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AAT Guideline for Neuromuscular Thermography  
Quality Assurance of Thermal Imaging Systems

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Prof. DDr. Kurt Ammer

Österreichische Gesellschaft für Thermologie  
Hernalser Hauptstr.204/14 A-1170 Wien, Österreich,  
Phone & Fax (43 1) 480 54 23 :  
e-mail:KAmmmer1950@aol.com

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Editor in Chief

Prof DDr. Kurt Ammer

Österreichische Gesellschaft für Thermologie  
Hernalser Hauptstr.204/14 A-1170 Wien, Österreich,  
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e-mail:KAmmer1950@aol.com

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# Guidelines For Neuromusculoskeletal Thermography

Practice Guidelines Committee of the American Academy of Thermology  
Robert G. Schwartz, MD, Chair.

The American Academy of Thermology, Wheeling, WV 26003, USA

## GENERAL STATEMENT

This guideline was prepared by members of the American Academy Of Thermology (AAT) as a guide to aid the neuro-muscular thermologist and other interested parties. It implies a consensus of those substantially concerned with its scope and provisions. The AAT guideline may be revised or withdrawn at any time. The procedures of the AAT require that action be taken to reaffirm, revise or withdraw this guideline no later than three years from the date of publication. Suggestions for improvement of this guideline are welcome and should be sent to the executive director of the American Academy of Thermology. No part of this guideline may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

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Thermology international 2006: 5-9

## Extremity and Spine Infrared Thermographic Evaluation

### Purpose:

Infrared thermography of the extremities and spine is performed to provide an overview of the location, extent and severity of vasomotor abnormality. The thermographic evaluation can be performed from the cranium to the base of the spine (inclusive of all segments) and torso to the extremities, extended to the fingers and toes.

### Common Indications

Some of the common indications for performance of extremity and spine infrared thermographic imaging include (1-10):

- Evaluation or follow-up of patients with known or suspected vasomotor instability.
- Assessment of patients with known Chronic Regional Pain Syndrome (CRPS) types I and II, Thoracic Outlet Syndrome, Vaso-motor Headache and Barre'-Leiou Syndrome.
- Pre-procedure assessment for planning of intervention.
- Follow-up to determine technical adequacy of surgical intervention, i.e., sympathetic block, sympathectomy and/or spinal cord stimulator placement.
- Follow-up to detect improvement, progression or spread of disease, which may reflect change in condition.
- Evaluation of vasospastic disorders, rheumatic inflammation and unexpected post operative or post fracture pain.
- Evaluation of trauma, shoulder hand syndrome or other disorders associated with autonomic dysfunction.
- Mapping of the extent of vasomotor instability to guide sympathetic response generator identification.
- Mapping of the location of vasomotor instability for impairment rating purposes.
- Confirmation of diagnostic inclusion criteria for clinical diagnostic purposes.

### Contraindications and Limitations

Contraindications for extremity and spinal infrared thermographic imaging include the following:

- Presence of casts, bandages or other technical factors that preclude the ability to expose skin to a temperature equilibration environment
- An uncooperative patient.

## Guideline 1: Patient Communication and Preparation

---

- 1.1 The examining physician explains why the extremity and spinal Infrared Thermographic examination is being performed to the patient, taking care to ensure that the patient understands the necessity for each aspect of the evaluation.
- 1.2 Responds to questions and concerns about any aspect of the examination.
- 1.3 Advises the patient about risk factors and symptoms of vasomotor instability or C Fiber (sympathetic) pain, and the benefits of movement in the presence of sympathetic pain or vasomotor instability.
- 1.4 Refers specific diagnostic, treatment or prognosis questions to the patient's physician.
- 1.5 Patient should not have contact with any object if that body part is being imaged. Cotton garments may be worn to cover breast or genital areas when they are not under study.
- 1.6 Shower or bathe the morning of the test to ensure that the skin is as clean as possible; however, avoid hot water exposure to the skin for at least two hours prior to the test.
- 1.7 Avoid placing any material of any kind on the skin, such as any skin lotions, deodorants, preparations, moisturizers, liniments, topical analgesics, etc. Avoid make-up if the face is to be examined
- 1.8 Wear loose clothing to the test; avoid anything binding against the skin; avoid support undergarments or pantyhose. Do not wear jewelry, including rings if the hands are to be examined.
- 1.9 Avoid skeletal manipulation, acupuncture, physical therapy, the use of TNS units, or electrodiagnostic testing for 12 hours prior to the test. Exceptions should be noted in the record.
- 1.10 Whenever possible steroids, sympathetic blockers, vasoactive medications, opiates and transdermal patches should be avoided for 24 hours prior to testing (8-16 hours minimum). Exceptions should always be recorded in the record.
- 1.11 When Stress examinations are being performed, medications that are not medically necessary and that alter sympathetic function should be avoided for at least 24 hours prior to testing.
- 1.12 In the absence of extenuating circumstances, for original diagnostic studies sympathetic and neurolytic blocks should be avoided for 3 days prior to testing (5,11,12,13)

## Guideline 2: Patient Assessment

---

Patient assessment should be performed before infrared thermographic imaging. This includes assessment of the patient's ability to tolerate the procedure and an evaluation of any contra-indications to the procedure (4,14).

- 2.1 Obtain a complete, pertinent history by interview and/or review of the patient's medical record.

A pertinent history includes:

- a. Current medical status, especially regarding pain and vasomotor instability.
- b. Presence of any signs or symptoms of allodynia or hyperalgesia in association with sudomotor, vasomotor or other autonomic dysfunction.
- c. Relevant risk factors for vasomotor instability: prior history of RSD or CRPS, trauma, fracture, repetitive use, vibration syndrome, peripheral neuropathy, spinal pathology, radiculopathy, vasomotor headache, rheumatic illness, cardiovascular disease, hypertension, diabetes, peripheral vascular disease, coagulopathy, birth control pill use, hypothyroidism or infection.
- d. Pathology/Laboratory investigation values.
- e. Current medication or therapies
- f. Results of other thermographic or vascular studies
- g. Results of prior autonomic, sympathetic or vascular interventions

- 2.2 Complete a limited, focused, detailed or extensive physical examination, which includes assessment of all structures under study. Trophic changes, vasomotor or sudomotor changes and possible pain generators should be documented.

## Guideline 3: Examination Guidelines

---

- 3.1 Infrared thermography both measures and maps the degree and distribution of skin temperature changes. Skin temperature is largely under the control of the autonomic nervous system and bilateral symmetry is expected through out

the body. Asymmetric patterns of 1 degree centigrade or greater (that are not due to local traumatic, inflammatory or vascular disease) occur when sympathetic pathology exists.

Thermography is not a test of structure, but rather physiology and therefore when structural injury is suspected other radiographic imaging or diagnostic studies should be performed. This is important as treating other previously undiagnosed conditions can often result in resolution of symptoms.

Due to the complex nature and etiology of painful conditions associated with skin temperature asymmetry patterns, only those doctors trained in the proper techniques required to perform and interpret thermographic studies should do so. When present, the pattern of asymmetry discovered by infrared thermographic examination should guide the treating physician in determining the source or generator of the abnormality. Both response to treatment and additional testing may still be required to complete this task (15-19).

3.2 All studies should utilize infrared technology with sensitivity of at least 0.1 degree centigrade (100 units nominal expansion thermal drift; NETD) and a minimum of 100 micro-radians spatial resolution.

3.3 All studies should be performed in a laboratory where ambient temperature is controlled, free from drafts and where there is no exposure to ultraviolet rays that may result in heating. The imaging room should be comfortably cool to allow for pull-off of superficial heat from the skin (20-25 degrees centigrade is commonly used). Unless a stress exam is intentionally being done no extraneous thermal stresses should exist.

