Infrared Applications Everywhere!

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ABSTRACT

Infrared thermographers see the world as a radiator, with eyes nobody else has. Getting paid to walk around and look at things with an infrared (IR) camera is a dream come true. To the interested, inquisitive, infrared thermographer, applications seem endless. This paper focuses on the myriad of great applications for this dynamic technology.

1. INTRODUCTION

It is our industry's challenge to improve the methodology for gathering and disseminating infrared data efficiently and effectively and to explore and develop new markets by finding new uses for this technology. With modern infrared cameras, computers and analysis software, infrared thermographers today are rarely limited by the infrared equipment's ability to measure temperatures and/or discern differences in temperature. Rather, they are limited by knowledge of what the object temperature or pattern signature should be, and/or how to create a condition that allows them to see what is happening with the object. This paper does NOT include a laundry list of applications. Any attempt to create a list would be limiting, and might imply that a finite number of applications are possible.

2. DETERMINING IF AN APPLICATION SHOULD BE TRIED

One should consider using the matrix in Figure 1 to determine whether or not IR may be used effectively for a particular application. Ask three questions; 1) If it can be done, would the information be **valuable** to the end-user, 2) Is it **possible** to successfully accomplish the test and get valid results and 3) Would obtaining the information **cost** more than it is worth to find out. Below, find some examples of applying this simple test.

Example A – Value
Discovering the cure for the common cold might be *expensive* and *difficult to test for,* but the *value* of the cure would be so tremendous that any costs or difficulty determining the answer would be infinitesimal when compared to the solution to the problem.

Example B – How to spend limited resources
A five-year old office building has a total of 6,000 pieces of electrical equipment. The owner decides that he would like to know if any of this equipment has loose connections or any other undesirable conditions which can be found using by infrared thermography. He has a limited amount of funds available for this purpose and wants to get the best return on investment. Using the matrix, decide which of the 6,000 items should be surveyed using infrared thermography.

? **The main electrical switchgear** consists of the power company transformers, main switchgear panels, automatic transfer switches, generators, bus ducts, step-down transformers, distribution panels, and HVAC electrical equipment. These add up to 500 items. Performing an infrared survey on the building's main electrical switchgear is determined to be extremely cost effective because of the high *value* of the equipment itself and the uptime, high *technical feasibility* (infrared thermography is accepted in industry as the way to check electrical gear for problems) and a high *economic feasibility*. With three high ratings, the owner decides to survey the main switchgear.

? **The main computer system** consists of 500 computers, servers, power distribution units (PDUs) and the uninterruptible power supply (UPS) system. The UPS system supplies constant and emergency power. In the event of a loss of normal power, the UPS system will allow the generators time to ramp-up and sync, restoring power in minutes. This equipment has a relatively high *value* itself, but the data is much more valuable, a high *technical feasibility* and a high *economic feasibility*. The decision is made to add this equipment to the infrared survey.

? **The 120volt receptacles** are connected to the usual things in an office building; 500 personal computers (PCs) and 4,500 pieces of miscellaneous office equipment like copying machines, printers, coffee machines and other electrical doodads. The 4,500 miscellaneous pieces of office equipment have a low *value* – because they are relatively inexpensive individually (other than the unlikely fire they could cause) and can cause little business disruption if they fail, a high *technical feasibility* – it is relatively easy to verify the status of any electrical device by applying current and measuring the rise above ambient, or comparing the temperature rise to other similarly loaded devices and a low *economic feasibility* – because it will take a lot of time [money] first, to determine an acceptable temperature rise, and then to perform the testing on so many receptacles in so many locations. The PCs are the most valuable equipment in this group. They are plugged in to the building's power and most have small consumer grade back-up battery devices for temporary loss of power. Probably 10-20% are not properly plugged in and set, or the batteries are dead. So, a certain percentage will suffer a failure and loss of data in the case of even a momentary loss of power. Still these have a low *value* (if they were valuable, they would me connected to the main UPS), a high *technical feasibility* and a low *economic feasibility*. The answer is that it is not a good idea to survey any of the 120volt receptacles.

Of the 6,000 items that can be surveyed, only 1,000 are worth surveying.

Example C – Choosing one application over another

A manufacturing plant operates 24/7 and has never been the subject of an infrared survey of electrical switchgear. Annually, the plant experiences 1% downtime due to electrical system related failures. After implementation of an extensive IR/PM program, downtime is reduced to $1/10^{th}$ of 1%. The cost of the electrical survey is $10,000 and savings from decreased downtime are $200,000. The management is extremely happy to have a net savings of $190,000 per year. The same plant has 100 widget machines, which produce annual revenues of $20,000,000. After a two-day survey of a couple of widget machines, the machines are adjusted and begin operating 10% faster with 10% less in product returns. Savings are in the millions. The savings from the reduction in downtime turned out to be only a small percentage of the increase in profits from addressing total production, since there are much more savings available from production equipment improvement, than from the electrical predictive maintenance. The matrix shows that while *technical feasibility* is lower on production equipment infrared (because of the lack of established standards and procedures for checking this equipment), *value* and *economic feasibility* are much higher than with electrical infrared.

