading and computations?



IEEE Gold Book Analysis

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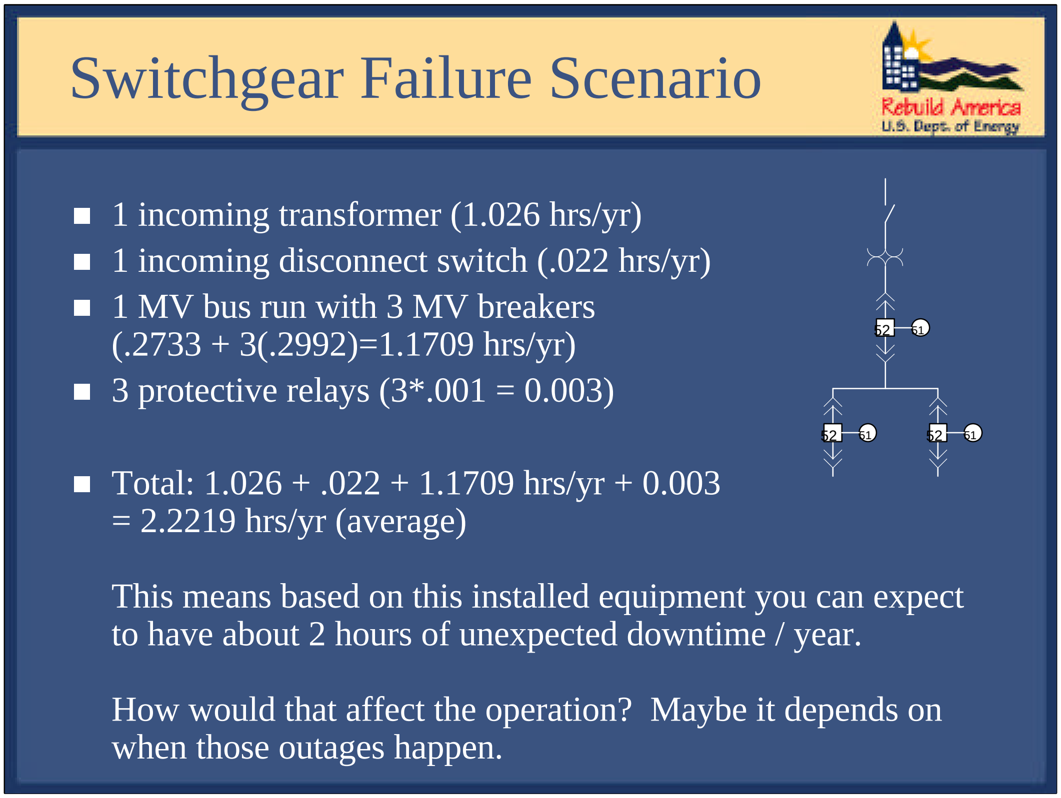
IEEE Std 493-1997, Table 7-1

Category	**Failures/yr**	**Hours/Failure**	**Hours/Yr**
Prot. Relays	.0002	5	.001
LV Swgr Bkrs	.0027	4	.0108
MV Swgr Bkrs	.0036	2.1 / 83.1*	.0076/.2992
LV Cable (1000 ft)	.00141	10.5	.0148
MV Cable (1000 ft)	.00613	26.5	.1624
Disc. Switches	.0061	3.6	.022
Transformer	.003	342	1.026
LV Swgr Bus	.0024	24	.0576
MV Swgr Bus	.0102***	26.8	.2733

* when no on-site spare is available ** below ground *** 3 connected to 3 breakers

The simplified method we are proposing recognizes that each electrical device has a certain likelihood of failure at any instant in time. The IEEE Gold Book includes most common electrical components and presents the likelihood of that component failing in any particular year. That in itself is good information, but by itself is not good enough to direct our efforts, because a component that is more likely to fail may cause fewer problems than a component that is less likely to fail. How can that be? What if that component with the higher likelihood to fail was easily replace resulting in minimal downtime, while the device that was less likely to fail required extensive effort and time to repair or replace? To get an overall effect of a component failure, we must combine both the likelihood of failure *and* the downtime caused by that failure. Since IEEE cannot estimate the collateral downtime caused by electrical failure for each industry, they simply say the downtime is the average (mean) time to repair the component. Taking this MTTR and multiplying it by the likelihood of a failure results in the total likely downtime for that device for the time period.



Switchgear Failure Scenario

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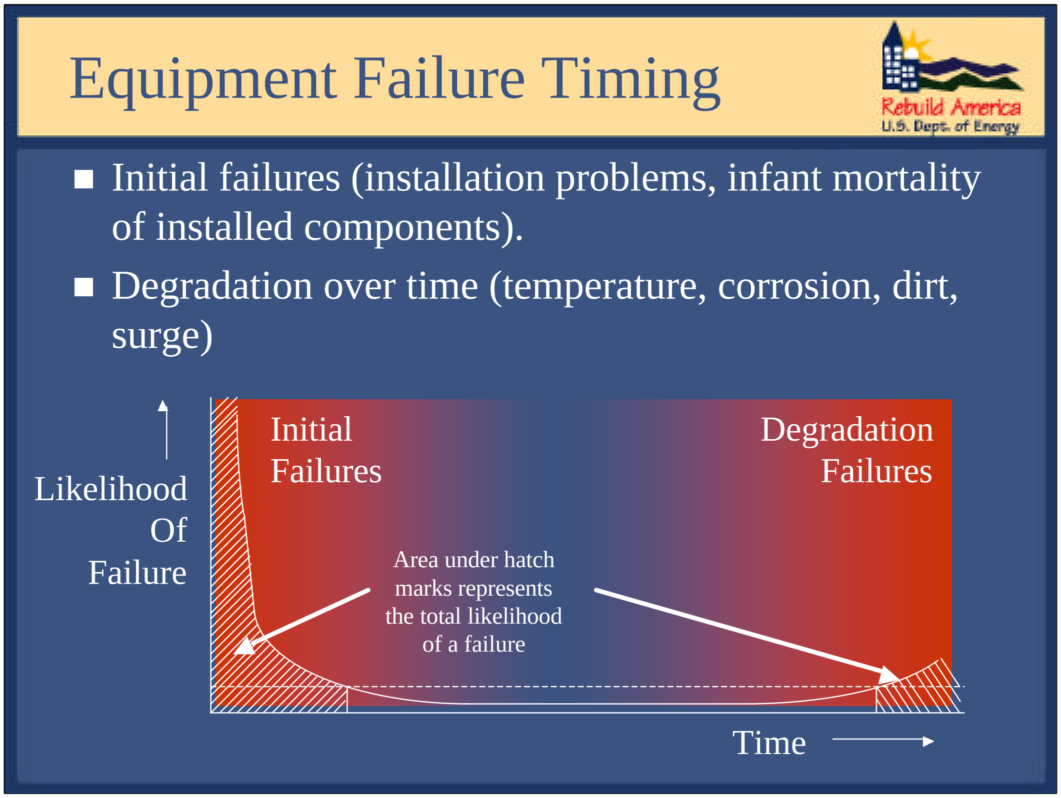
- 1 incoming transformer (1.026 hrs/yr)
- 1 incoming disconnect switch (.022 hrs/yr)
- 1 MV bus run with 3 MV breakers (.2733 + 3(.2992)=1.1709 hrs/yr)
- 3 protective relays (3*.001 = 0.003)
- Total: 1.026 + .022 + 1.1709 hrs/yr + 0.003 = 2.2219 hrs/yr (average)

This means based on this installed equipment you can expect to have about 2 hours of unexpected downtime / year.