3.4 Ventilation systems should be designed to avoid direct airflow onto the patient. Carpeted flooring is preferred. Exposing the patient's feet may assist with equilibration, even with upper extremity examinations. Standard fluorescent lights are appropriate.

3.5 While a single set of images can be adequate in cases where obvious thermal asymmetry exists, repetition at specified time intervals (usually fifteen minutes, but not to exceed twenty minutes) allows for assessment of reproducibility and progressive change with increased exposure to the ambient temperature. No equilibration period is required for post block or stress test examinations.

3.6 A standard exam protocol for each segment evaluated should be used. This will frequently require multiple infrared thermographic windows with different points of focus (arm, forearm, wrist, hand, thigh, leg, foot, cervical, thoracic and lumbosacral spine). Each point of focus should include anterior, posterior, medial, lateral or oblique views. Contralateral and AP views should be equidistant and fill the image screen.

3.7 The patient's physical and mental status is assessed and monitored during the examination, with modifications made to the procedure plan according to changes in the patient's clinical status during the procedure. Also, findings are analyzed throughout the course of the examination to assure that sufficient data is provided to the physician to direct patient management and render a final diagnosis.

3.8 Appropriate infrared thermographic instrumentation, which includes real time display, electronic static image capture, storage, post capture annotation or hard copy documentation capabilities.

3.9 Evaluate the patient's physical and mental status prior to discharge (20-25).

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#### Guideline 4: Review of The Infrared Thermography Examination

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4.1 The data acquired during the extremity and spinal infrared thermographic examination should be reviewed to ensure that a complete and comprehensive evaluation has been performed and documented. Any exceptions to the routine examination protocol (i.e., study omissions or revisions) should be noted and reasons given.

4.3 Record all technical findings required to complete the final interpretation so that the measurements can be classified according to the laboratory diagnostic criteria (these criteria may be based on either published or internally generated data, but must be internally validated regardless of the source). (see Appendix)

4.4 Complete required laboratory documentation of the study.

4.5 Alert medical director or other responsible physician when immediate medical attention is indicated, based on the infrared thermographic examination findings.

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#### Guideline 5: Presentation Of Exam Findings

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5.1 Provide preliminary results as provided for by internal policy based on examination findings.

5.2 Present the record of diagnostic images and when applicable, explanations for sub-optimal examination findings to the interpreting physician for use in diagnosis and archival purposes.

- 5.3 Alert laboratory medical director or appropriate health care provider when immediate medical attention is indicated.

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### Guideline 6: Exam Time Recommendations

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High quality and accurate results are fundamental elements of the infrared thermographic examination. A combination of direct and indirect exam components is the foundation for maximizing exam quality and accuracy.

- 6.1 Indirect exam components include pre-exam procedures:
- a) obtaining previous exam data, completing pre-exam paperwork,
  - b) exam room and equipment preparation and
  - c) patient assessment, history, and positioning (Guideline 1 & 2).
- 6.2 Post exam procedures include:
- a) clean up consisting of compiling, processing, and reviewing data for preliminary and/or formal interpretation (Guidelines 3 and 4),
  - b) patient communication (Guideline 2),
  - c) examination charge and billing activities where appropriate. Recommended time: 30-40 minutes.
- 6.3 Direct exam components include equipment optimization, patient positioning throughout the exam, and the actual hands-on examination process. (Guideline 3) Recommended time: 60 minutes.

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### Guideline 7: Continuing Professional Education

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Certification is considered the standard of practice for infrared thermographic technology. It indicates an individual's competence to perform medical thermographic technology at the entry level. After achieving certification, all Registered Infrared Thermographic Technologists are expected to keep current with:

- 7.1 Advances in diagnosis and treatment of sympathetic pain syndromes with and without vasomotor instability.
- 7.2 Changes in infrared thermographic examination protocols or published laboratory diagnostic criteria.
- 7.3 Advances in thermographic technology used for the extremity and spine examinations.
- 7.4 Advances in other technology used for extremity and spinal thermographic examination.

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### Needs Assessment

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Pre-existing vasomotor tone and vasomotor capacitance plays a significant role in thermoregulation, clinical symptomatology and manifestations of systemic illness.

Thermography is the only non-invasive technology available to image and map microcirculatory arterial-venous shunting (vasomotor instability) associated with these disorders. It can play an important role in clinical diagnosis and in distinguishing between central and peripheral etiologies of thermal change. Medical Thermography can also be used to document drug induced symptoms and paradoxical responses to blocks (8,15,21,25).

Other technologies like PET scan, MRI, Spectroscopy, Electrodiagnostics or EEG do not provide the same information offered by Medical Thermal imaging (17). The clinical application of Thermography can help physicians both understand the patho-physiology associated with these changes and improve patient outcomes (6,24,26,27).

The mission and bylaws of the American Academy of Thermology support the incorporation of thermal imaging into clinical medicine. The AAT recognizes a current and ongoing need to promulgate CME in the science and methods of thermal imaging and the clinical application of heat asymmetry patterns obtained from thermal imaging among both physicians and thermal technologists.

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### Appendix

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It is recommended that published or internally generated diagnostic criteria should be validated for each thermography system used. When validating infrared thermographic diagnostic criteria, it is important to realize that equipment, operator and interpretation variability is inherent to this process.

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Address for correspondence:

Robert G. Schwartz, MD,  
Piedmont Physical Medicine & Rehabilitation, P.A  
Chair, Practice Guidelines Committee,  
American Academy of Thermology,  
317 St. Francis Drive, Suite 350,  
Greenville, SC, 29601  
RGSHEAL@aol.com

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# Quality Assurance of Thermal Imaging Systems in Medicine

P. Plassmann, E.F.J. Ring, C.D. Jones

Medical Imaging Research Group, School of Computing, University of Glamorgan, Pontypridd CF37 1DL U.K.

## SUMMARY

Standardisation protocols are of importance for reliable use of infrared thermal imaging in medicine. Infrared camera systems are now of higher performance with improved reliability, which can lead the operator to assume that the system is continually giving optimal performance. This paper describes some simple procedures that can be used by a thermographer to monitor performance, and determine the calibration offset. These are: a start-up drift test, long term drift test, offset variation, image non-uniformity, and thermal flooding effect.

It is important to know the length of time from switching the power on, to reaching radiometric stability, which may differ from the manufacturer's general guidelines. Knowledge of the camera's function is important for reliable follow-up imaging in the clinical environment, the electronic exchange of images with other centres, and the routine monitoring of infrared systems being used continuously, as in mass fever screening in airports etc. These tests are not intended to replace those performed by manufacturers or calibration laboratories, but can provide valuable information on both short and long-term camera performance.

**Key words:** quality assurance, thermal imaging, monitoring performance

## QUALITÄTSSICHERUNG BEI MEDIZINISCHEN THERMOGRAPHIESYSTEMEN

Standardisierte Durchführungsanleitungen haben für den zuverlässigen Einsatz der Infrarotthermographie in der Medizin großer Bedeutung. Infrarot Kamerassysteme bieten jetzt einen höheren Funktionsumfang mit verbesserter Zuverlässigkeit, sodass der Anwender annehmen darf, dass das Gerät kontinuierlich eine optimale Funktion gewährleistet. Im Folgenden werden einige einfache Maßnahmen beschrieben, die dem Thermographieanwender eine Überwachung des Funktionsumfangs und die Erkennung von Eichungsfehlern erlaubt. Im Einzelnen sind das Tests für Messungenauigkeiten nach Einschalten und bei langdauernden Betrieb des Systems, ein Test über die Messfehler in einem bestimmten Temperaturbereich, ein Test zur Bestimmung der Bildgleichförmigkeit, und zum thermischen Flut-effekt.