Example D – The dreaded economic feasibility factor

A process engineer is trying to discover a plastic polymer that is stronger than anything on the market. The trouble is that a sophisticated infrared system is required to constantly adjust the machine production line. It costs over $100,00 per machine line to make the line run properly. Even though the *value* is high and *technical feasibility* is high, it is not *economically feasible* to install infrared cameras at every machine in all the facilities.

Example E – No Way

This thermographer for one would love to be able to tell if the grouted cell in a concrete block wall has a reinforcing bar in its center. Seeing the difference between the empty and grouted cells is 'duck soup' for an experienced thermographer of buildings with a sensitive camera. However, the difference in mass between a ½ inch diameter rebar in the center (as much as 5 ½ inches inside the solid wall) of the cell and the grout/block mass, is not sufficient to change the temperature on the surface – no matter how much heat is applied. This is a case where there is no *technical feasibility*.

3. PLANNING AND DOING THE WORK

Once an application has been selected for trial, infrared thermographers should consider the following:

Which comes first the heat or the…
Surgeons cut, radiologists radiate and chemotherapists administer chemicals. It is the same with non-destructive testing (NDT). Infrared thermographers should first consider using what they know about to solve problems. Infrared thermography has an advantage over other NDT methods because it is immediate, graphic and it is usually pretty easy to find out if it will work. This is a big advantage when trying to obtain funding for untried applications. Having a picture that a manager can understand (often, a person with limited engineering savvy) may be the linchpin in the approval process. Thermographers should exploit this advantage. If they would just take a few moments to look at something that they have not imaged, consult with the owner/operator and think about the possibilities, chances are a new application will be discovered. What comes first…the heat or the vibration or the sound or the smell…who cares…you are an infrared thermographer, try that first.

Using Finite Element Analysis (FEA)
Finite Element Analysis can be used to determine if an application can be performed using IR without even using an infrared camera. FEA is a method for performing calculations of complex systems, usually by using a computer. There are many types of calculations that can be used…like heat transfer (conduction, convection, and radiation). Using FEA first, can save thermographers time, money, and effort. It may be impossible to image certain objects because of their mass, for instance, no matter how much heat is applied to the surface. By performing an analysis of their heat transfer behavior; FEA can be used to determine if one is about to embark on a wasted trip halfway across the country to look at something that cannot be successfully imaged. FEA can also be used to select the conditions for IR testing that will be successful, so that additional applications can be developed. These calculations are better left to a person with a good understanding of heat transfer phenomena, material properties, and system behavior-since the FEA answers need to be correct. Kleinfeld has presented examples of applying FEA to IR[1].

The right tool for the job – selecting the infrared camera
The infrared camera should be matched to the application and capable of performing the task given. There are four detector characteristics that should be considered: the sensor's thermal sensitivity, spatial resolution, response speed and spectral range[2]. Other factors include the convenience of using the unit – its physical size, ruggedness, ease of operation, image storage speed, format and capacity, connectivity, power supply and post-processing capabilities. Bells and whistles are nice if you can afford them since you might find yourself needing one, especially on a project with unknown requirements. There are a wide range of windows, filters and lens options available. These should be used whenever applicable.

Have a clear understanding with the end-user of the project possibilities
Before starting on an infrared project, it is a good idea to write down the goal of the project along with what procedures might be used and discuss the potential for success. Also, the possible problems that could be encountered should be brought to light. It is extremely important to explain the limitations of the physics to potential end-users so they will have a clear understanding of what the project will and will not be able to accomplish. Sometimes however, they will not want to hear what you are telling them. Here is an example:

The operators of electric utility transmission lines sometimes use aerial infrared thermography to find and **classify** problems so repair activities can be prioritized. Telling someone who has been using temperature readings to classify problems for years – that those numbers are not, and cannot be accurate, often this gives them the inclination to ignore the facts and find someone who will provide them with temperatures. Their judgment might be called into question if all of a sudden they stop getting reports with temperature readings. Listen carefully and you can almost hear their boss saying, “What…we’ve been using inaccurate temperatures to prioritize repairs on the circulatory system of our utility all this time!”