How would that affect the operation? Maybe it depends on when those outages happen.

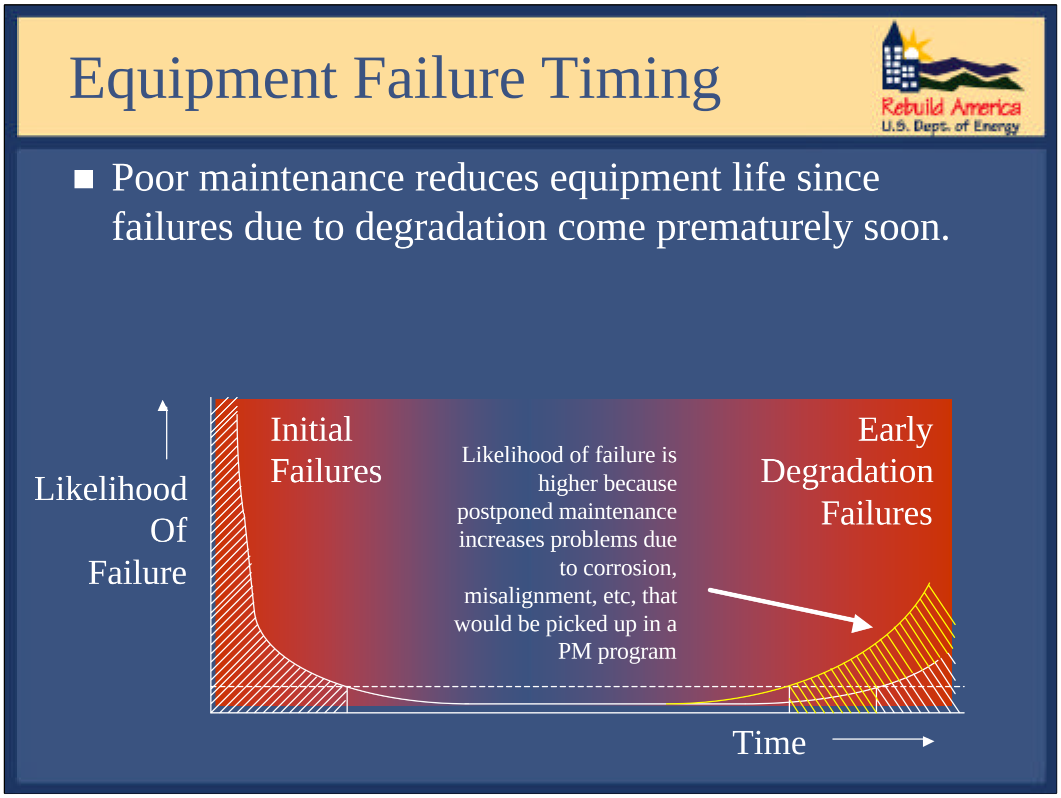
We can now do something to predict where to spend our maintenance time. Let’s use an example to see how this method works. Assume we have a simple distribution system that includes one incoming un-fused medium voltage switch feeding a step-down transformer. The transformer feeds into a draw-out, medium voltage main breaker, which in turn feeds a medium voltage bus within the switchgear down to two medium voltage feeder breakers. Each breaker includes a single protective relay. We don’t (or care yet) what is downstream from the feeder breakers, but we would like to know the likelihood of a failure per year and how long would that failure last. From the previous page, we know the downtime per year of each component. We will assume we want to know the downtime that could occur on either feeder, so we sum all the “hours per year” values for each component, since our assumption is that a failure of any component will cause an outage on at least one feeder. The final value is surprisingly high. Refer to the Gold Book for more details as to why this works. Once you know what downtime you should, on average, expect per year, you must decide what that downtime would cost. If your cost to maintain is less than this downtime cost, then you would wise to perform the maintenance, as you would spend less, on average, over the year. Our assumption is that if we perform the necessary maintenance on the equipment, we can extend its life to over 50 years, which in many installations is considered indefinitely. Therefore, if we do the required maintenance, the likelihood of failure of that device drops to statistically insignificant levels.



Equipment Failure Timing

- Initial failures (installation problems, infant mortality of installed components).
- Degradation over time (temperature, corrosion, dirt, surge)

You can further refine this by realizing that electrical equipment fails in known ways. Typically it fails very early in its life or very late. The later failures are due to equipment degradation due to usage.

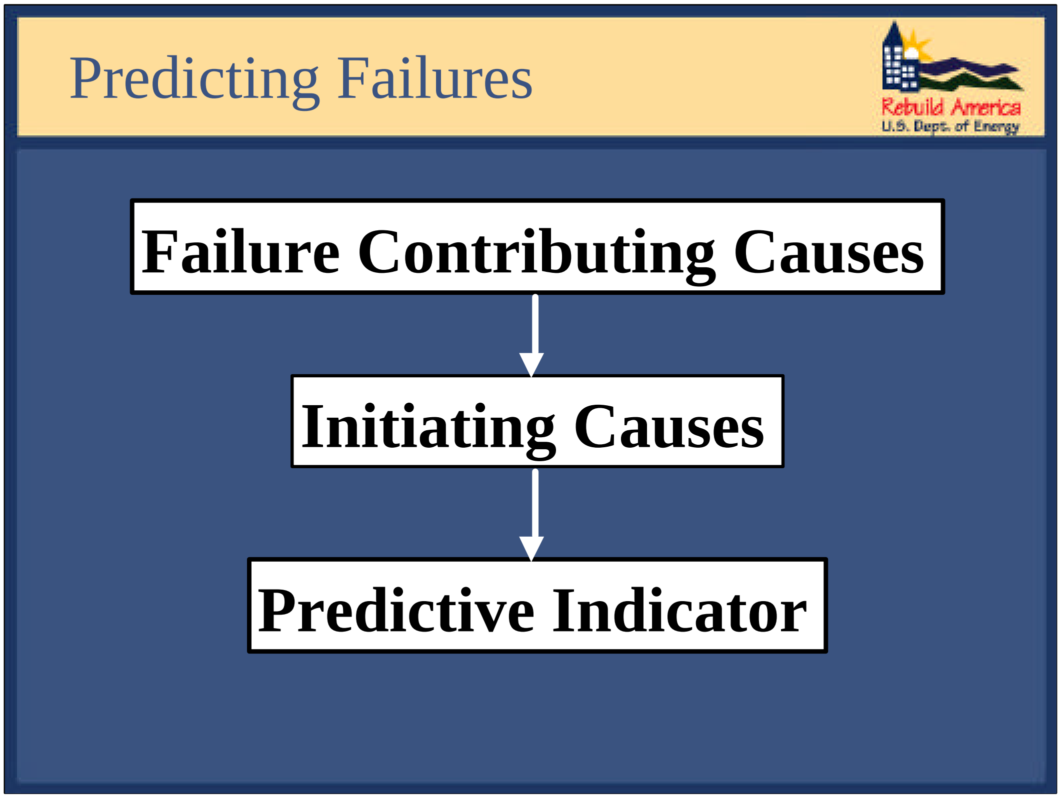


Equipment Failure Timing

- Poor maintenance reduces equipment life since failures due to degradation come prematurely soon.