Die Kenntnis der Zeit die nach dem Einschalten der Kamera bis zum Erreichen ihrer radiometrischen Stabilität vergeht, hat Bedeutung und kann sich von den Angaben des Kameraerzeugers unterscheiden. Wichtig ist das Wissen um das funktionelle Verhalten der Kamera ist für zuverlässige Kontrolluntersuchungen im klinischen Umfeld, für den elektronischen Austausch von Wärmebildern zwischen verschiedenen Zentren und in der Routine-Überprüfung von Infrarotsystemen, die ununterbrochen verwendet werden wie z.B. für das Screening nach Fieberpatienten auf Flughäfen. Diese Tests sollen jene, die vom Kameraerzeuger oder Eichungseinrichtungen durchgeführt werden, keinesfalls ersetzen. Sie können jedoch wertvolle Informationen über den Funktionsumfang im Kurz- und Langzeitbetrieb liefern.

**Schlüsselwörter:** Qualitätssicherung, Thermographie, Leistungsüberwachung

Thermology international 2006, 16: 10-15

## Introduction

Infrared imaging technology has significantly advanced over the past three decades. More agreement in standardisation of technique in medicine has been achieved, with careful attention to the preparation of the patient, the environment, use of the imaging system and image processing (1).

Higher thermal and spatial resolution can now be achieved from less expensive and more reliable thermal imaging systems than in the past. Furthermore, as the focal plane array technology has improved, a wider choice of uncooled bolometers has emerged that can be used for clinical thermography. While high quality performance is given by cooled detector systems, the cost of replacing the cooling unit, with a finite life, has resulted in more uncooled cameras being supplied for medical applications, due to their low maintenance.

Many manufacturers supply thermal imaging systems for medical use with advice that the camera should be returned to the manufacturer, or supplier on a regular basis. In practice, this is not always followed. The result is that a slow

decline in performance over more than one year is likely to occur, which may be undetected by the operator. Furthermore, calibration of the camera for temperature measurement may be satisfactory at the time it is installed, but may have drifted over time, if the maintenance schedule has not been carried out. Many practitioners of medical thermography are also unaware that according to manufacturers' specifications even after calibration the vast majority of infrared cameras on the market today are accurate to  $\pm 2^\circ\text{C}$  only. This  $4^\circ\text{C}$  range of uncertainty amounts to approximately 20% of the normal human temperature range and can thus invalidate many clinical investigations if not accommodated or compensated in the measurement protocol.

This paper describes some simple procedures that, with a modest outlay, can be used by an operator of thermal imaging systems on a regular basis. By monitoring the performance of the camera at regular intervals, changes are detected, and alert the operator of the need for maintenance or servicing.

## Test procedures

Five test procedures are described with example results obtained from testing four thermal imaging cameras used for medical thermography. If a number of cameras are in use in one center, it is preferable to use an adjustable thermal reference source to carry out these tests. A number of publications describing the construction of a “Black Body Reference” can be found, and several commercial sources are obtainable for use with thermal imagers. Medical applications, however, require a reference source that operates between 25 and 40°C maximum to obtain a reliable calibration at the temperature range of human skin. Since this

equipment can be both expensive and unavailable for regular use in a clinical environment, an inexpensive alternative is described. All 5 procedures outlined here can be performed using water and occasionally ice as reference surfaces, both of which are very good thermal radiators.

Figure 1 illustrates the fact that the emissivity of water and ice in the commonly used 3-5µm and 9-12 µm bands are very similar (within a range of 0.05). A container with a capacity of at least one litre, having a diameter of some 15cms is suitable for this purpose.

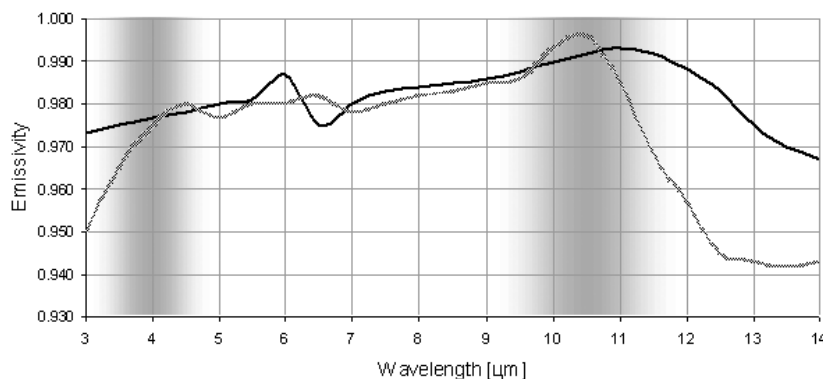


Figure 1 Emissivity of ice (grey line) and water (black line) in the commonly used IR wavelengths of 3-5µm and 9-12µm (shaded areas). Figure based on data from the MODIS UCSB emissivity library (NASA/CFSC/SBRC): <http://www.icess.ucsb.edu/modis/EMIS/html/em.html> (last accessed 3 January 2006)

Table 1: Start-up Drift test

| Problem Severity                 | High. Error up to several °C.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Consequences                     | Can introduce severe systematical error into measurements, e.g. if the measurement protocol stipulates that members of a control group are measured 10 minutes after camera start and the patient group 2 hours later, results may show a significant statistical difference of several °C between both groups as a result of start-up drift.                                                                                                                                                                                                                                                                        |
| Cause                            | All IR cameras include control circuitry to stabilise the camera electronics. These circuits, although temperature compensated, need time to settle and adjust to changing conditions, e.g. camera electronics warming-up and sensor array cooling-down after switching on.                                                                                                                                                                                                                                                                                                                                          |
| Materials required / preparation | Container of ice & water. Keep room temperature stable at usual examination setting. If possible pre-set the camera to an emissivity of 0.98 (for 3-5µm cameras) or 0.99 (for 9-12µm cameras) respectively, a distance of 1m and a narrow temperature range around zero °C (e.g. -5 to +5).<br>Switch camera off and allow it to acclimatise to room temperature for at least one hour.                                                                                                                                                                                                                              |
| Method                           | After the camera has acclimatised fill a small container with equal amounts of cold water and ice cubes. Insulate the container with towels so that about a quarter of the ice will survive for about 2 hours. Point the camera perpendicular towards the ice/water surface from a distance of about 1 metre.<br>Switch the camera on and (if you couldn't do so before) set emissivity, distance and temperature range. Take a baseline image of the ice water surface as soon as possible. Continue taking images every 5 minutes during the first 30 minutes, every 10 minutes after that for a total of 2 hours. |

