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Results from problem-modeling diagnostic engines and statistical analysis of infrared PdM inspections to provide solutions to the management of facility infrared PdM inspection programs.

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Problem-Modeling Diagnostic Engines Used with Statistical Analysis of Infrared PdM Inspections Provide Solutions for the Management of Facility-Wide Infrared PdM Inspection Programs

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ABSTRACT

The ever increasing need to have answers to problems and not just more data about them leads the evolutionary path in development and implementation of a facility's Infrared PdM Inspection Management program. Part of this natural evolution to provide a solution is the utilization of advanced relational database architecture with the incorporation of diagnostic engines based on problem modeling and profiling. The focus is then placed on the statistical analysis capabilities of the database architecture vs. findings in the field to provide solutions to maximizing the return of implementing a successful Infrared PdM inspection program.

This paper outlines the concepts of problem-modeling and provides executive summaries on the analysis of findings of field research that has been done over the last 10 years. Emphasis is placed on the actual findings as they relate to trending of problem conditions within facility, and measurable results of implementing an infrared inspection program. This paper also provides reviews of overall results of problem tracking / reconciliation from multiple inspections, cost breakeven analysis results, materials and labor, identification of key equipment failure ratios and root cause failure analysis studies.

Keywords: Problem, Modeling, Diagnostic, Engine, Infrared

1. INTRODUCTION

The need for better ways to manage infrared inspection programs has gone through a continuous evolution, particularly regarding what data is captured and how it is collected and shared. From the earliest days of the 1970's with black and white Polaroid thermograms through the video tape recorders of 1980's and digital storage in 1990's, the data as well as the documentation of inspection findings have been continually evolving. Today, robust database programs like Microsoft SQL Server or ORACLE manage this data. With the continued evolution of the computer, thermography has similarly developed in the scope of how we can manage the data that infrared inspections offer. As we look at the data we start to ask ourselves questions, then turn to the computer for answers to those questions. If we find that we don't have the right kind of information in the database, then we need to go back to the drawing board. We need to redesign the database so that we can store the kind of information that is most valuable to us in answering the pertinent questions.

Definitions used in this paper:

- **PM or Preventive Maintenance:** scheduled or routine maintenance. For example: changing the oil in your car every 3 months or 3,000 miles which ever comes first.
- **PdM or Predictive Maintenance:** Inspections or analytical studies that lead to assessing the health of equipment and directing specific maintenance needs of individual pieces of equipment.
- **CMMS or Computerized Maintenance Management Systems:** software programs whose purpose is to manage the scheduling and tasking of Preventive Maintenance programs.
- **EDMS or Electronic Document Management System:** software programs that manage the storage, retrieval, and archiving of electronic documents. For example: work orders, CAD drawings, inspection procedures, maps etc.
- **Queries:** analysis that is done on a set of data to distill data into meaningful information. For example: "How much did I save this year by implementing my Infrared PdM Inspection Management program?"
- **Diagnostic Engine:** specialized analytical and statistical queries that analyze the data based upon problem profiles.
- **Problem Modeling:** a statistical analysis of data grouped by similar equipment and problems conditions
- **Problem Profiling:** the acquisition and comparison of real world data against a problem model
- **Problem Profile Report:** queries that are run by the diagnostic engine of the real world data against the problem model to provide a statistical analysis report.

2. DEFINING THE PERTINENT QUESTIONS FOR AN INFRARED ELECTRICAL INSPECTION

When performing a typical infrared electrical inspections, the analysis of the thermogram and the temperature measurements are done as we stand right in front of the equipment out on the plant floor. It is at this point that we determine whether a problem exists which requires documentation. The need for analysis of the infrared image after the problems have been documented in the field is seldom required; however, information about the equipment and its operating condition is critical to accurately determine the consequences of the equipment's failure to the facility's operation. We need to gather other critical pieces of information other then emissivity settings and distance-to-object or "background reflected ambient" in order to analyze each problem's impact on the operation of a facility. Infrared cameras now offer advanced computerized thermal analysis tools and software for report generation (which can produce line profiles, histograms, 3D-image mapping, multiple spots and areas, image subtraction etc.). These are all effective tools for research and development analysis, but they don't answer the key questions that facility managers are asking:

- What are the consequences of failure?
- Is it less expensive to fix it now or later?
- How much time will it take to fix?
- Do I have similar pieces of equipment that I can expect to experience a similar problem on?
- How long can I go before I need to fix it?