Likelihood of failure is higher because postponed maintenance increases problems due to corrosion, misalignment, etc, that would be picked up in a PM program

This equipment degradation can be accelerated if the equipment is exposed to non-optimal conditions or is not properly maintained. The result is that saving money on maintenance tends to shorten the useful life of the equipment. So, in addition to unexpected downtime expenses, premature failure of the equipment will increase capital costs by necessitating more frequent equipment replacement. We will now define these non-optimal conditions and how focusing maintenance effort by choosing the most important problems helps provide the best payback for our maintenance resources.



Predicting Failures

Failure Contributing Causes

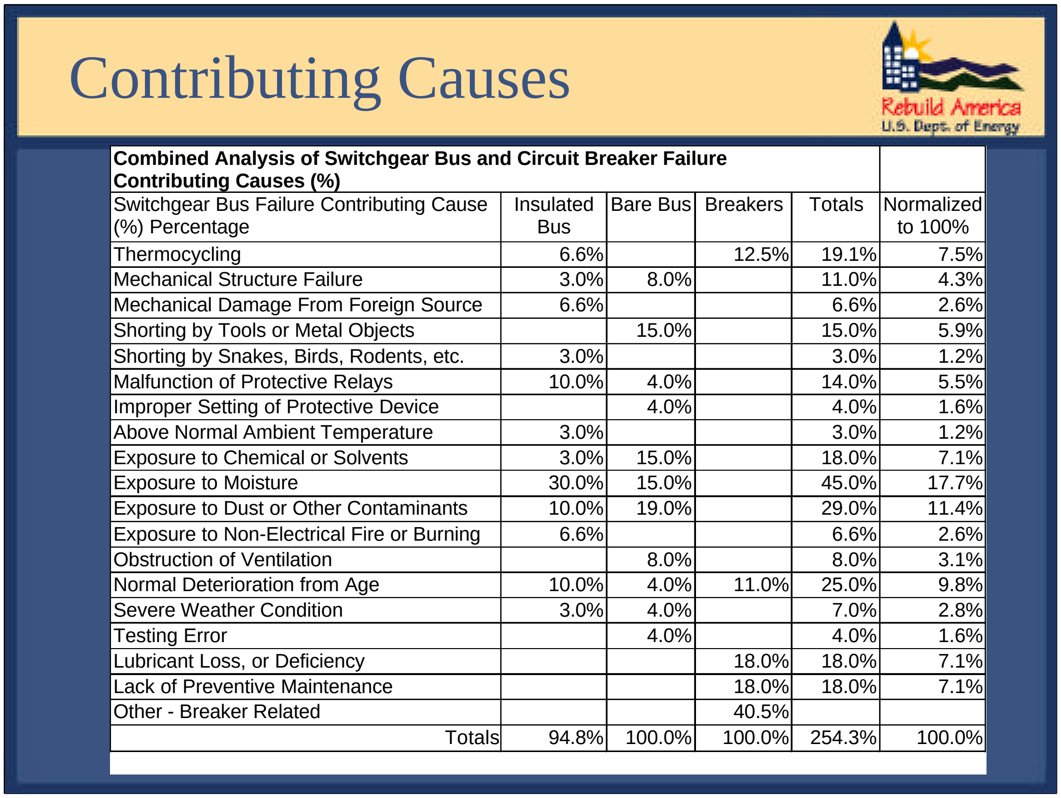
↓

Initiating Causes

↓

Predictive Indicator

To analyze these conditions, we first recognize that a failure can be traced back to some “initiating cause”. If we had a method of identifying this initiating cause, we would have a predictive indicator that could be used to provide advance warning of our failure. Having such an indicator would help direct our maintenance efforts toward areas that were indicated to have a potential pending failure. If we could prevent the failure, we eliminate the costly collateral damage and consequently reduce our effort and expenses. So what causes electrical equipment to fail?



Contributing Causes

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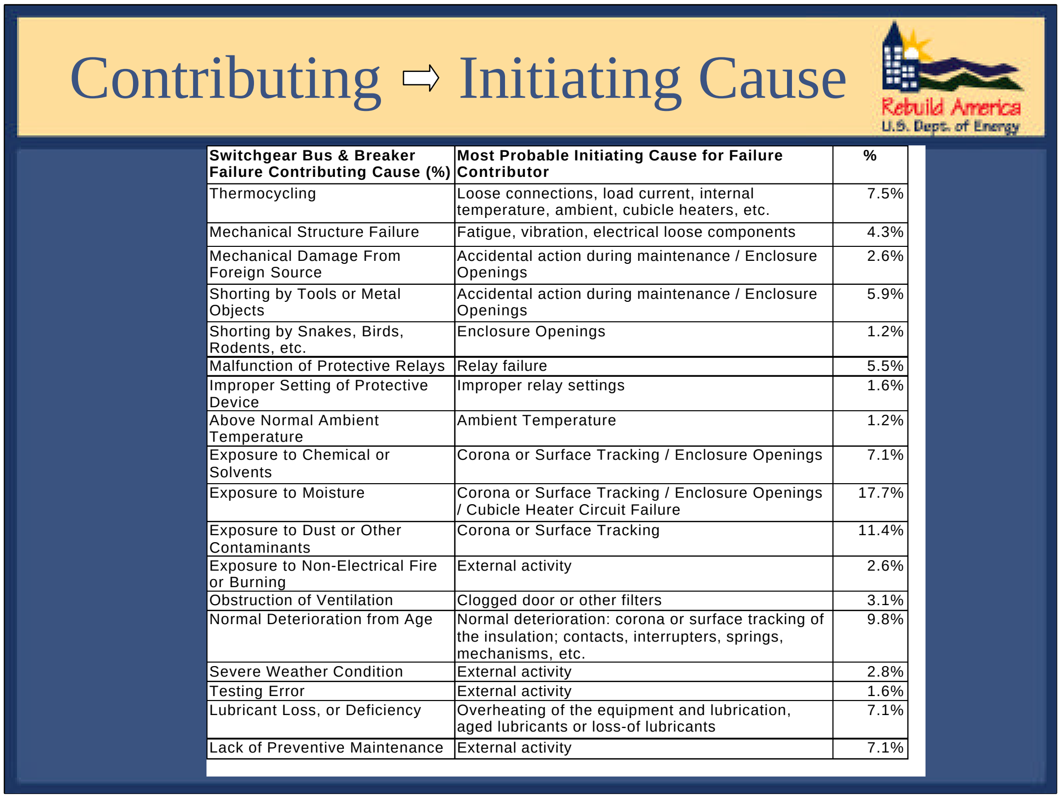
Combined Analysis of Switchgear Bus and Circuit Breaker Failure Contributing Causes (%)					
Switchgear Bus Failure Contributing Cause (%) Percentage	Insulated Bus	Bare Bus	Breakers	Totals	Normalized to 100%
Thermocycling	6.6%		12.5%	19.1%	7.5%
Mechanical Structure Failure	3.0%	8.0%		11.0%	4.3%
Mechanical Damage From Foreign Source	6.6%			6.6%	2.6%
Shorting by Tools or Metal Objects		15.0%		15.0%	5.9%
Shorting by Snakes, Birds, Rodents, etc.	3.0%			3.0%	1.2%
Malfunction of Protective Relays	10.0%	4.0%		14.0%	5.5%
Improper Setting of Protective Device		4.0%		4.0%	1.6%
Above Normal Ambient Temperature	3.0%			3.0%	1.2%
Exposure to Chemical or Solvents	3.0%	15.0%		18.0%	7.1%
Exposure to Moisture	30.0%	15.0%		45.0%	17.7%
Exposure to Dust or Other Contaminants	10.0%	19.0%		29.0%	11.4%
Exposure to Non-Electrical Fire or Burning	6.6%			6.6%	2.6%
Obstruction of Ventilation		8.0%		8.0%	3.1%
Normal Deterioration from Age	10.0%	4.0%	11.0%	25.0%	9.8%
Severe Weather Condition	3.0%	4.0%		7.0%	2.8%
Testing Error		4.0%		4.0%	1.6%
Lubricant Loss, or Deficiency			18.0%	18.0%	7.1%
Lack of Preventive Maintenance			18.0%	18.0%	7.1%
Other - Breaker Related			40.5%		
Totals	94.8%	100.0%	100.0%	254.3%	100.0%

