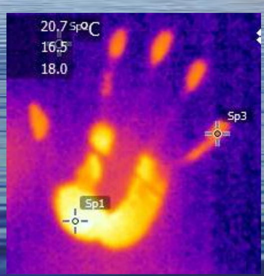
Infrared thermal imaging as a collections management tool

Nigel R. Larkin BA MSc



Email: nrlarkin@easynet.co.uk Web: wwww.natural-history-conservation.com Mobile: 07973 869613

Affiliated Researcher, Cambridge University Museum of Zoology.

Research Associate (Geology), Norfolk Museums & Archaeology Service.

Abstract

A museum collection may contain specimens with conflicting environmental requirements. Therefore the (sometimes subtle) differences in environmental conditions within a collections storage area or display area should be exploited appropriately - if the different microenvironments can be identified and quantified.

Digital infrared thermal imaging cameras can be used to instantly and accurately measure and visualise even subtle temperature gradients within a store, to provide a much more detailed understanding of the complexities of a three-dimensional space than any other datalogging equipment can currently provide. The differences in temperature can be used to infer likely differences in relative humidity levels as well.

Digital infrared images present their temperature data immediately in a highly visual format that is generally intuitively understood but it can also be very easily numerically analysed with the software so that areas within and between images can be compared. Using an infrared camera to investigate storage or display areas will reveal, for instance, temperature gradients due to stratification, hot spots, cool drafts, damp patches and unlagged heating pipes under floors *etc* – all of which would otherwise be invisible. Some of these differences will be subtle but some can be surprisingly abrupt and extreme, and none would be picked up by 'traditional' monitoring methods unless a huge amount of time and money were deployed.

Whilst infrared cameras are sometimes used in museums to investigate where energy (and therefore finances) can be conserved, their application for collections management purposes is rare simply due to a lack of awareness of how the technology can be usefully applied. Several factors influence the accuracy of the interpretation of the data so training is required.

The equipment

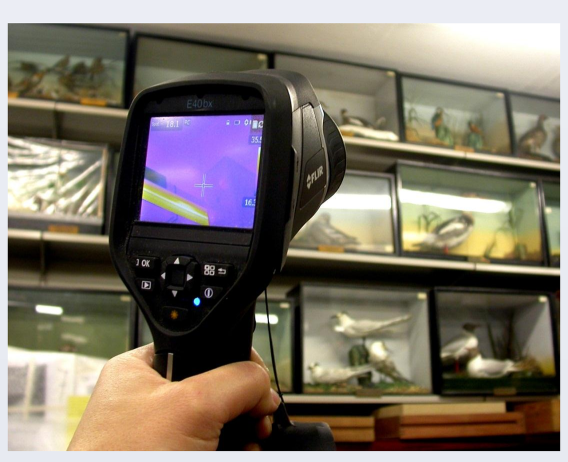


Fig 1 (left). An example of an infrared thermal imaging camera: the author's 'FLIR E40bx' in use. This has an image resolution 160 × 120 pixels (providing 19,200 separate temperature data points!); it takes digital infrared still images and video; its working range is minus 20˚C to plus 120 ℃; its thermal sensitivity is <0.045˚C; it has a built-in 'normal' digital camera (3.1 megapixels); one LED spotlight; and wireless/Bluetooth technology.

Measurements	°C
Sp1	5.2
Sp2	13.8
Sp3	14.4
Sp4	14.3
Sp5	3.9
Sp6	4.4
Sp7	4.2

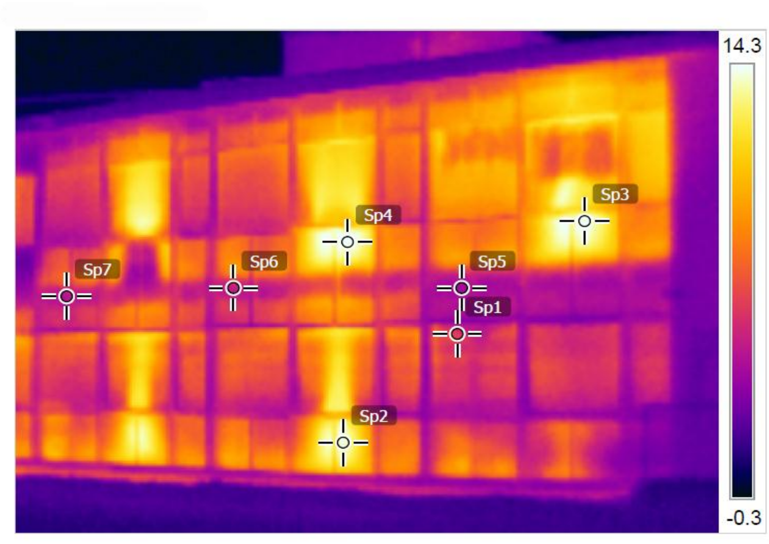


Fig 2 (right). This image taken early in the morning is of museum offices and store rooms losing heat: the glowing areas of this external wall show where the radiators inside the building are conducting enough heat through the wall to raise the outside of the wall by about 9℃ or 10℃. This image shows how the temperature data related to individual pixels can easily be shown in an image, and how such cameras are normally used.