The answers to these questions won't come from changing the distance-to-object parameter or placing a line profile on a thermogram. We must define, collect and analyze another set of data to provide a professional determination of a facility's potential risk of equipment failure.

Traditionally, within the infrared consulting sector there has been resistance to this level of professional evaluation for one simple reason: it requires more work of the thermographer. Regrettably, many thermographers will balk at the first mention of keeping a full, complete and accurate inventory of the test status of the facility's equipment. If the discussion progresses to include collecting the rest of the data required for accurately assessing potential risk to a facility operation, more resistance is evident. Many thermographers feel that it is sufficient to document hot-spots, and nothing more. I would argue that with the affordable technology so readily available in today's marketplace, there is no excuse not to deliver to the customer a wealth of historical decision-making data, along with the typical thermograms.

By adding the inventory of equipment to be inspected and assessing the equipment's criticality to the operation of the facility, we can also establish inspection schedules that will determine what equipment is to be inspected and when. If we don't have an inventory of the equipment that is going to be scheduled for testing, then it is impossible to set a schedule. We will also need to have accountability for what equipment was not tested because it was out of service at the time the inspection was scheduled. Otherwise equipment can go un-inspected for years because it keeps missing the schedule date of the inspection. Simply speaking, we must establish and manage an inventory of equipment that is to be inspected because this sets the pace for how much data is to be collected and when.

Criticality to Operation	**Inspection Frequency**
Crucial	Every 3 Months
Essential	Every 6 Months
Non-Essential	Once a Year
Follow up on problems / repairs	Every 3 Months

Inspection Schedule in Months	**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**
Crucial	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Essential	X		X		X		X		X		X		X		X		X
Non-Essential	X				X				X				X				X
Follow up on Problems / Repairs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

The real power of the available technology comes by giving the thermographer the ability to have critical information at his finger tips while he is standing in front of a potential problem, right there on the plant floor. Critical information can be easily collected in the field by utilizing mobile computers and databases. By using bar code technology, the thermographer can easily retrieve data relative to individual pieces of equipment. A quick scan of the barcode will display the historical record right on the thermographers computer screen. Past problems can be reconciled and new ones can be put directly into the database at the time they are found, ensuring that all of the information is gathered accurately the first time.

The equipment inventory should contain some key pieces of information. Capturing the manufacturer and type of each piece of equipment allows one to analyze reliability by manufacturer and/or equipment type. By comparing the cost of repairing observed problems, we can look at the impact by manufacturer on the total operating expense of a facility. This, in turn, allows one to improve future buying decisions. (See section 5.2)

There are important benefits which come from the problem-modeling aspect of the diagnostic engine. One is the ability to anticipate future problems. This is done by analyzing problems found in the existing equipment, and then making projections on equipment that has not yet experienced problems. Another benefit is the ability to track the success or failure of particular repair methods. Past problems can be reconciled against the equipment's work orders to see which type of repairs successfully corrected the problem, or which proactive steps are effective in preventing reoccurrence.

It is imperative that each piece of equipment has its criticality to operation established and recorded. This provides one with the ability to assess the potential consequences to a facility's operation if failure occurs. This information is necessary to determine the priority of repairs. For instance, temperature rise has historically been the key factor in determining the priority of repairs. However, consider this example. Two problems are found aboard a ship. One problem has a temperature rise of 15 deg. C., the other a temperature rise of 40 deg. C. Which one should be repaired first? If you don't know the Cruciality to operation one would assume the problem with the 40 deg. C. rise. If you are made aware that the problem with the 15 deg. C. rise is in the main steering gear controller, and that the problem with the 40 degree C. rise is in a lighting panel for the crew cabins, the decision is equally obvious but entirely different. If we had just looked at which piece of equipment had the highest temperature rise, and fixed it first, then we would have run the risk of loosing the ability to steer the ship and perhaps run it aground.

Problem-modeling diagnostic engines also help identify chronic problems. This is done in the reconciliation of past problems with those recently documented. Trends in chronic problems can be tracked over time to show the percentage of change. We can build problem models based on past data to compare current and past problems. We can project what might happen if the operating conditions change (for example: if the load or ambient conditions change). We can also track changes in the percentage of problems by severity (temperature rise) or Criticality to operation. Over time, the problem count will provide a good profile of the facility's condition and the effectiveness of its maintenance program. Multiple sites can be measured to evaluate their overall and comparative fitness. Future maintenance can be anticipated. Loss Control insurers look favorably on facilities that provide thorough documentation of their infrared maintenance programs.