Years of experience has shown that many conditions contribute to the failure of electrical equipment. For example, bolts come loose from vibration and equipment falls. Workers accidentally short out a circuit. Water or rodents invade equipment. When you look at the historical data, you see that the most common contributing causes to electrical equipment failure is exposure to moisture and exposure to dirt. Because this data was collected from open bus and insulated bus equipment, summing the totals gives a number greater than 100%, in fact it gives 254.3%. To get a true understanding of the total number of problems by type, we normalize by dividing each failure percentage by 254.3. The results now sum to 100%. 40.5% of the problems are listed as “other” breaker problems. Since we can’t identify the cause of those problems, we need to recognize that our analysis will not detect those problems. So what percentage of the problem are we not able to detect? If we add the 40.5% to the existing 254.3% we get 294.8%. That becomes our new normalizing value. Dividing 40.5% by 294.8% we get 13.7%. That means that 13.7% of the problems won’t be identifiable by the techniques we discuss here. The good news is that 86.3% (100-13.7) *will* be identifiable. We will come back to this 86.3% later.



Contributing ⇨ Initiating Cause

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Switchgear Bus & Breaker Failure Contributing Cause (%)	Most Probable Initiating Cause for Failure Contributor	%
Thermocycling	Loose connections, load current, internal temperature, ambient, cubicle heaters, etc.	7.5%
Mechanical Structure Failure	Fatigue, vibration, electrical loose components	4.3%
Mechanical Damage From Foreign Source	Accidental action during maintenance / Enclosure Openings	2.6%
Shorting by Tools or Metal Objects	Accidental action during maintenance / Enclosure Openings	5.9%
Shorting by Snakes, Birds, Rodents, etc.	Enclosure Openings	1.2%
Malfunction of Protective Relays	Relay failure	5.5%
Improper Setting of Protective Device	Improper relay settings	1.6%
Above Normal Ambient Temperature	Ambient Temperature	1.2%
Exposure to Chemical or Solvents	Corona or Surface Tracking / Enclosure Openings	7.1%
Exposure to Moisture	Corona or Surface Tracking / Enclosure Openings / Cubicle Heater Circuit Failure	17.7%
Exposure to Dust or Other Contaminants	Corona or Surface Tracking	11.4%
Exposure to Non-Electrical Fire or Burning	External activity	2.6%
Obstruction of Ventilation	Clogged door or other filters	3.1%
Normal Deterioration from Age	Normal deterioration: corona or surface tracking of the insulation; contacts, interrupters, springs, mechanisms, etc.	9.8%
Severe Weather Condition	External activity	2.8%
Testing Error	External activity	1.6%
Lubricant Loss, or Deficiency	Overheating of the equipment and lubrication, aged lubricants or loss-of lubricants	7.1%
Lack of Preventive Maintenance	External activity	7.1%

In this chart we take the normalized contributing causes and keep them in the far right column. We also keep the contributing cause in the far left column. We add a new middle column that identifies the most probable initiating cause for items in the left column. Once we know the initiating cause, how can we use this information to predict and prevent a failure?