The subtly different environments within a room

It is important not only to understand what parts of a collection require a higher or lower humidity or temperature but also to know which part of your storage area best provides the optimum conditions for the specimen or sub-collection as not only will conditions vary from store to store but even within a store. There will inevitably be some stratification (Fig 3), especially in higher-ceilinged rooms with no active air circulation and more dramatically so if heated in winter. The surfaces of external walls will probably be at a slightly different temperature to those of internal walls. There will be drafts around doors and window frames and unless large glass window panes are very well double or triple glazed they will conduct heat effectively to the outside, and act as a source of 'coolth' in a room. Poorly lagged or unlagged hot water pipes will create localised warm spots diurnally (Figs 4 & 5), and even plant running servers, lifts, heating or ventilation systems can create permanent warm spots on the walls of adjoining rooms (Fig 6).

If these sorts of environmental peculiarities within a room are quantified and understood, the variations can be exploited by rearranging specific parts of a collection, taking into account the needs of the material. However, whilst most museums now record the environment of at least some of their stores some of the time, even the best live telemetric environmental data logging system only produce data relating to a very small area around the sensors in what is a usually a large and varied three dimensional space. Until recently, it would have been extremely time consuming and costly to investigate and understand such subtle differences, requiring multiple sets of environmental data loggers and associated number crunching and graph wrangling to produce even a sketchy picture of the temperature and RH gradients across a room. Therefore it is generally underappreciated just how much environmental conditions can vary within a store room or gallery. However, recent improvements in infrared thermal imaging technology and a consequent drop in the price of the equipment has the potential to revolutionise the way we assess and manage our museum environments.

N.B. The camera has to be set for the right 'emissivity' of the materials being surveyed; it needs to be as parallel as possible to the surface being assessed; and the images have to be interpreted very carefully - infrared radiation can be reflected in just the same way as visible light, damp areas can be interpreted as cold areas and vice versa, warm spots might be a temporary artefact and air flows from ventilators can cool down the surfaces of materials while the object underneath the surface is actually warmer, *etc.*

Examples of the use of infrared imaging in collections management

Fig 3 (right). To assess the potential stratification of the air column in this modern museum store with full air conditioning and heating, after taking the infrared image with the camera you can either manually chose individual pixels (e.g. spots 1 to 6) and immediately see what temperature data is associated with each of the pixels, or you can use the software to draw a line (here, three lines li1, li2 and li3), and the software will give you the maximum, minimum and average temperature values along that line, along with coloured arrows indicating of which ends of the line are warmer or cooler.

Measurements		°C
Sp1		17.9
Sp2		17.5
Sp3		17.3
Sp4		17.1
Sp5		17.0
Sp6		16.8
Li1	Max	19.1
	Min	16.7
	Average	17.3
Li2	Max	18.3
	Min	16.8
	Average	17.3
Li3	Max	18.0
	Min	16.7
	Average	17.4

Whilst the average temperatures values of these lines are fairly constant, there is definitely some stratification of the approx 2m high air column, varying by 1.3 to 2.4℃. Whilst some of this variation may be due to exactly how and where the lines are drawn, knowing there is (probably a constant) variation of even just 1.5℃ between the lower and upper shelves gives a collections manager options when it comes to deciding on which shelf an item should be permanently stored.

Measurements		°C
Ar1	Max	22.3
	Min	20.5
	Average	20.9
Ar2	Max	19.2
	Min	17.6
	Average	18.6
Sp1		17.0
Sp2		31.2

Shapes can be drawn with the analysing software, and it automatically provides the minimum, maximum and average temperatures within that shape (here, comparing the spines of the books in Area 1 with those in Area 2).