Example

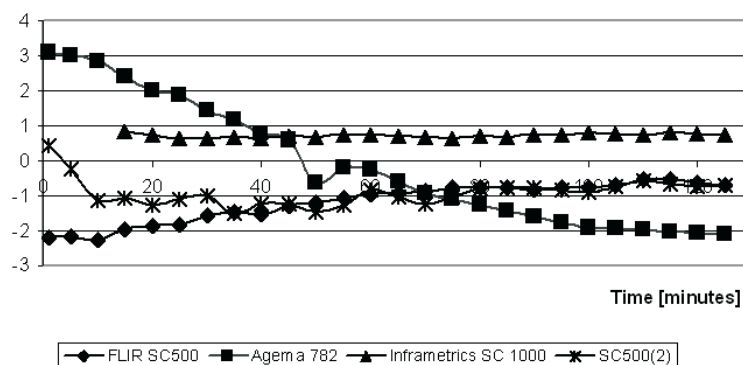


Figure 2: Start-up drift [°C] of 4 IR cameras over 2 hours

| Table 2: Long-Term Drift ( days/months) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Problem Severity                        | Medium                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Consequences                            | Long-term drift can have an effect on longitudinal studies, e.g. a follow-up of a patient cohort over time.                                                                                                                                                                                                                                                                                                                                                          |
| Cause                                   | The ageing process of electronic components inside the camera leads to slow changes in signal amplifiers, internal temperature references and other control circuitry.                                                                                                                                                                                                                                                                                               |
| Materials required / preparation        | Container of ice, some water. Every time this experiment is performed adjust the room temperature to exactly the same value. Switch the camera on and allow it to settle (about 1 to 2 hours, use the results of the start-up drift experiment in Table 1 above). Set the camera to an emissivity of 0.98 (for 3-5 $\mu$ m cameras) or 0.99 (for 9-12 $\mu$ m cameras) respectively, a distance of 1m and a narrow temperature range around zero °C (e.g. -5 to +5). |
| Experimental method                     | After the camera has settled fill a small container/bucket with equal amounts of cold water and ice cubes. Point the camera perpendicular towards the ice/water surface from a distance of about 1 metre. Stir well. Take a single image of the ice water surface.                                                                                                                                                                                                   |
| Analysis                                | In the captured image define a statistics area of at least 10x10 pixels in size and calculate the average temperature for this area. Over time you can build a drift control chart for your camera. Once the drift exceeds manufacturer's specifications it is time to have it calibrated again.                                                                                                                                                                     |

| Table 3: Offset Variation over Temperature Measurement Range |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Problem Severity                                             | Medium. Up to 1 °C over the normal medical range between 15 and 40 °C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Consequences                                                 | Whereas the first two experiments expose errors that are consequential when comparing measurements taken from a series of images (inter-image offset drift), this effect reveals errors within individual images (intra-image offset variation). Drift affects the image as a whole and temperature differences intra-image are therefore not affected. Offset variation affects your confidence to say: "in this image point A is 0.5°C warmer than point B".                                                                                                                                                                                                                                                                                                                                                                                                        |
| Cause                                                        | Different amplifications of the camera sensor array readout for different temperatures.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Materials required / preparation                             | Container of warm water at about 40°C. Calibrated thermometer, ideally a platinum resistance thermometer (PRT) with calibration table demonstrably traceable to the international temperature scale of 1990 (ITS90). Alternatively use a precise mercury thermometer.<br>Switch the camera on and allow it to settle (about 1 to 2 hours, use the results of the start-up drift experiment in Table 1). Set the camera to an emissivity of 0.98 (for 3-5 $\mu$ m cameras) or 0.99 (for 9-12 $\mu$ m cameras) respectively, a distance of 1 m and a temperature range between approximately 20 to 40°C. Keep these settings throughout the experiment.                                                                                                                                                                                                                 |
| Method                                                       | After the camera has settled fill a small container with about 1 to 3 litres of warm water at about 40°C. Use the thermometer to stir it for at least 1 minute, thus producing a homogeneous temperature distribution throughout the water body and allowing the thermometer to assume the water temperature as well. Point the camera perpendicular towards the water surface from a distance of 1 meter, take an image and obtain a thermometer readout. Make a note of the image file name and the corresponding thermometer readout. While the water is cooling, take images and thermometer readings every 0.5°C or so. Always stir the water for 1 minute before taking a reading/image. You may find that adding small amounts of cold tap water is beneficial to speed-up the cooling, especially once the temperature is close to or below room temperature. |
| Analysis                                                     | In each of the captured images define a statistics area of at least 10x10 pixels in size and calculate the average temperature for this area. Plot this temperature against the corresponding thermometer readout or plot the difference between both against the thermometer readout as shown in figure 3.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

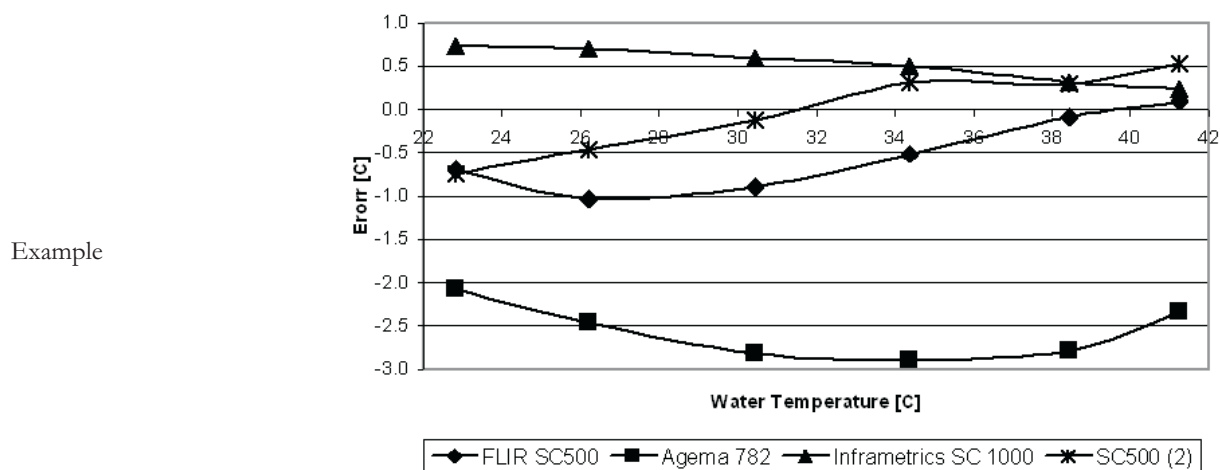


Figure 3: Offset variation of 4 cameras over a clinically relevant temperature range

| Table 4: Image non-uniformity    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Problem Severity                 | Small in cameras with good lens systems, moderate in others.                                                                                                                                                                                                                                                                                                                                                                                                          |
| Consequences                     | Affects inter-image measurements, for example in timed series. Affects absolute temperature readouts in individual images                                                                                                                                                                                                                                                                                                                                             |
| Cause                            | Flooding is caused by the introduction of a warm object into the observed scene. Radiation from the warm object “floods” the entire image area, making other objects appear to be warmer than they are. The underlying cause for this effect is insufficiency in the optical path of the camera, e.g. stray radiation.                                                                                                                                                |
| Materials required / preparation | Container of water at room temperature as a reference. Container with warm water at approximately 40°C. Allow the camera to settle (about 1 to 2 hours, use the results of the start-up drift experiment in Table 1 above). Set the camera to an emissivity of 0.98 (for 3-5µm cameras) or 0.99 (for 9-12µm cameras) respectively, a distance of 1m and an appropriate temperature range to include both the room temperature water bath and the warm water container |
| Experimental method              | After the camera has settled, stir the water container for 30 seconds, to produce a homogeneous temperature distribution at the surface. Point the camera perpendicular towards the water surface from a distance of about 1 metre and take an image. Immediately after that introduce the hot container into the scene and take a second image of both room temperature water bucket and the warm container.                                                         |
| Analysis                         | In each of the captured images define a statistics area of at least 10x10 pixels in size and calculate the average temperature for this area. The apparent difference between both average temperatures is a measure for the susceptibility of the camera to flooding.                                                                                                                                                                                                |