Initiating ⇨Available Solutions

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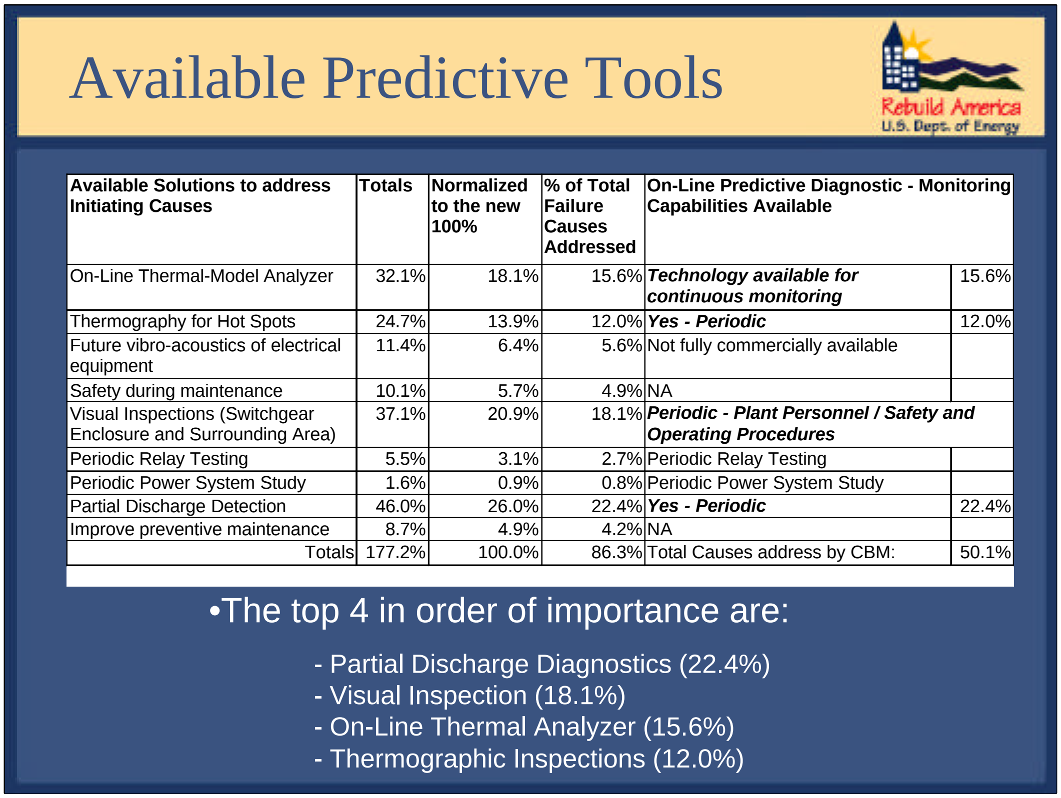
Most Probable Initiating Cause for Failure Contributor	Available Solutions to address Initiating Causes	%
Loose connections, load current, internal temperature, ambient, cubicle heaters, etc.	On-Line Thermal Model Analyzer & Thermography for Hot Spots	7.5%
Fatigue, vibration, electrical loose components	Thermography for Hot Spots and Future Vibro-acoustics of electrical equipment	4.3%
Accidental action during maintenance / Enclosure Openings	Safety during maintenance & Visual Inspections	2.6%
Accidental action during maintenance / Enclosure Openings	Safety during maintenance & Visual Inspections	5.9%
Enclosure Openings	Visual Inspections	1.2%
Relay failure	Periodic Relay Testing	5.5%
Improper relay settings	Periodic Power System Study	1.6%
Ambient Temperature	On-Line Thermal Model Analyzer	1.2%
Corona or Surface Tracking / Enclosure Openings	Partial Discharge Detection & Visual Inspection	7.1%
Corona or Surface Tracking / Enclosure Openings / Heater Circuit Failure	Partial Discharge Detection & Visual Inspection & On-Line Thermal Model Analyzer	17.7%
Corona or Surface Tracking	Partial Discharge Detection (External visual inspection can not detect internal bus)	11.4%
External activity	On-Line Thermal Model Analyzer & Inspection of External area	2.6%
Clogged door or other filters	On-Line Thermal Model Analyzer & Thermography for Hot Spots	3.1%
Normal deterioration: corona or surface tracking of the insulation; contacts, interrupters, springs, mechanisms, etc.	Partial Discharge Detection and Thermography for Hot Spots	9.8%
External activity	None	2.8%
External activity	Safety during maintenance & Improved preventive maintenance	1.6%
Overheating of equipment and lubrication age or loss-of lubricants	Future vibro-acoustics of electrical equipment	7.1%
External activity	Improve preventive maintenance	7.1%

We do this through a variety of technologies. For example, 7.5% of equipment failure can be traced to loose connections, overcurrent or other issues that cause the equipment to thermocycle through hot and relatively cooler periods. Using technology such as on-line thermal modeling devices or infra-red cameras we can see a heating problem before it causes a problem. On-line thermal modeling devices are devices such a motor protective relays that compute heating effects within motors by examining other electrical parameters. Infra red cameras detect heat and convert to a false-color image that quickly identifies objects that are too hot relative to the surrounding objects. Now that we know how to detect the problems, we look for devices that can identify the largest percentage of our problems. For example, we see that the largest problem (17.7%, which we recall was exposure to moisture) and the second largest (11.4%, which we recall was exposure to dirt) and the third largest (9.8%, which we said was normal deterioration from age) and the fifth largest (7.1%, which was exposure to chemical solvents) can be detected by Partial Discharge sensors. We are not done yet, since notice that 17.7% of the problems can also be detected using On-Line Thermal Model Analyzers (protective relays with motor heating algorithms) or visual inspection. So if 46% of the problems can be detected with Partial Discharge sensors and how do you account for the 17.7% of the problems that can be detected with on-line thermal model analyzers or the same 17.7% that can be detected through visual inspection. The solution is to sum all the possible solutions and normalize by that sum.



Available Predictive Tools

Available Solutions to address Initiating Causes	Totals	Normalized to the new 100%	% of Total Failure Causes Addressed	On-Line Predictive Diagnostic - Monitoring Capabilities Available	
On-Line Thermal-Model Analyzer	32.1%	18.1%	15.6%	***Technology available for continuous monitoring***	15.6%
Thermography for Hot Spots	24.7%	13.9%	12.0%	***Yes - Periodic***	12.0%
Future vibro-acoustics of electrical equipment	11.4%	6.4%	5.6%	Not fully commercially available	
Safety during maintenance	10.1%	5.7%	4.9%	NA	
Visual Inspections (Switchgear Enclosure and Surrounding Area)	37.1%	20.9%	18.1%	***Periodic - Plant Personnel / Safety and Operating Procedures***	
Periodic Relay Testing	5.5%	3.1%	2.7%	Periodic Relay Testing	
Periodic Power System Study	1.6%	0.9%	0.8%	Periodic Power System Study	
Partial Discharge Detection	46.0%	26.0%	22.4%	***Yes - Periodic***	22.4%
Improve preventive maintenance	8.7%	4.9%	4.2%	NA	
Totals	177.2%	100.0%	86.3%	Total Causes address by CBM:	50.1%

- The top 4 in order of importance are:
  - Partial Discharge Diagnostics (22.4%)
  - Visual Inspection (18.1%)
  - On-Line Thermal Analyzer (15.6%)
  - Thermographic Inspections (12.0%)

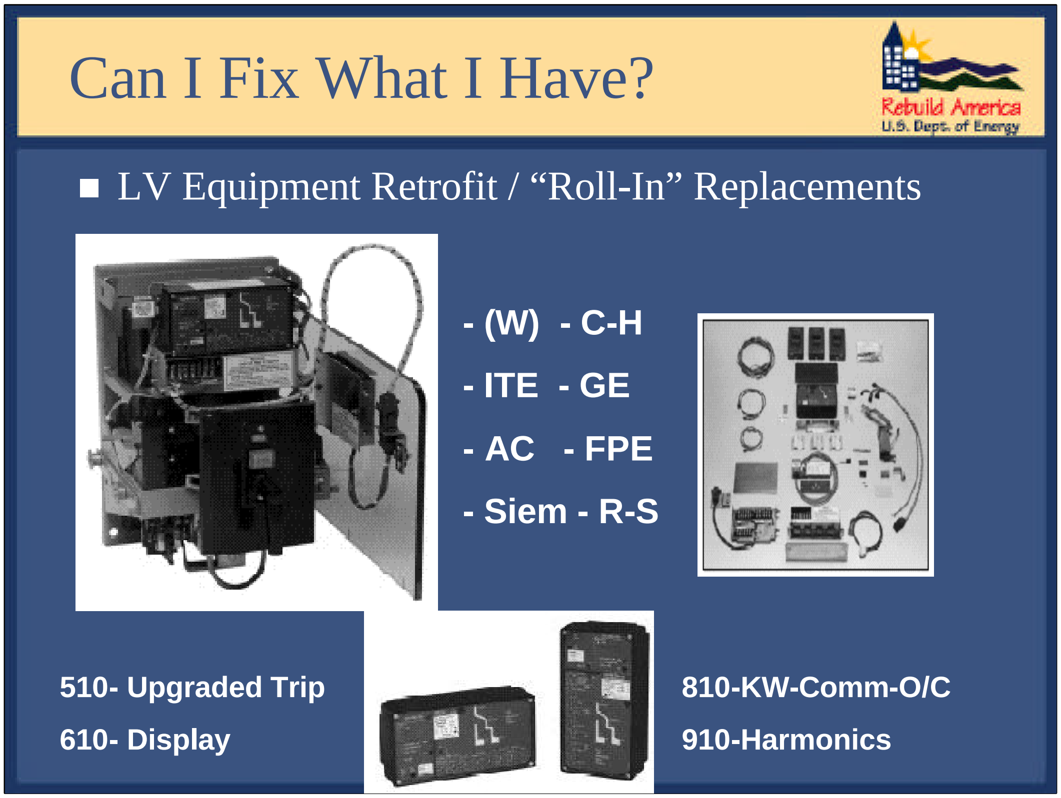
Here is how we normalize the detection solution so that the total number of problems that each detects is a fraction of 100%. Notice from the chart that Partial Discharge can detect 46% of the problems, but since there is overlap with the other solutions, we sum all the solutions. We next take each individual solution's percentage and divide by that total. In the case of partial discharge we take 46% and divide by 177 and get 26%. Repeating for each of the other solutions, we create a new column called "normalized to the new 100%".