The fact is that infrared cameras that are in general commercial use today cannot measure accurate temperatures on small spots from distances of 50 feet, much less than from reliably safe flying distances of 500-1,000 feet. A one-inch target cannot be measured from that distance, plain and simple, although it can be detected. The spot size from 500 feet is unmanageable and inaccurate on any target that does not have a large homogeneous heat signature. The ground resolution element (GRE) defines the area represented on the ground (or transmission line) by one pixel of the sensor of a remote sensing device. This measure of spatial resolution is all-important in aerial infrared thermography. Nyquist's frequency theorem states that an object less than two times the size of a sensor's ground resolution element cannot be resolved for measurement. A 3x3 pixel or GRE spot is needed for reliably obtaining measurements. This shortcoming may be addressed by using more powerful lenses to reduce the GRE for a given distance, but then the sensor's field of view is reduced, limiting the area covered over a given period of time. So, if one is using a moderate spatial resolution IR camera, say, 256x256 pixels in a helicopter only 50 feet away from a 1 inch “hot spot”, it is impossible to obtain accurate temperatures using a standard lens. The smallest “hot spot” that could be accurately measured with a standard lens (16 degree) for this camera is over 2", even at that extreme short distance. And, from the air, using a more powerful lens does not work well because vibration is more evident in the form of image 'shaking'. Image 'smearing' may also occur due to an increase in the apparent speed of the sensor's view across the ground. In the air, there are few substitutes for a large pixel array. Even if one uses imagers with large detectors, say, 512x512, they cannot and should not profess to measure temperatures from the air on very small objects. These anomalies can be seen, and by comparing them to similarly loaded phases or equipment, potential problem areas can be identified. For ‘good’ measurements, a ground verification team should be used to inspect suspect hot spots from the ground (cloudy nights are best) and verify the findings of the aerial IR survey. They will be closer to the target and with a powerful lens on a stable surface, much more accurate.

Creating a transient condition
In general, there are two ways to make a judgment about what is going on with any object(s).
Either:

1) Monitor (passive) the radiated energy from the object or,
2) Create (active) the conditions needed.
   To create a transient condition:
   ? Apply heat (or cold) to the object and monitor what happens when the object heats, or,
   ? Apply heat (or cold) to the object and monitor what happens when the object cools, or,
   ? Put a heat (or cold) source behind the object and watch what happens when the heat comes through it or around it.

The general idea is that surface temperatures will be affected by any variations (defects or differences) in the mass of the object because if heat is applied evenly, it should be absorbed and diffused evenly. With pulse active thermography, the object receives a “pulse” of light energy. The event is recorded at high speed and processed with a computer. Another way is use sonic waves to vibrate an object. Localized heat is generated from friction at crack locations in the material. There are other variations on these and new techniques are being explored daily.

Give your reports that high quality look
We may be infrared thermographers…but we are in the image *business*. Chances are, the imager you are using cost about $50,000.00. Don’t ruin your reports with 640x480 photographic images from a $50.00 camera. Take high-resolution photographs (see Figure 2). Thermography has the advantage of not being a bunch of lines on a graph, so exploit this advantage and use as many high quality, correctly focused and well lined-up photographic and thermographic images as you need to get the point across. And print them on photo paper with a photo-quality printer. Even if you are sending reports on the Internet, eventually someone is going take a printed report page in the field. Make high resolution reports – they are your best form of advertisement.

4. THE DISCONNECT BETWEEN THE THERMOGRAPHER AND THE POSSIBILITIES

The allocation of time, money and resources to new applications for infrared thermography is often a communication problem. Power (therefore resource allocation) in most organizations follows 'alpha' personalities, not smart thinking. Many infrared thermographers belong to a specific department where tasks are handed down by short-term thinking, task-oriented management with job tunnel vision, who do not know (or worse, do not care) that thermography has so many other uses. Often, predictive maintenance groups handle infrared thermography along with other techniques like ultrasound, eddy current, vibration, oil ferrography, etc., This leaves even less time for trying out IR. Then there are the universal problems of high turnover of motivated personnel, lack of proper training, departments being in 'competition' with one another.

Thermographers must lobby for these resources, advertise their successes and take the initiative to try out new applications. Alas, thermographers are often technicians and not salespersons. They may be uncomfortable looking at (or making a judgment on) something that has no published standard. There are many uses for IR, but someone has to want to do them, recognize their value and pay for the survey to take place.

Lately, with the introduction of lower cost infrared imagers on the market, established infrared thermographers have expressed concern that untrained and inexperienced people will get these devices and make wrong or misleading assumptions about all things infrared, causing those in management to think less of the technology as a whole which could jeopardize all infrared programs. The lament here is not about IR programs; it is about job security. Let me put all those beautiful minds at ease. Just as a rising tide lifts all ships, so will the proliferation of infrared imagers lift the industry as a whole and all those in it, including *and especially* all those infrared gurus among us. Don't be scared of change; it is inevitable, so embrace it, celebrate it and promote the myriad of applications at every opportunity.

5. CONCLUSIONS

The future of infrared thermography is very bright indeed and opportunities are limitless. The transfer of energy happens everywhere around us and we can see it. We need to constantly improve methodology, explore new markets and find new uses for this fantastic technology. Never just walk by anything that you think can be imaged; try it. Not every application will work. Many will fail the test. Start failing...so you can start succeeding.

6. REFERENCES

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Figure 1. Matrix
(Click for a larger image)

Figure 2. Image taken with a 4.0 mega pixel photographic camera.
(Click for a larger image)