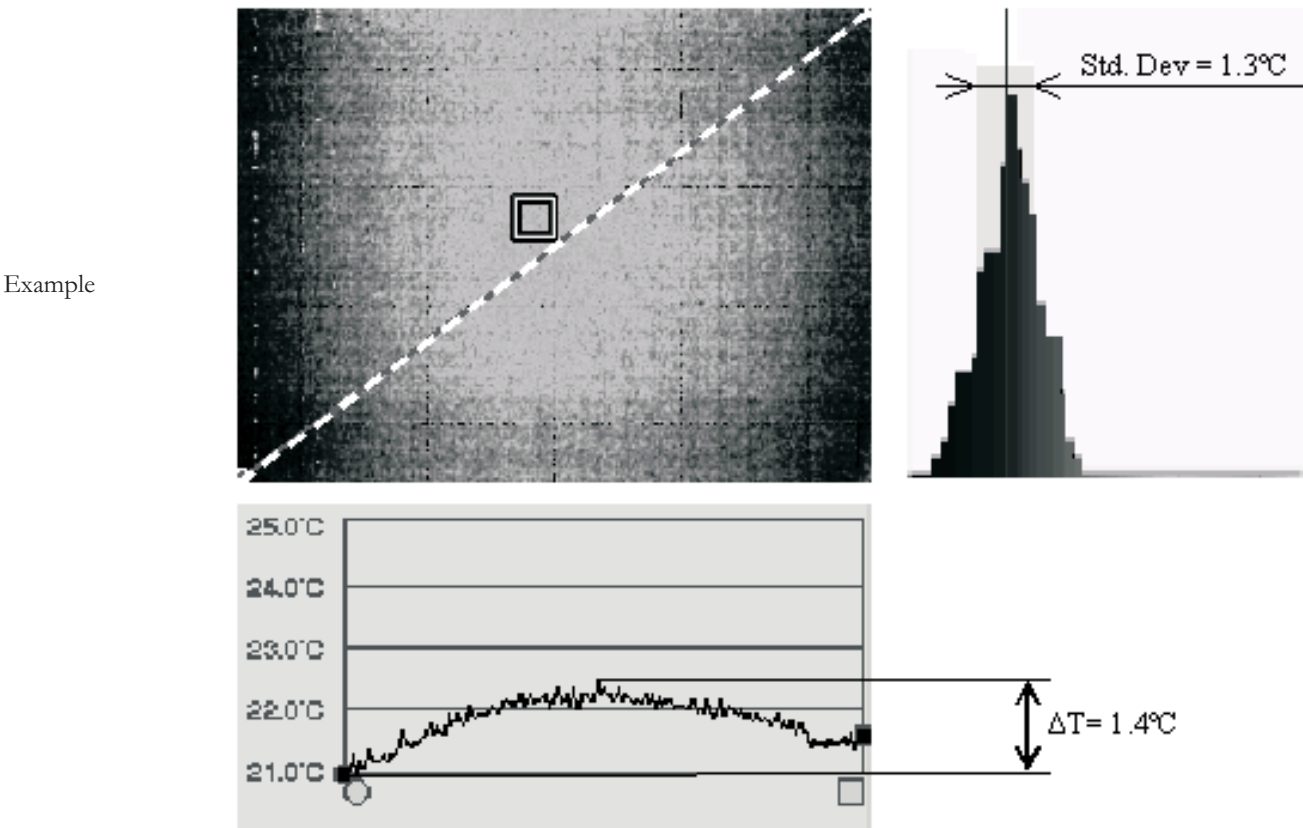
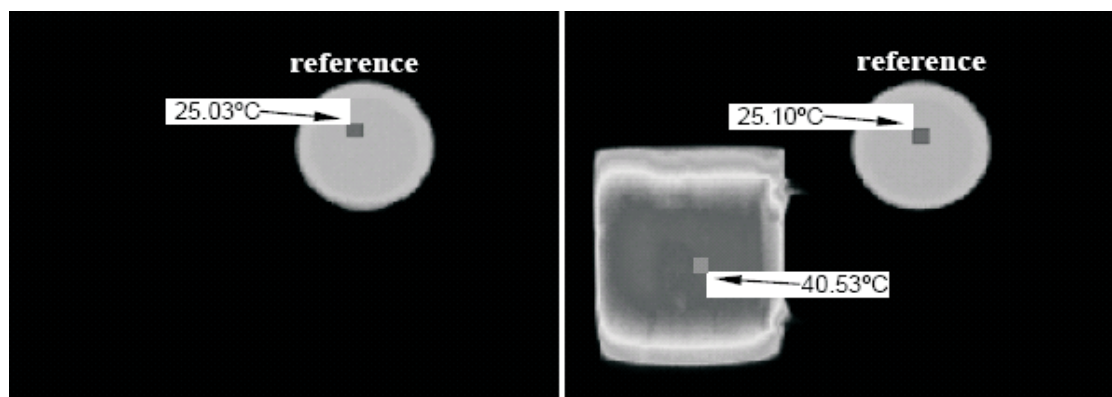


Figure 5: Apparent increase in temperature of a reference source by introduction of a warm object into the camera’s field of view

Table 5: Thermal Flooding Effects

|                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Problem Severity                 | Small in cameras with good lens systems, moderate in others.                                                                                                                                                                                                                                                                                                                                                                                                           |
| Consequences                     | Affects inter-image measurements, for example in timed series. Affects absolute temperature readouts in individual images.                                                                                                                                                                                                                                                                                                                                             |
| Cause                            | Flooding is caused by the introduction of a warm object into the observed scene. Radiation from the warm object “floods” the entire image area, making other objects appear to be warmer than they are. The underlying cause for this effect is insufficiency in the optical path of the camera, e.g. stray radiation.                                                                                                                                                 |
| Materials required / preparation | Container of water at room temperature as a reference. Container with warm water at approximately 40°C. Allow the camera to settle (about 1 to 2 hours, use the results of the start-up drift experiment in Table 1 above). Set the camera to an emissivity of 0.98 (for 3-5µm cameras) or 0.99 (for 9-12µm cameras) respectively, a distance of 1m and an appropriate temperature range to include both the room temperature water bath and the warm water container. |
| Experimental method              | After the camera has settled, stir the water container for 30 seconds, to produce a homogeneous temperature distribution at the surface. Point the camera perpendicular towards the water surface from a distance of about 1 metre and take an image. Immediately after that introduce the hot container into the scene and take a second image of both room temperature water bucket and the warm container.                                                          |
| Analysis                         | In each of the captured images define a statistics area of at least 10x10 pixels in size and calculate the average temperature for this area. The apparent difference between both average temperatures is a measure for the susceptibility of the camera to flooding.                                                                                                                                                                                                 |



**Figure 5:** Apparent increase in temperature of a reference source by introduction of a warm object into the camera's field of view

## Discussion

The simple laboratory procedures described here are not intended to replace the established calibration procedures used by manufacturers which include the determination of important data used in the definition of optical performance of a thermal imager. One of these is, for example, obtained by measuring the minimal resolvable temperature difference (MRTD) sometime referred to as ‘thermal resolution’. This test is needed to determine the probability of detecting a small temperature difference as defined for the particular application (e.g. military, civil engineering, medical etc.) This is a parameter that describes the ability of the imager for the human detection in the image of low contrast details of the target subject (2,3). A simple spatial resolution chart has been produced by the authors that is suitable for performing an assessment of spatial resolution from a warm target. This heated plate, with black bars and spots of differing sizes has been described in a paper comparing different thermal imaging systems (4,5). In practice the authors have experienced problems with a particular un-cooled focal plane array camera where the detector has progressively become less efficient over a period of one year. Without performing some of the test procedures describe above on a regular basis it would have been impossible to detect the imager's degrading performance and to

maintain acceptable quality assurance over time. Using the water substitute for a thermal reference body, is a low cost option, but still requires some time to be set aside to perform the tests. The high performance of modern infrared imaging systems has raised the expectations of its operators, and the manufacturers guidebooks do not currently give such guidance for on-site monitoring procedures. Furthermore, some older systems with an analogue output are connected to a computer through an analogue to digital converter. Here, both the settings for the converter and its electronic performance can add a further dimension to the problem of drift and inaccuracy. Simple performance tests will show any changes in the whole thermal imaging system including the software and hardware involved in image capture and analysis. The standardisation of thermal imaging techniques in medicine is of great importance (6,7). It has been shown that the technique can be made more reproducible when attention to standardisation and optimisation of image capture is applied. A series of standard views for the human body have been devised so that images from difference centers across the world may be combined in the construction of a normal reference thermographic image database (8). Apart from the essentials of technique, it is also a requirement that the thermal imaging systems used