As you can see, a tremendous amount of valuable knowledge can be gained by implementing a complete infrared PdM inspection program that collects and analyzes the <u>pertinent</u> data. Today's infrared cameras are marvelous tools for measuring and recording temperatures in the field; but the camera alone can provide both too much superfluous data, and too little pertinent data. The thermogram is the starting point of problem documentation. But for PdM purposes, the direction is not towards advanced computer image analysis (of which the camera can do alone), but rather towards facility-wide performance analysis, which requires a strong database program and, equally important, the right data.

As I've said, the infrared camera is just a tool and the thermogram is just the starting point in the data gathering process. The next step is to establish methods to ensure the right data is collected efficiently. These methods should define procedures to guarantee that the data quality is consistent from inspection to inspection and/or from thermographer to thermographer. These methods must not impair the pace of the inspection but should help in expediting the collection of data and aid the thermographer in his ability to better diagnose problem conditions in the field.

3. METHODS OF COLLECTING DATA & REPORT GENERATION

Thermograms are an integral part of data collected as part of a comprehensive Infrared PdM program. However, it is not the purpose of this paper to discuss methods of thermal imaging. Instead, I will focus on methods for collecting the equally pertinent data required to monitor a facility's health.

Important decisions must be made in the type of software programs that are used, the data that is collected, and how that data is handled. A Computerized Maintenance Management Software (CMMS) program is very good at providing specific operational procedures for scheduled maintenance and tracking inventories and work orders. A CMMS program produces reports that are based on queries for the data that they track. Many companies are trying to utilize CMMS or **Preventative** Maintenance (PM) programs to manage their facilities' **Predictive** Maintenance (PdM) Inspection programs. This presents a problem. The Preventative Maintenance (PM) software program was designed for assigning tasks to people on a regularly scheduled basis and tracking inventories of spare parts. A Predictive Maintenance (PdM) Inspection program is designed to assist the technician with the actual inspection and assess the health of the facilities equipment. Changing the oil every 3 months on a CMMS schedule is not going to tell you if the engine is healthy or failing. You need to do a Predictive Maintenance oil analysis test to assess the engines health. A CMMS Preventive Maintenance (PM) program is like running every day to keep your body healthy but you should still see your doctor for your annual physical to evaluate the actual health of your body, like the Predictive Maintenance (PdM) **Inspection** program. There are also differences between management and analysis of Preventive Maintenance (PM) vs. Predictive Maintenance (PdM) programs.

PdM programs require specialized queries. The data that is collected is specific to that PdM inspection type i.e. oil, vibration, or infrared, and the analysis is specific to that inspection type as well. For example, you can not perform vibration analysis inspections using oil analysis software and vise versa. Each inspection type has its own unique requirements and queries for the type of data that is required to perform the analysis. There may be similarities in the data sets, but the analysis is completely different. Infrared thermography as a PdM inspection type is unique as well. Some of the data is similar to Oil and Vibration Analysis but the paths taken to analyze that data are completely different. The important point is that each analysis complements the other. Thus, rather than trying to force an existing Preventive Maintenance CMMS software program to become an infrared PdM inspection program, the aim must be to utilize CMMS software programs **in conjunction with** an Infrared PdM inspection management database program.

An example management question is: "How much did I save this year by fixing problems before failure vs. after failure?" Below is a matrix of software programs with their data and queries trying to give the right answer for this question.

	SOFTWARE PROGRAMS	DATA		QUERIES	TYPE	RESULTS	
1	PM, CMMS, IR Image Analysis / Report Software	Right Data	+	Wrong Analysis Queries	PM	=	Wrong Answers
2	"	Wrong Data	+	Wrong Analysis Queries	PM	=	Wrong Answers
3	"	Wrong Data	+	Right Analysis Queries	PdM	=	Wrong Answers
4	"	Right Data	+	No Analysis Queries	N/A	=	No Answers
5	"	No Data	+	No Analysis Queries	N/A	=	No Answers
6	IR PdM Inspection Management Database	Right Data	+	Right Analysis Queries	PdM	=	Right Answers