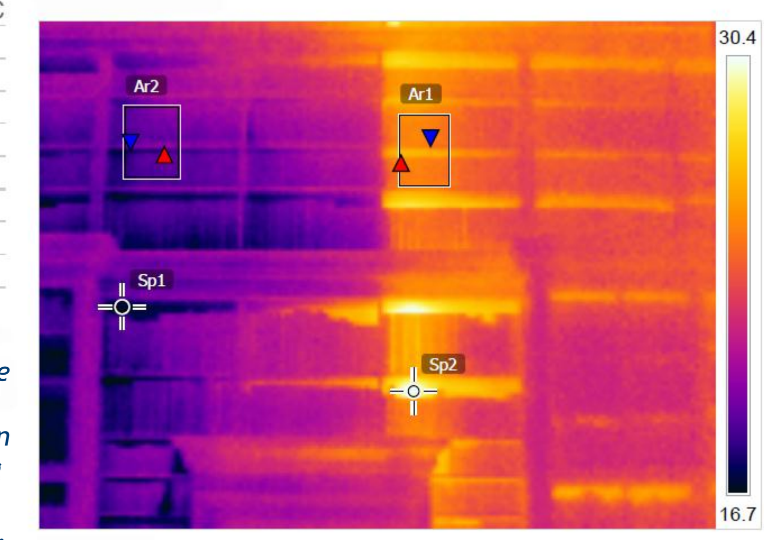
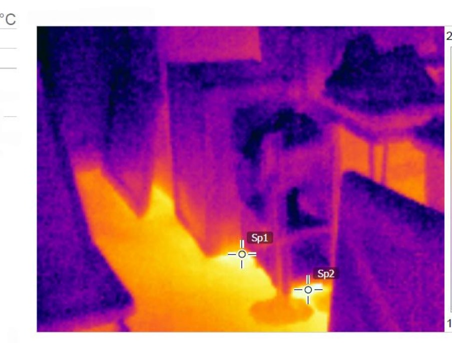


Fig 4 (left). During a recent demonstration, curators were horrified to be shown that warm pipes ran behind some items in a rare books and manuscripts room. Parts of the wall behind the books were over 14℃ warmer than equivalent parts of the walls nearby (Sp1 & Sp2). The spines of these books facing in to the room were over 2℃ warmer than the spines of other books nearby, and the rear edges of these books (facing the warmer wall) were 2℃ warmer again, resulting in a theoretical difference of about 20% relative humidity across the object. The rear of these books were over four degrees warmer than the spines of the books on the cooler shelves nearby. The area could be insulated to reduce the localised warming.

Measurements	°C
Sp1	23.0
Sp2	22.9



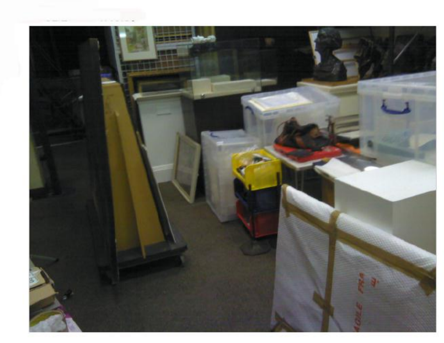


Fig 5 (above). Unlagged or poorly lagged hot water heating pipes were discovered running under the entire length of the floor of this art store during a recent energy conservation survey. They ran right under a large permanent area of clutter where the temperature of the carpet (Sp1 & Sp2) was at 23˚C, making this area under the boxes and tables ripe for a pest infestation. By storing the clutter elsewhere, the potential for pest infestation was immediately reduced. Important pictures were moved away from the diurnally changing source of heat.

Measurements		°C
Ar1	Max	24.8
	Min	23.8
	Average	24.4
Ar2	Max	20.2
	Min	19.9
	Average	20.1
Sp1		24.8
Sp2		23.7
Sp3		20.1

Fig 6 (above). This warm spot (Sp1, Ar1) was found low down on a wall in a store right next to a cabinet containing very valuable bird remains (*Dodos*, in fact!). No-one had any idea that this part of the wall was permanently warmer than the surrounding walls (by over 4℃ in this image). There is HVAC machinery in the room next door creating this warmth, illustrating that until you check with infrared you really do not know your store. This image shows areas can be selected (e.g. Ar1 and Ar2) and the maximum, minimum and average temperatures within the areas are automatically calculated and easily be compared to one another. As many of these shapes can be drawn as required.

Measurements		°C
Ar1	Max	19.2
	Min	18.9
	Average	19.1
Ar2	Max	19.0
	Min	15.9
	Average	17.1
Sp1		13.0
Sp2		20.9
Sp3		18.5

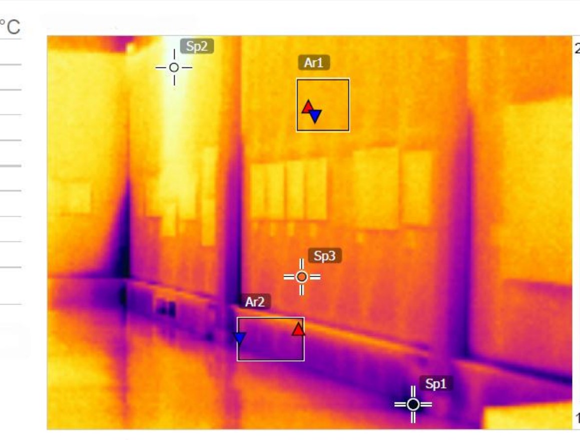


Fig 7 (right). This art gallery was recently checked as part of a museum's energy conservation survey. 'Sp2' is a warm spot on the wall created by a nearby spotlight and it is about 2˚C warmer than the average for area 'Ar1' which is part of the wall nearby that is only slightly lower in height. Cool air is issuing from the vents at the bottom of the wall (even though it was winter), adding to the stratification and uneven temperatures and RH. There is a difference of up to 8℃ between various parts of this gallery wall and this is likely to have an effect on RH levels as well. Traditional environmental monitoring would not reveal a fraction of these subtle differences. Note that the very shiny hardwood floor is reflecting the infrared in the same way it reflects visible light.