Remember earlier when we said that 40.5% of circuit breaker problems were "other" (that is non-identifiable) and when we normalize it we discovered that we could only detect 86.3% of the problems? Since 86.3% of the problems can be identified with these techniques, we normalize those values to identify the percentage of Total Failure Causes Addressed. Doing that, reduces Partial Discharge to identifying 22.4% (26% x 86.3%) of the total failure causes. When we rank the top four diagnostic techniques, we see Partial Discharge followed by visual inspection, followed by on-line thermal analyzer and finally thermographic inspections.

To recap, we have identified the amount of downtime expected and we know the most productive diagnostic technology that can be used to focus attention on the biggest problems.

How do we figure out how much is justifiable to spend on the preventative maintenance including these diagnostics? Since you know what your downtime is worth, you can place a monetary value on the preventative maintenance activity. For example, recognizing that partial discharge diagnostics will only detect 22.4% of the 2.2 hours of annual downtime, or about ½ hour, ask yourself "is the cost of the PD analysis more than or less than ½ of downtime" on that circuit. If the PD cost is less, investing in it makes sense.

Now, suppose you have invested in the technology and have discovered a problem. Are there other more prudent ways of spending maintenance funds than buying brand new replacement equipment?



Can I Fix What I Have?

- LV Equipment Retrofit / “Roll-In” Replacements

- (W) - C-H

- ITE - GE

- AC - FPE

- Siem - R-S

510- Upgraded Trip

610- Display

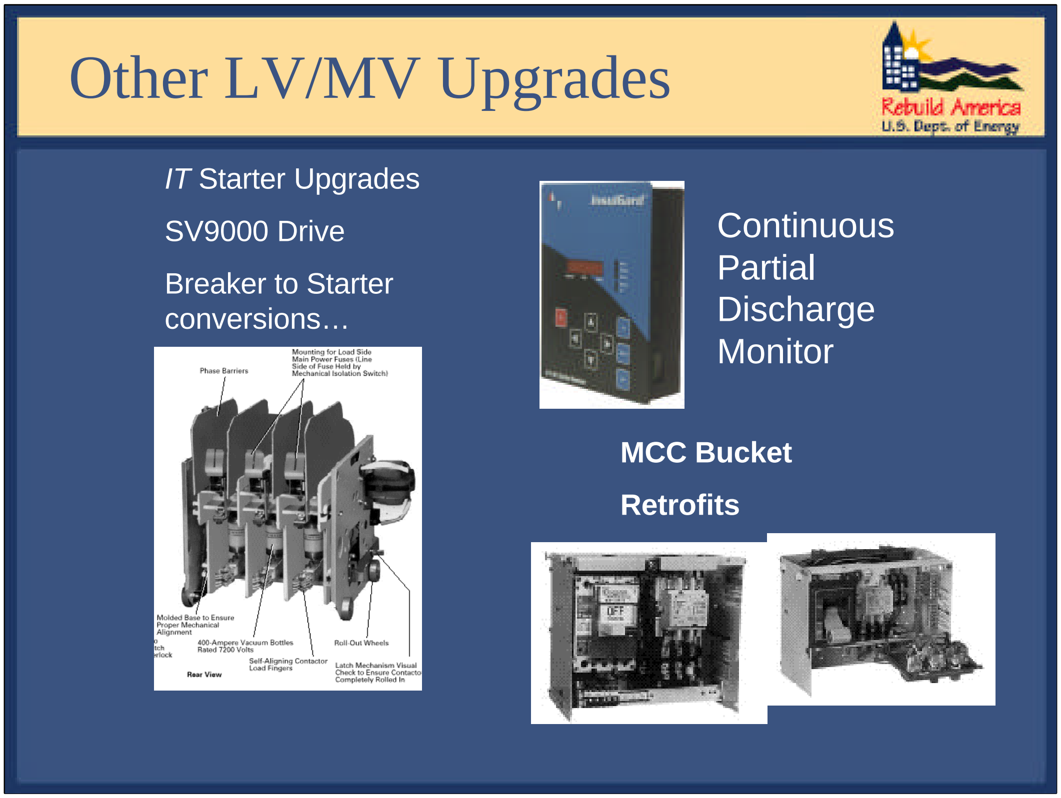
810-KW-Comm-O/C

910-Harmonics

One way to conserve maintenance funds is to refurbish existing equipment to new or better than new standards. Low voltage draw-out power circuit breakers are excellent candidates for upgrading. These old breakers typically have analog electronic trip units that compute current using a “peak sensing” technology. When these breakers were installed, there were far fewer computers, network printers and other microprocessor based power supply devices consuming non-linear (harmonic) current from the system. Unfortunately peak sensing technology results in nuisance trips on systems with harmonic current. Retrofitting this trip unit with a true rms (root mean square) sensing trip unit gives the breaker accurate tripping characteristics even when measuring high harmonic currents.

LV Rack-In Replacement

If the breaker switching mechanism itself is in need of replacement, consider installing a form-fit-function replacement using a modern power circuit breaker in the old draw out mechanism. These new circuit breakers can be mounted into a variety of manufacturer’s draw out assemblies. This provides a new warranty and because the breaker is of current design, more easily obtained and less expensive spare parts.