are optimised and cross-calibrated. Digital imaging has a strong part to play in the future of hospital medicine, and loss-less electronic transfer of digital images will increasingly be required. Thermal imaging will be included in this, making reliable technique and regular quality assurance an important issue in such applications. In certain applications such as mass fever detection, as used during the SARS crisis in 2004/5, thermal cameras in an airport may be in continuous operation for many hours every day. Under such conditions, it is essential to apply routine tests, and where necessary be able to replace a camera at short notice if its characteristics and performance is shown to be deteriorating. In medical and human applications for thermal imaging the temperature range is relatively small. Most cameras are, however, designed for higher or lower temperatures over a wider range than the human skin temperatures which are often less than 10°C and rarely more than 20°C in range at temperatures below 36°C. An increase in maximum temperature to >38.0°C in facial temperature as described in fever is a significant percentage of the total temperature ranges of the system, hence the need for regular quality checks.

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*Address for correspondence*

Prof Francis Ring

Medical Imaging Research Group, School of Computing,  
University of Glamorgan. Pontypridd CF37 1DL U.K

Email efring@glam.ac.uk

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# Thermology 2005 – a computer-assisted literature survey

Kurt Ammer

Austrian Society of Thermology, Vienna, Austria  
Medical Imaging Group, School of Computing, University of Glamorgan, Pontypridd, U.K.

## SUMMARY

A comprehensive literature search in multiple databases yielded 2926 hits for the search terms thermometry and thermography. Therefore, this literature survey is based only on publications listed in the databases Embase and Medline between 1.1.2005 and 31.12.2005 and matching with one of the following 8 keywords: “thermography”, “thermology”, “thermal imaging”, “infrared imaging”, “thermometry”, “temperature measurement”, “skin temperature” and “core temperature”. After restricting the number of hits by combining the search terms with the key word “human”, 735 references were obtained. Thermal imaging was the main subject of 169 papers, all other publications were related to temperature measurements in humans. This literature survey has demonstrated a continuously high interest in both temperature related physiology and temperature related treatment mainly hypothermia for patients in a critical state of health.

**Key words:** literature search, thermology, temperature measurement

## THERMOLOGIE 2005- EINE COMPUTERGESTÜTZTE LITERATURSUCHE

Eine umfassende Literatursuche in mehreren Datenbanken erbrachte für die Suchbegriffe Thermometrie und Thermographie 2926 Treffer. Deshalb beruht diese Literatursuche nur auf Publikationen, die zwischen 1.1.2005 und 31.12.2005 in die Datenbanken Embase und Medline aufgenommen worden waren und zumindest eines der folgenden 8 Suchbegriffe enthielten: “Thermographie”, “Thermologie”, “thermal imaging”, “infrared imaging”, “Thermometrie”, “Temperaturmessung”, “Hauttemperatur” und “Kerntemperatur”. Nachdem die Zahl der Treffer durch die Kombination der Suchbegriffe mit dem Schlüsselwort “Mensch” eingeschränkt worden war, fanden sich 735 Zitate. Thermographie war das Thema von 169 Artikeln, alle anderen Publikationen berichteten über Temperaturmessungen beim Menschen. Diese Literatursuche zeigte sowohl für die Temperatur abhängige Physiologie als auch an temperaturabhängigen Behandlungsmethoden, hauptsächlich der therapeutischen Hypothermie bei Patienten im kritischen Gesundheitszuständen, ein anhaltend hohes Interesse.

**Schlüsselwörter:** Literatursuche, Thermologie, Temperaturmessung

Thermology international 2006; 16: 16-37

## Introduction

The 2005 literature survey on thermology is the 17<sup>th</sup> in line of a series that started in 1989 and which was originally intended to continue the International Bibliography of Medical Thermology compiled by Margaret and Thomas Bradford Abernathy in 1987 (1). However, in recent years papers on methods of temperature measurement or heat applications in fields outside of medicine and biology were included in this annual review (2,3). In that sense, this 2005 literature survey of papers dedicated to thermology, will provide the reader with a broad overview of the current role of temperature measurements in medicine and in basic and applied sciences related to medicine. The database of this report has been constructed from the hits of a search in the medical databases Medline and Embase.

In addition, abstracts from conferences in Zakopane, Baton Rouge, Vienna and Teddington have been included in the database of this report.

## Methods

A literature search was performed in the medical databases Journals@Ovid, British Nursing Index CINAHL, EMBASE, International Bibliography of the Social Sciences INSPEC, Mantis, Ovid MEDLINE(R) In-Process, Other Non-Indexed Citations, Ovid MEDLINE(R), and

SPORTDiscus using the following key words: “thermography”, “thermology”, “thermal imaging”, “thermometry”, “temperature measurement”, “skin temperature”, “core temperature”. The time period selected was between 01.01.2005 and 31.12.2005.

This search yielded 3572 publications and after removal of doubles 2926 hits remained in the database. Due to space restrictions, this amount of citations cannot be displayed in this article. Therefore, the literature search was repeated in the databases EMBASE and MEDLINE only, using the same key words as above, but restricted to the combination with the search term “human”. The lists of hits in all databases were checked for doubles and identified double hits were excluded.

However, all references from the first search in multiple databases will be included in the database of references for thermal imaging and temperature measurement available at the web site of the Medical Imaging Research Group, School of Computing, University of Glamorgan, at [www.medimaging.org](http://www.medimaging.org). The full list of all references will be also available from the author on request.

The database from the second search was analysed to show the origin of authors, the language and the journal and

issue number of publication. Papers were allocated with respect to the topic of the publication into medical and non medical publications. Non medical papers were further classified into basic sciences, applied sciences and biology.

## Results

A total of 735 publications were found from the two databases, which yielded 423 hits in EMBASE and 314 in MEDLINE). 63 abstracts from 4 conferences on Medical Thermology completed the database with 800 citations in total.

169 publications appeared with the key words “thermography” or thermology or “thermal imaging” or “infrared imaging” 32 papers were related to temperature measurements in humans and the term “thermometry” yielded 237 hits in combination with the key words “human” and “publication year 2005”. Finally, searching with the terms “core temperature” or “skin temperature” restricted to “humans” and “publication year: 2005” found 539 citations. Combining the searches with all terms resulted in a total of 735 citations after exclusion of doubles

Only 3.1 percent of all papers of this database were not published in English. German, Japanese and Russian were the next frequently used language for publication (each 5 papers), followed by French and Polish (each 3 papers), Chinese, Spanish, Norwegian and Danish (each 1 paper).

599 institutes in 43 countries (Figure 1) were involved in temperature measurements. 17,7 % of these research facilities were located in the United States and 55% of institutions are situated in European countries.

In total, 456 journals published papers on temperature related matters. Due to included abstracts, the highest number of publications, i.e. 76 were found in Thermology international. 6 journals published 10 or more papers. Top rank were the American Journal of Physiology together with International Journal of Hyperthermia. (each 15 papers) Next were the Journal of Applied Physiology (12 papers), Aviation Space & Environmental Medicine (11 papers), Physics in Medicine & Biology and Zhongguo Linchuang Kangfu (each 10 papers).