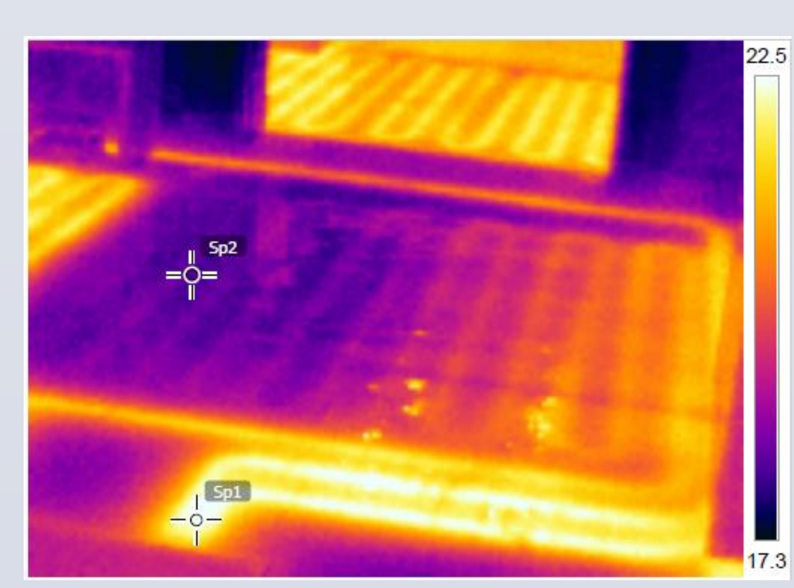


Fig 8 (above). Not only is underfloor heating very easily assessed to check if it is working (here, above, a section has failed), but the locations of the hot water pipes can be recorded in some detail so that specimens or display cases can be sited more appropriately in the future, to reduce the chances of damage by overheating.

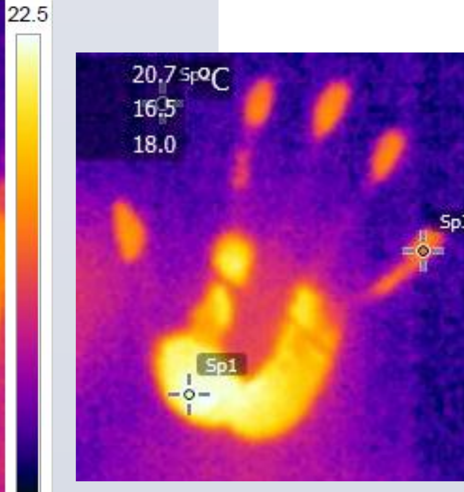


Fig 9 (above). To give an idea of how sensitive the cameras are: This handprint was left behind on a wall after the wall was touched for less than two seconds. The print was still discernible five minutes later.

Fig 10 (above). Cold drafts are easy to spot (here, issuing inside under a museum door) and this can help to identify where pests may easily enter a museum.

Conclusions

For many years infrared thermal imaging has been used to show where energy is being wasted in buildings, enabling effective energy conservation plans to be devised and savings to be made in carbon dioxide as well as in financial terms. It is now clear that infrared thermal imaging can also be applied effectively in museums as a collections management tool to enable a much more detailed understanding of the subtle environmental differences within a storage or display area. This can help curators, conservators and collections managers to ensure that sensitive specimens are placed in the most appropriate environment available.

Infrared thermal imaging has rarely been used in museums for collections management purposes simply due to a lack of awareness of the relevance of the technology rather than the cost, which is falling. A large budget for hardware and training is not even necessary as only a relatively small sum would be required to hire an appropriately experienced museum professional with their own camera to get the best possible use out of storage and display areas for the long-term benefit of specimens.

Acknowledgements

Thanks are due to: the various curators and other museum staff who have invited me to undertake energy conservation surveys or demonstrations of thermal imaging in their institutions, from which some of the images above are taken; and to staff at the University of East London and the Centre for Alternative Technology where I recently studied for my MSc degree in 'Architecture: Advanced Environmental and Energy Studies'

References

Larkin, N. R. (2013) *Infrared thermal imaging as a collections management tool.* Journal of Natural Science Collections, Volume 1, pp 59 - 65.