Other LV/MV Upgrades

IT Starter Upgrades

SV9000 Drive

Breaker to Starter conversions…

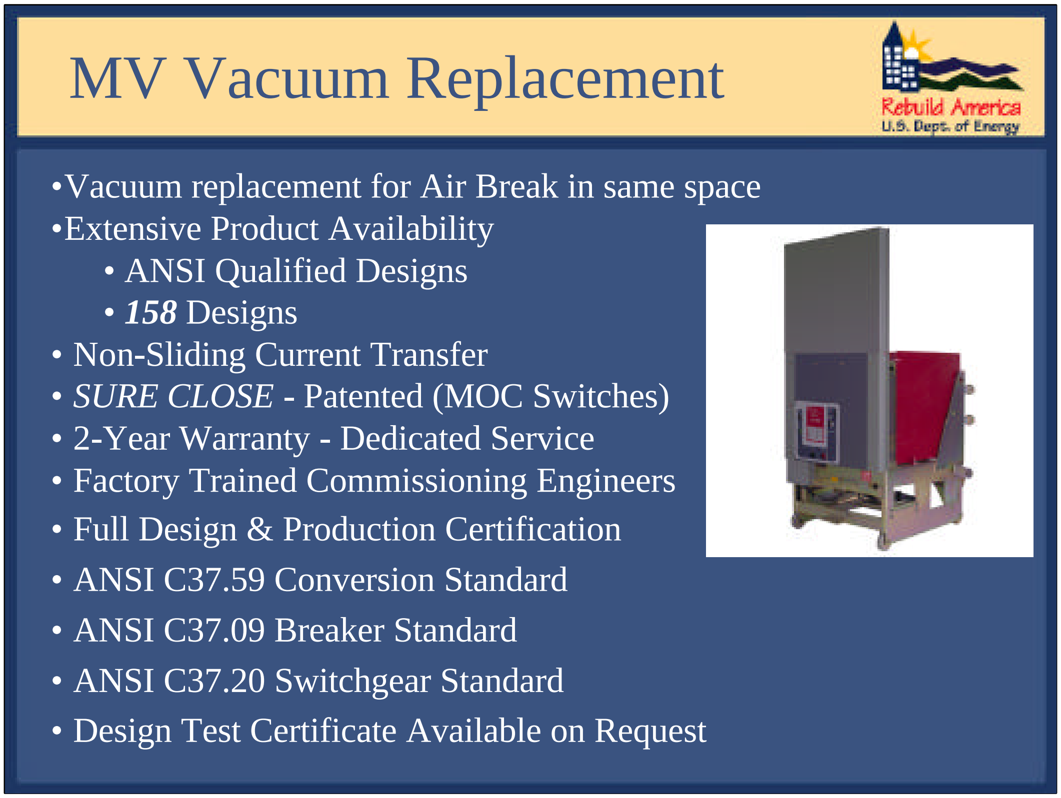
Continuous Partial Discharge Monitor

MCC Bucket

Retrofits

Besides low voltage power circuit breakers, this retrofitting of old switching devices to new can be done on low and medium voltage motor control centers. The old MCC switching device can be replaced with a new device in the same draw out bucket or assembly. The more modern motor starters can include soft-start in the *same space* as old across-the-line starters. This can have major savings if you plan to add load to an MCC, but are concerned about voltage drop during motor starting on the now more heavily loaded MCC.

Partial discharge monitors can be installed on your medium voltage equipment using new high-frequency CTs or other easy to install technologies.

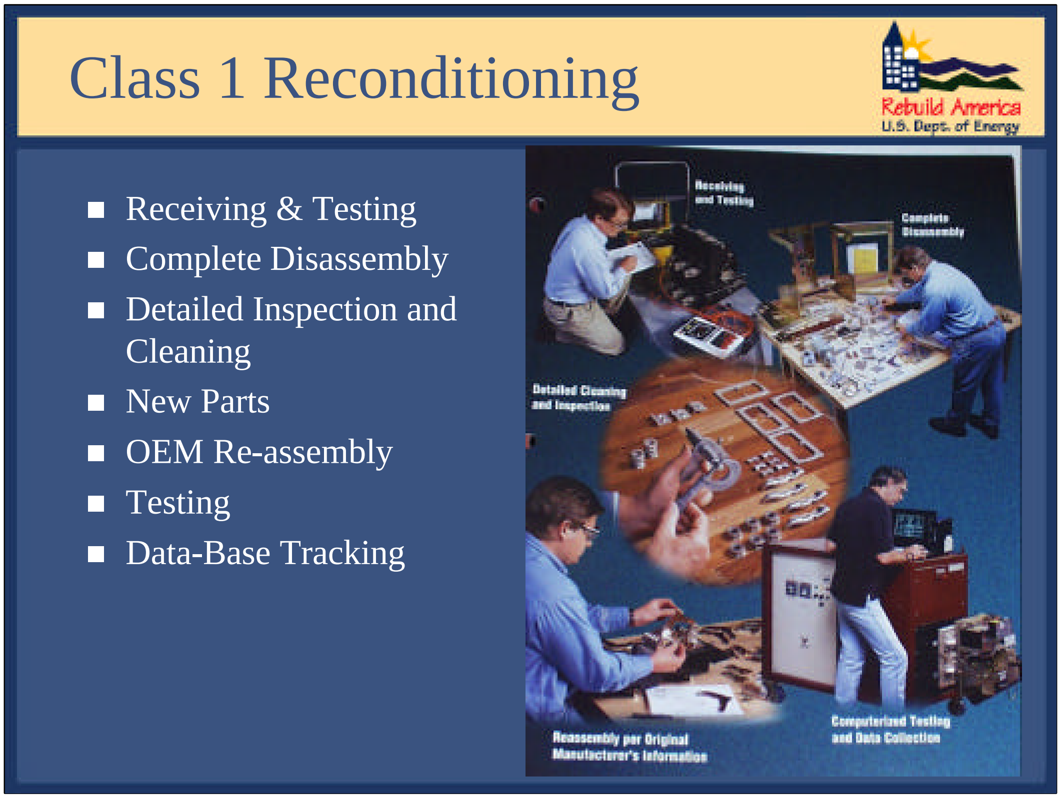


MV Vacuum Replacement

Rebuild America
U.S. Dept. of Energy

- •Vacuum replacement for Air Break in same space
- •Extensive Product Availability
  - ANSI Qualified Designs
  - ***158*** Designs
- Non-Sliding Current Transfer
- *SURE CLOSE* - Patented (MOC Switches)
- 2-Year Warranty - Dedicated Service
- Factory Trained Commissioning Engineers
- Full Design & Production Certification
- ANSI C37.59 Conversion Standard
- ANSI C37.09 Breaker Standard
- ANSI C37.20 Switchgear Standard
- Design Test Certificate Available on Request