As you can see, only the Predictive Maintenance Inspection software can answer the question. (See section 5.3)

An Infrared PdM inspection database must have a well-designed architecture. The database must be robust and have a sufficiently solid foundation to support the amount of data that will be stored in it. This data should also be accessible, so that it may be shared with other software programs (CMMS, PM, etc.) The database architecture must be flexible enough to handle the demands of continually changing requirements. Once a strong Infrared PdM Inspection database is established, the ability to easily manage an infrared program becomes crystal clear. This is demonstrated by the wealth of information that the program delivers. (See section 5 for example)

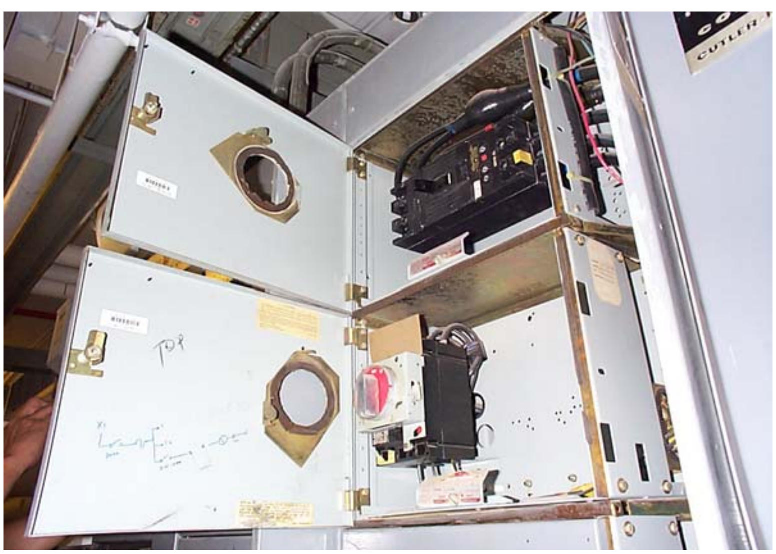
The database is only as good as the data that is collected. For this reason we must place considerable emphasis on how to gather the data. In the past, the two most established methods were: 1) utilizing paper forms that the thermographer filled out in the field when he found a problem, or 2) using a voice dictation audio recorder. There are pitfalls to using either method. In the first instance, there is the risk of lost data and errors from misinterpreting field notes. In the second instance, transcription errors can occur when typing up the inspection findings away from the site after the inspection has been completed. Further more the thermographer in the field does not have in his hand the analysis capabilities of the PdM software when it is of most valuable to him in doing his job.

The solution is this: instead of trying to bring the field data back to the computer to enter it into the database, let's bring the database to the field to have the data entered directly into the database during the inspection. Again, it is important to use <u>powerful</u> pen computers in the field that run the IR PdM inspection database. This has proven to be the most reliable method of data collection available to the thermographer.

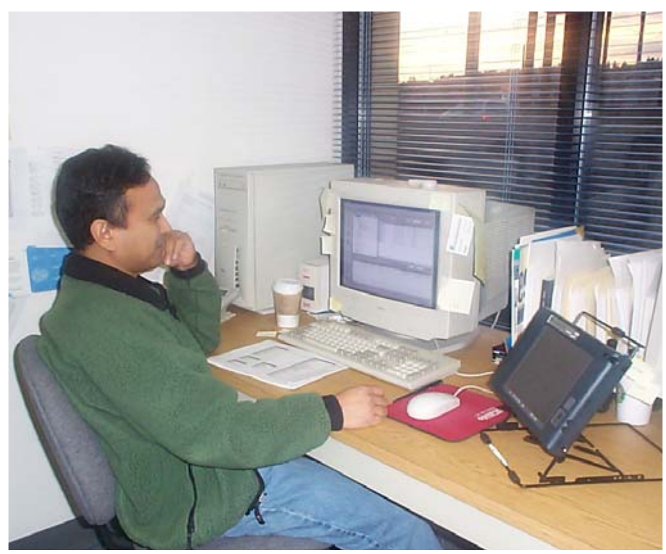
Thermographer with camera and Mobile Pen Computer running the Thermal Trend Infrared PdM Inspection Management Database.

By scanning the bar code the database automatically looks up the equipment so that the thermographer can review the equipment past history.