73 publications reported clinical trials which were performed either in a controlled or randomised controlled study design. 22 papers were dedicated to standardisation and evaluation studies of equipment (290, 304, 305, 307, 336, 362, 375, 410, 494, 495, 496, 504, 574, 581, 598, 604, 606, 648, 699, 713, 716, 790). The technology of temperature measuring devices was discussed in 38 papers (130, 131, 140, 141, 153, 179, 180, 237, 245, 261, 262, 265, 269, 274, 279, 280, 300, 310, 333, 338, 341, 342, 343, 344, 387, 477, 479, 497, 510, 522, 561, 566, 622, 689, 705, 717, 719, 779).

In 15 animal experiments (55, 112, 196, 218, 315, 326, 366, 379, 400, 502, 505, 523, 567, 640, 684) temperature measurements were performed. 70 review papers were related to medicine, 18 case reports were published. 7 editorials and 61 letters or comments also dealt with temperature measurement.

In total 3035 authors were found. Of these, 117 authors appeared with two papers, 46 authors with three papers. 12 authors published 4 papers and 6 others had 5 contributions to temperature measurement. 4 scientists had six and 3 seven papers. K. Ammer had 8 and B. Wiecek 9 publications. Most of these high numbers of publications by single authors is based on inclusion of meeting abstracts into the database.

## Medical publications

Medline and Embase allocated their listed citations to distinct fields of medicine. For all other sources the appropriate allocations were performed by the author.

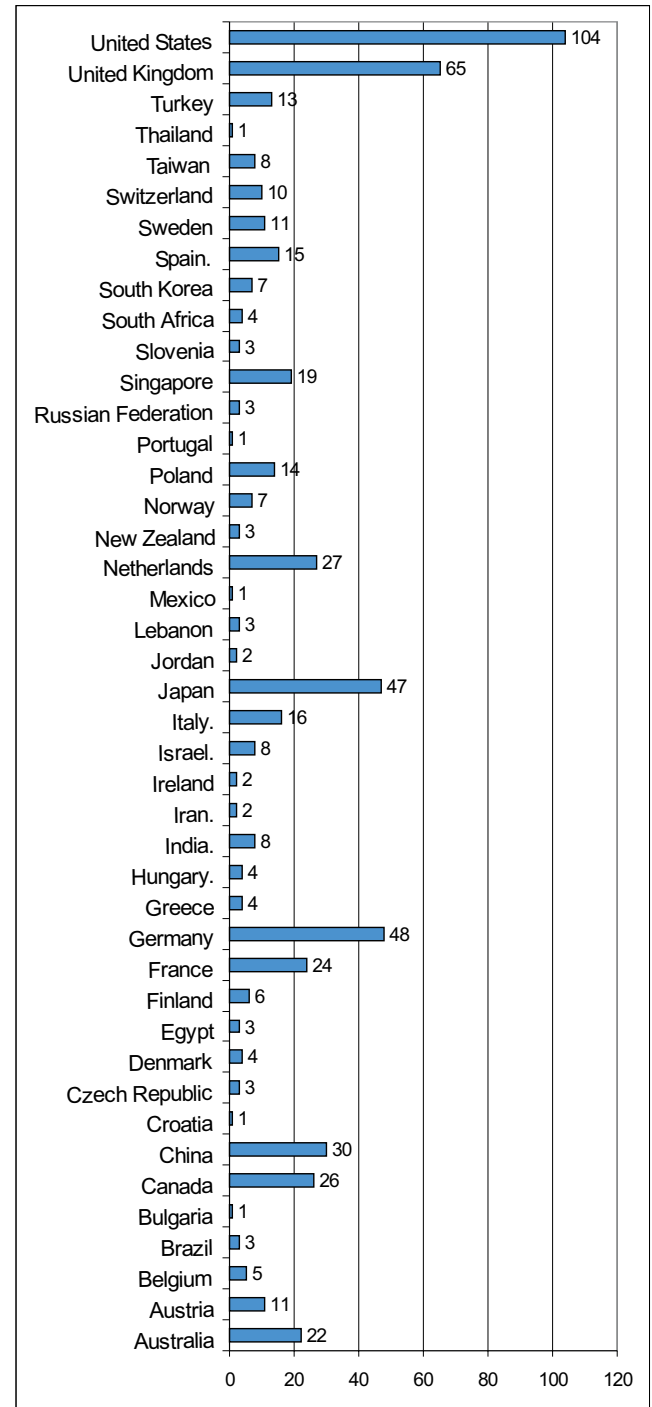


Figure 1,  
Institutions which published temperature research

Table 1 shows the allocations to fields of medicine. Physiology, Physical Medicine, Rehabilitation and Sports Medicine and were the most frequent allocated specialities of medicine. Drug treatment, neurology, dermatology and anaesthesiology were the next in frequency of allocation. Occupational medicine, angiology, pediatrics and surgery were other medical fields related to temperature measurements.

## Non medical publications

### Basic Sciences

A small number of papers were related to Physics (5, 192, 484, 638), Chemistry (75, 149, 175, 245, 592, 799) and Biochemistry (144, 249, 270, 367, 461, 620, 728, 741).

Table 1  
Papers allocated to medical fields

| Reference                                                  | Field                                                                                                                                                                                                                                                                                                                    |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Anaesthesiology, Emergency Medicine and Intensive Care     | 4,64, 66, 67, 84, 107, 113,126, 137, 163, 173, 174, 180, 181, 223, 225, 229, 230, 232, 261,274, 275,286, 293, 308,321,345, 349, 414, 425, 464, 469, 419, 500, 524, 538, 542, 545, 549, 556, 558, 565, 596,598,600,606, 612,621,658,660,670,671,707,710,724,729,772,790                                                   |
| Anatomy and Histology General Pathology and Histopathology | 120,239, 247,367                                                                                                                                                                                                                                                                                                         |
| Andrology, Urology and Reproduction                        | 50, 188, 204, 206,289,302,312, 350,368,499,585,619,627,632,692,720,789                                                                                                                                                                                                                                                   |
| Angiology                                                  | 38, 43,65, 108, 125, 129, 132, 133, 146, 148, 162, 202, 203, 235, 253, 257, 270, 279, 280, 290, 295, 313, 317, 371, 452, 491, 507, 576, 588, 616, 633, 664, 672, 686, 687, 688, 696, 739, 750, 754, 770, 776, 791,798                                                                                                    |
| Arthritis and Rheumatism                                   | 18, 141, 230, 231, 314, 318,415, 446, 449,457,536,537,544,572,631,                                                                                                                                                                                                                                                       |
| Cancer                                                     | 7,9, 46, 210,289,302,322,353,430,517,521,547,562,601,703,712,725,782                                                                                                                                                                                                                                                     |
| Cardiovascular Diseases and Cardiovascular Surgery         | 34, 54, 83, 96, 142, 160, 275,297,299,318, 325, 349,360, 362,365, 394, 466, 469, 476, 493, 519, 520, 539,545,550,566,584,611,624,626,652,669,679,714,715,730,763                                                                                                                                                         |
| Chest Diseases, Thoracic Surgery and Tuberculosis          | 24, 49, 118, 172, 232, 273, 277, 282,399,404, 406, 424, 447, 494, 522, 535, 598, 617, 621, 717, 719, 746, 756                                                                                                                                                                                                            |
| Complementary Medicine                                     | 47, 110, 151, 209,266,391,392, 427,492,502,578,615,672,765,768,782                                                                                                                                                                                                                                                       |
| Dental Medicine                                            | 20, 80, 85,243,389,390,487,653,727,800                                                                                                                                                                                                                                                                                   |
| Dermatology and Venereology                                | 8,22,23, 44, 74, 87, 135,154, 161, 172, 183, 185, 186, 188, 226, 278, 279, 280,285, 296,307,335, 353, 355,357,380, 385, 450, 451, 455, 475, 485, 560, 565, 571, 591, 593, 596, 597, 602, 620, 629, 630, 690, 697, 722,780,783,784,785,786,793                                                                            |
| Endocrinology and Nephrology                               | 14, 15,16,17, 24,41, 45,61, 62, 76, 89, 90, 119, 133, 136, 164, 216,258, 288, 327, 433, 448, 455, 457, 472,527,539,542,595,668,688,702,737,754                                                                                                                                                                           |
| Forensic Medicine                                          | 708                                                                                                                                                                                                                                                                                                                      |
| Gastroenterology                                           | 322, 517,547,726                                                                                                                                                                                                                                                                                                         |
| General Surgery                                            | 11, 43, 52, 101, 106, 124, 126, 150, 189, 248, 260, 284,285,334, 378,396,498, 523, 583, 587, 607, 609,625,648,660,742,797,                                                                                                                                                                                               |
| Genetics, Microbiology and Infectiive Diseases             | 112, 147, 179, 189, 351, 354,397,398,402,477,481,503,562,568,599,617,666,678,709,753                                                                                                                                                                                                                                     |
| Gerontology and Geriatrics                                 | 30, 93, 131, 187, 196, 224, 251, 252,383,460,468,509,676,677                                                                                                                                                                                                                                                             |
| Immunology, Cell Receptors                                 | 569,595,673,723,764,769,781,795                                                                                                                                                                                                                                                                                          |
| Medical Education                                          | 28, 29, 99,                                                                                                                                                                                                                                                                                                              |
| Neurology , Neurosurgery and Neuroscience                  | 32, 37,46, 73, 78, 88, 91, 113, 119, 128, 152, 153, 154, 159, 183, 184, 199, 200, 205, 207, 211, 212, 221, 228,251, 252, 291, 331, 359, 361, 377, 408, 415, 453, 458, 471, 485, 508, 511, 512, 514, 516, 561, 564, 586, 605, 623, 626, 639, 655, 661, 667, 679, 695, 697, 698, 700, 701, 711, 729, 735, 755, 781,787,794 |
| Obstetrics, Gynaecology and Breast Disease                 | 7, 9,21, 36,38,43,59, 81, 97, 102, 117, 143, 190, 195, 254, 264,272,356, 370, 393, 438, 467, 540, 591, 640,698,712, 792                                                                                                                                                                                                  |