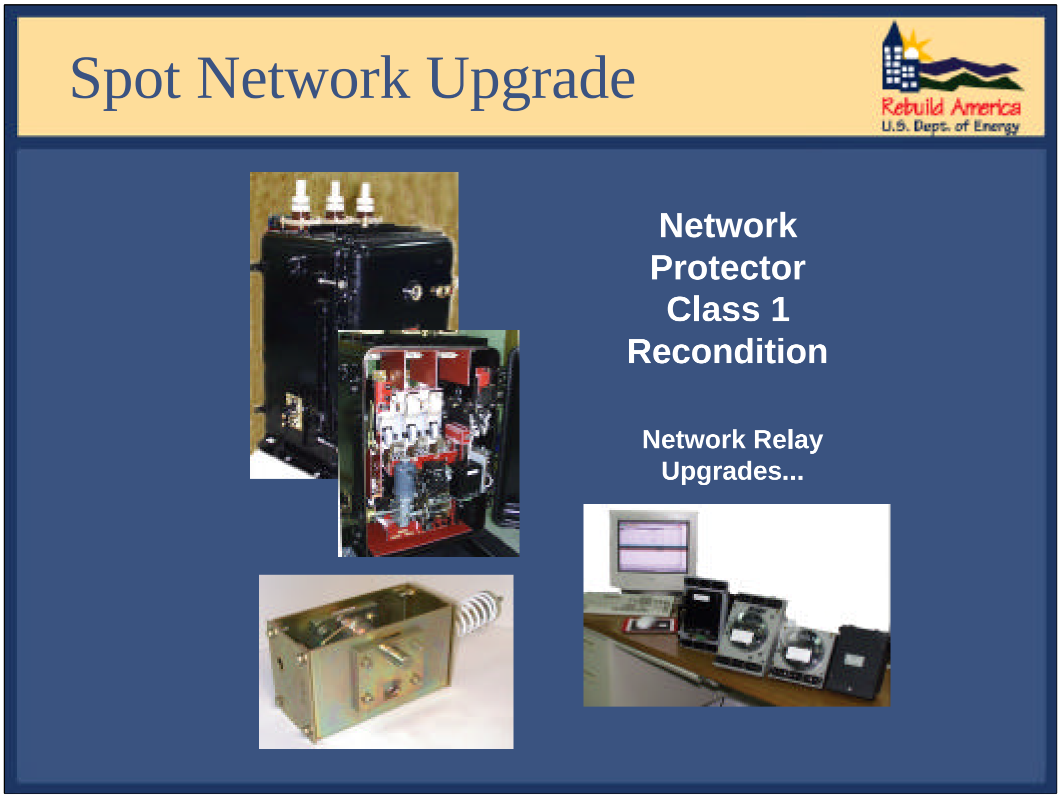
Even large medium voltage air-break circuit breakers can be modernized by replacing the old air-break technology with vacuum switching technology. Because the vacuum technology is so small, faceplates are made to cover the same space within the existing switchgear. The new vacuum breaker is a direct roll-in replacement. Note that this design has be tested and third party certified for 158 designs originally built by Westinghouse, Allis-Chalmers, Federal Pacific, GE and Siemens. That means a design for your old breaker most likely exists. Don’t tear out your old switchgear. Extend its service life with new circuit breaker elements and protective relays.



Class 1 Reconditioning

- Receiving & Testing
- Complete Disassembly
- Detailed Inspection and Cleaning
- New Parts
- OEM Re-assembly
- Testing
- Data-Base Tracking

Even low voltage breakers can be brought to “like-new” condition using a technique known as “class 1 reconditioning”. In this technology the circuit breaker is disassembled to its smallest parts. Each part is inspected. Parts out of tolerance are replaced and acceptable parts are cleaned. The breaker is reassembled, tested to the industry standards and warranted. This is an option if new breakers are not available and you don’t want to replace the existing switchgear.



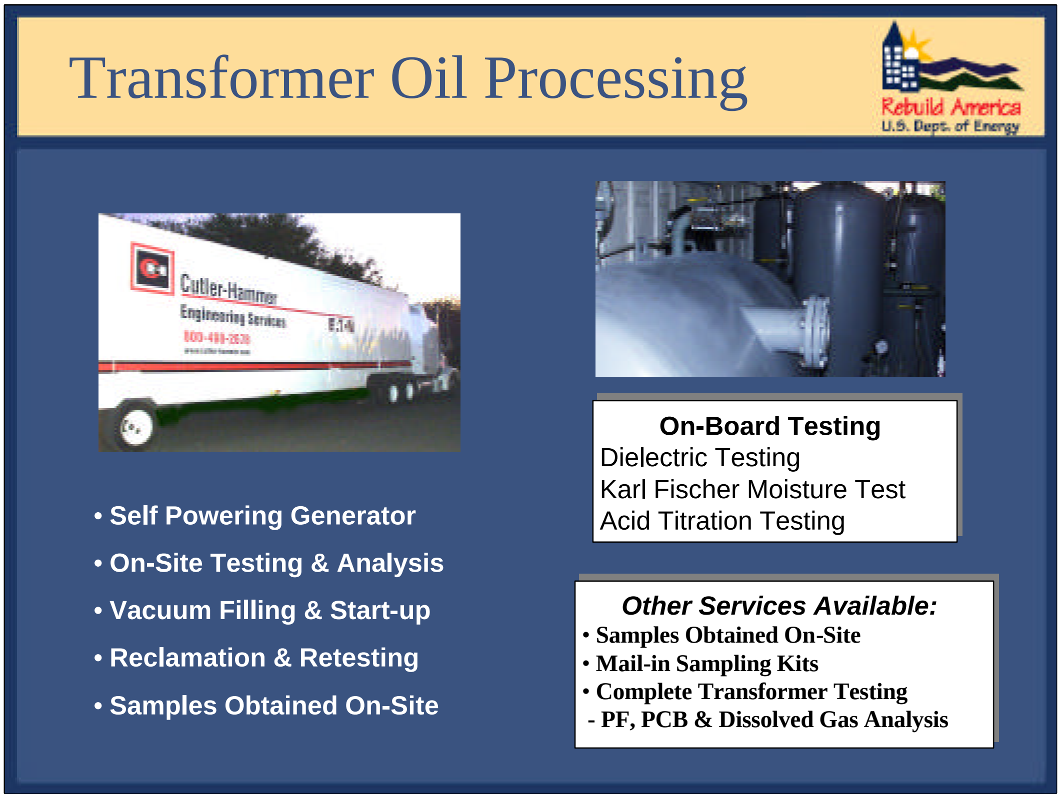
Spot Network Upgrade

Rebuild America
U.S. Dept. of Energy

Network Protector Class 1 Recondition

Network Relay Upgrades...

If you have a spot network, you will have network protectors. Old network protectors can be rebuilt with new switching elements and new network protector relays. These new relays substantially reduce the internal wiring, reducing the points of failure, while at the same time providing new diagnostics and protective settings to insure better operation of your spot network.



Transformer Oil Processing

- **Self Powering Generator**
- **On-Site Testing & Analysis**
- **Vacuum Filling & Start-up**
- **Reclamation & Retesting**
- **Samples Obtained On-Site**

On-Board Testing
Dielectric Testing
Karl Fischer Moisture Test
Acid Titration Testing

Other Services Available:
- **Samples Obtained On-Site**
- **Mail-in Sampling Kits**
- **Complete Transformer Testing**
  - **PF, PCB & Dissolved Gas Analysis**

As we learned with our example, transformers represent one of the largest risks of downtime. By extracting a sample of the oil and performing tests on that sample, you can determine much about the internal condition of the transformer. If the tests indicate impending problems, rather than replacing the transformer, the oil can be processed to remove the contaminants. And since the process involves circulating the oil through the transformer, impurities are also washed from the core and coil assembly.

In summary, we have learned how to calculate the expected downtime for various pieces of equipment. We have learned what diagnostic equipment is most suitable for detecting the greatest number of problem, and thereby saving valuable money earmarked for preventative maintenance. Finally we learned what solutions are available other than purchasing new equipment, should a diagnostic technique discover a problem.