By using a pen computer running the database in the field, this allows the thermographer to enter problem information quickly into the database at the time of the inspection. This eliminates the need for typing up the report at the office.



Bar code labels are placed inside the door or next to the equipment to be inspected. This allows for easy tracking of equipment by the database and provides the thermographer the ability to have 100% accountability for what he has and has not tested.



Management simply reviews the data that was collected in the field by the thermographer as soon as the inspection is done. Information can easily be shared over the intra-internet, or hard copy reports can quickly be printed out.

One reason a database on a mobile pen computer will yield the best inspection results is because testing procedures can be methodically followed. Key information can be simply selected from drop down menus in the software to ensure consistency. This is extremely efficient (no typing, no syntax problems) and improves data accuracy. This method has many benefits over conventional methods. For example: Past problem conditions on a chronic problem are immediately displayed and can be reviewed in the context of the newly documented problem. Furthermore, the redundancy of data collection can be eliminated because information that was stored in the past does not need to be re-entered into the database. Another benefit of using a pen computer in the field are maps, work orders, inspection procedures and other pertinant documents can be brought into the field since the database can work as an Electronic Document Management System (EDMS). Another efficiency is that of the instant turn-around-time of report generation. Since all of the necessary information is put into the database at the time of the inspection, the database is able to do the rest.

It has been shown that by utilizing a pen computer with an infrared PdM database in the field, a thermographer can double the number of problems written up in a day (from 50 to 100 problems), and completely eliminate report generation time.

Typical times of inspections and report generation (*Inventory of equipment, Prioritized list of problems, Documentation)

Method	Inspection Time	# of Problems	Report Generation Time*	Totals .
Paper / Voice Dictation	8 Hours (1 Day)	50	6 to 8 Hrs.	14 hours / 50 problems
Pen Computer w/ IR PdM Database	8 Hours (1 Day)	100	0	8 hours / 100 problems

Reports can easily be generated on paper or electronically. The database can also be shared over the inter/intranet. Users can easily generate reports electronically by using their web browser or choose to print out the standard reports. A web interface to the main database eliminates the need to install software on every manager's computer. Management can get detailed analyses on virtually every aspect of the infrared inspection program by using established report queries. For example, engineers in Germany can easily review results from an inspection done in Mexico as soon as the inspection data is uploaded to the main database.

4. THE CONCEPTS OF PROBLEM MODELING & PROFILING

Diagnostic Engines used in Infrared PdM databases that are based on statistical analysis of Problem-Modeling & Profiling, provides us with a powerful tool in the ability to look at different scenarios and anticipate the potential “what-ifs” of changing parameters on equipment and their associated problems. Data is collected on specific equipment’s environment, temperature of the problem and the reference components, as well as the running load and the rated load. We can then determine what the normal operating conditions are vs. the abnormal problem conditions in a variety of situations. Problem-Models are built on specific types of equipment with data from real world problems. When problems are documented, they are grouped by their respective equipment and fault types. Then, when the problem's work orders are compared to the fault types that were found and the repairs that were actually made, we can reconcile and refine the correct procedures for making repairs. Furthermore, associated time, materials and cost data can be associated to the equipment and fault type combinations, allowing for projections of "before vs. after failure" to be built right into the model.

Problem Modeling and Problem Profiling is not an exact science, like earthquake or volcanic predictions, but just knowing that the volcano is probably going to erupt is much better than not knowing at all. And the more information that is placed into the database’s problem modeling diagnostic engine, the more meaningful are the statistical analysis results. The value is in the real world data on which the databases are built. With a wide variety of equipment and fault types, a data set of at least 25,000 problems is recommended to build a meaningful result set. Once the engine is designed and implemented, it also needs to be expandable and "learn" as new equipment and faults are documented.

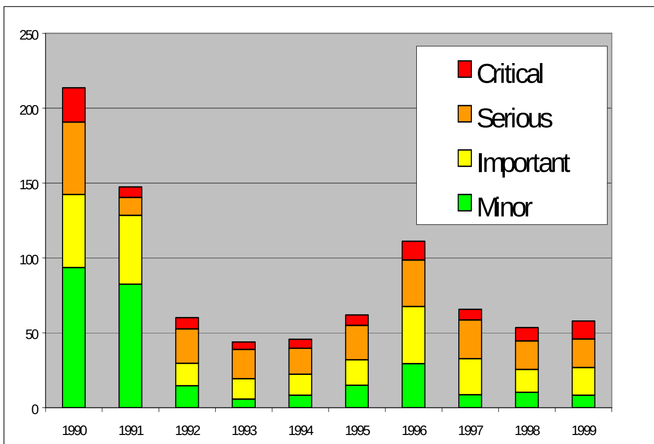
The analysis that is provided by these engines generates invaluable information on problem conditions that are found in plants. For example, by analyzing how Manufacturer “A” vs. Manufacturer “B” 100A 3 phase circuit breakers are working, you can tell what the normal operation temperatures are at any given load and ambient operating condition. We can also analyze specific characteristics of problems to find similarities in the source of problem conditions. Chronic problems that have been documented over time provide us with the ability to build a model with a time-over-temperature envelope that can be compared to the actual problems that were documented. By normalizing the load factors to specific percentages, we can easily make comparisons on chronic problems over time to see the percentage of change and the rate towards failure. By reviewing the types of equipment that have a specific type of problem and querying the database for similar equipment that has not had any problems yet, we can flag this equipment as more susceptible to potential failure. Then we can work towards the establishment of preventive measures to ensure that the risk of failure is minimized.

By designing into an Infrared PdM inspection database, a diagnostic engine based on problem modeling in this fashion, we can easily profile new problems against their respective models to see what type of failures may be anticipated. Also, we can view the what-ifs scenarios if the operating conditions on the equipment change. Furthermore, profiling allows for the comparison of conditions so that we can calculate the rate of anticipated change based on known information.

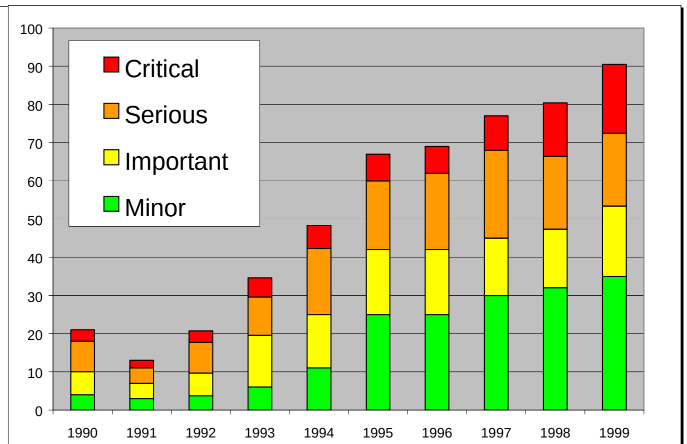
Another enormous benefit with the database problem profiling is for new thermographers to use as a training tool when they are beginning to document problems and need to review past problems. This will help them more fully understand the entire picture of the problem and the associated fault conditions. By integrating the diagnostic engine with a seamless user interface into the infrared PdM inspection software, you can greatly improve the speed and accuracy of documenting problem conditions, even for new technicians. By design, these diagnostic engines can grow and learn as time goes on and can also work in tandem with other databases, such as CMMS systems, to complement the overall effectiveness of managing the infrared PdM inspection program.

5. EXECUTIVE SUMMARIES ON THE ANALYSIS OF FINDINGS OF FIELD RESEARCH OVER THE LAST 10 YEARS.

Note: The following analysis of data presented here is from data collected for over 10 years by Colbert Infrared Services, Inc. utilizing the Thermal Trend Infrared PdM Inspection Management Database. Omission of actual client and manufacturers' names and specific products is intentional to protect the clients and manufacturers. Data has been collected from all over the world on all kinds of manufacturers and plant environments. The data that this analysis comes from is on over hundreds of thousands of problems and pieces of equipment.



Overall problem count by year of a specific industrial site shows the trend in problems over 10 years. The graph shows a significant reduction in the number of problems up in till 1995. At this point there was a change in management and they did not fix their problems. This is shown by the problem count in 1996 increasing by over 100%. But by 1997 they were able to reduce their problem count back to the average level of problems for their particular industry and size of plant.



Overall problem count by year of a specific new ship shows the trend in problems over 10 years. As the ship gets older, the number of problems has increased each year. Maintenance has worked hard to fix all of the problems but as the ship ages, the problem count on this ship has increased. Infrared thermography has helped to provide the staff with a strong diagnostic tool to find the problems and the database has allowed for the management of the inspection program.

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measured phase to phase is **54º F**.

5.1 REVIEW OF OVERALL RESULTS OF PROBLEM TRACKING / RECONCILIATION FROM MULTIPLE INSPECTIONS

Chronic Problems over Time by Industry

These are problems found but have not been repaired.
Problems documented in year 0 are reported for the first time.

	Y0	Y1	Y2	Y3	Y4
Industrial / Commercial Electrical Systems:	0	25%	22%	18%	15%

	Y0	Y1	Y2	Y3	Y4
Transmission / Distribution Electrical Systems:	0	23%	20%	17%	13%

	Y0	Y1	Y2	Y3	Y4
Marine Electrical Systems:	0	30%	28%	25%	22%

5.2 IDENTIFICATION OF KEY EQUIPMENT FAILURE RATIOS

By establishing parameters for equipment and the type of failures that they have by manufacturer, we can analyze the problems in the database and establish ratios for specific faults on key equipment. This leads to the ability to study the equipment thoroughly and analyze what factors play an important role in their failure. This provides insight into the correct preventative maintenance measures to be taken so that future problems are minimized.

Problem Profile Report
Findings by Manufacturer Ratios for specific equipment and fault types*

Component	**Fault Type**	**Manuf. X**	**Manuf. Y**	**Manuf. Z**
100 A 3 Phase Fuse Disconnect Switch				
	Line Side Wire Lug Connections	10 %	2 %	3 %
	Disconnect Contacts at Knife Blade Stab Area	20%	19%	5%
	Pivot Contact Area on Switch Arm	NA	20%	NA
	Line Side Fuse Clips	15%	10%	12%
	Load Side Fuse Clips	14%	8%	13%
	Load Side Wire Lugs	3 %	3%	4%
		Manuf. A	**Manuf. B**	**Manuf. C**
100 A 3 Phase Circuit Breaker				
	Line Side Wire Lug Connections	5%	10%	8%
	Internal Contacts	1%	20%	3%
	Load Side Wire Lugs	3%	5%	4%
1200 A 3 Phase Breaker		**Manuf. L**	**Manuf. M**	
	Line Side Stab Connections to Bus	4%	1%	
	Contacts Area	10%	2%	
	Pivot Area	1%	1%	
	Load Side Stabs	5%	1%	
	Load Side Wire Lug Connections	4%	4%	

* Omission of actual manufacturers' names and specific product is intentional to protect the manufacturers. Ratios are based on total similar equipment of a specific manufacturer vs. the number of incidences that the equipment/fault has been recorded.

5.3 COST BREAKEVEN ANALYSIS RESULTS FROM MATERIALS AND LABOR

Out of 55 industrial manufacturing sites, a total of 976 problems were documented. A cost benefit analysis on the 976 problems shows a "before vs. after" failure savings on materials and labor of $408,040 US. The average cost saving per problem if it is fixed before it fails for material and labor works out to be $418.07 US. This number is very conservative and does not take into consideration the potential loss to revenue or loss to production nor the risk of financial loss from personal injury lawsuits.

5.4 MEASURABLE RESULTS OF IMPLEMENTING AN INFRARED INSPECTION PROGRAM

From a return on investment (ROI) perspective, infrared PdM inspection programs have proven that on average for every dollar spent on outsourcing a competent professional consultant to perform an infrared electrical inspection there is a four dollar return on investment for materials and labor by fixing the problems before it fails. This conservative 1:4 ratio clearly identifies the importance of maximizing the return on investment of implementing a comprehensive in-house or outsourced infrared PdM inspection program. Furthermore, by reducing losses and increasing productivity, which in turn increases revenue, the return on investment ratio in some cases is closer to 1:20, depending on the industry.

SUMMARY

From the information and data presented above, we can clearly see the benefit of establishing an infrared PdM inspection management program. By setting up a mobile database and tracking the pertinent information and recording it consistently, we can more efficiently gather important information regarding the health of a facility. By using problem modeling and problem profiling, we can review the success of our repair procedures; track root causes, analyze "what-if" situations, and make informed equipment buying decisions. Management reports can be quickly generated from the database without manually sifting through all the past hard copy reports and summarizing the data into Excel. The ability to clearly understand, manage and administer the complexities of an infrared inspection program for a facility is a task that can not be taken lightly, but once it is properly established, the value it delivers is unequaled.

ACKNOWLEDGMENTS

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