## Applied Sciences

5 papers dealt with Climatology & Meteorology (35, 339, 641, 678,721). Computing and Modeling (197, 286, 298, 315, 323, 352, 366, 386, 407, 473, 474, 506, 518, 610, 630, 638, 767,789,791,795) was the topic 20 papers.

Engineering, Bioengineering and Medical Instrumentation (6, 26, 27,33,54,57,59, 61, 70, 83, 97, 103,108,109,110, 115, 120, 121, 130, 131, 134, 138, 140, 142, 146, 151, 153, 160, 166, 168, 173, 174, 177, 209,210, 211, 216, 221,241, 247, 258, 266, 269,277, 282, 289, 309, 329, 368, 373, 374, 377, 403, 411, 448, 482, 573, 577, 636, 639, 648, 692, 693, 697, 699, 746) had the highest number of hits in the allocation applied sciences.

Table 1 continued

|                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Occupational Health and Industrial Medicine           | 5,13,48,58, 60, 72, 101, 135, 156, 170, 187, 203, 250, 271,284,290,295,301, 306,328,330, 347, 348, 363, 372, 381, 382,384, 401, 418, 419, 421, 432, 434, 513, 514, 541, 663, 680, 681, 736, 739, 775, 776, 798                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Ophthalmology                                         | 57, 115, 234, 263,309, 395,410,546,554,555,590,635,643,644,777                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Orthopedic Surgery                                    | 177, 182, 256, 291,439, 489,544,563,603,645,665,741                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Otorhinolaryngology                                   | 53,386,420,435,530,532,593,656,751,759                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Pharmacology, Toxicology and Drug Therapy             | 22, 23,63,66, 108, 138, 148, 194, 208, 218, 224,264, 278,285,296, 317,318,321,335, 345, 355, 366, 379, 436, 441, 442, 459, 461, 464, 470, 471, 480, 486, 488, 502, 524, 526, 527, 529, 530, 534, 551, 559, 567, 568, 570, 578, 582, 593, 599, 614, 620, 655, 656, 657, 690, 700, 701, 709, 718,762,771,772,774,777,779, 795,796.                                                                                                                                                                                                                                                                                                                                                                                             |
| Pediatrics and Pediatric Surgery                      | 51, 67, 107, 114,193, 200, 208, 227, 261,282,284, 333, 346, 360, 365, 404, 409, 447, 463, 465, 470, 477, 480,496,589,600,606,622,636,642,654,667,671,684,685,706,738,759,760, 761,762,778                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Psychology and Psychiatry                             | 19, 79, 137, 316, 340,437,456,460,478,490,525,534,635,764                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Physical Medicine and Rehabilitation, Sports Medicine | 10, 25, 31,36,41,43,45,56,69, 70, 71, 82, 86, 95, 111, 122, 124, 139, 158, 165, 167, 178, 198, 213, 214, 215, 219, 233, 238, 240, 255, 256, 276, 278, 281,291,311,313, 324, 331,332,337, 364, 370, 380, 383, 384, 429, 431, 433, 440, 443, 454, 462, 501, 533, 557, 579, 594, 603, 608, 628, 634, 646, 647, 651,691,732,733,734,736,796                                                                                                                                                                                                                                                                                                                                                                                      |
| Physiology                                            | 5, 13, 39,40,43,45, 51, 55, 58, 68, 69, 79, 82, 84,86, 88, 89, 90, 91, 92, 93, 94, 98, 111, 118, 124, 125, 127, 129, 132, 136, 137, 148, 152, 158, 159, 161, 166, 167, 178, 181, 185, 186, 190, 194, 195, 198, 213, 214, 215, 217, 220, 223, 233, 255, 276, 281,283, 294, 298,303, 304, 311, 313, 315, 319, 320, 321,326,330,331,332,337, 352, 354, 359, 364, 371, 379, 382, 384, 405, 407, 412, 413, 414, 417, 418,422,423, 426, 428, 431, 438, 440, 441, 442, 444, 445, 448, 452, 462, 464, 468, 471, 501, 507, 511, 512, 529, 531, 551, 561, 590, 594, 604, 607, 608, 628, 634, 640, 650, 658, 661, 676, 677, 682, 683, 691, 700, 701, 704, 711, 731, 732, 733, 734, 745, 750, 752, 757, 758, 773, 774, 775, 787, 788,796 |
| Public Health, Social Medicine and Epidemiology       | 104, 106, 116,222, 343,491,503,547,612,613,641,654,721,738                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

Various applications of lasers were discussed in 51 papers (46, 140, 243, 246, 268, 300, 309, 416, 483, 560, 630, 674, 675,694,727,759, 791) including laser Doppler flowmetry and imaging (356, 357,427, 441, 444, 445,631,799,800). Radiofrequencies in the short and microwave range was the topic of 37 papers (5,267,269,289,323,325,434,482,487, 532, 543, 546, 566, 580, 618, 627,656, 689,751) and papers were published on ultrasound (120,240,344,362,396,398, 400,489, 505, 506, 540,585,601).

Environmental Health and Pollution Control (107, 145, 236,259, 358, 399) were also addressed.- Some papers were related to Zoology (515,528,740,757, mainly animal physiology)) and Veterinary Medicine (12, 191, 218, 552, 553, 747,748, 749).

## Discussion

The first search in multiple databases yielded more hits than last years survey. The second search, restricted to the databases Embase and Medline and to the combination of search terms with the key word “human”, obtained a similar distribution of publications in subgroups of clinical medicine. As in last years survey, high numbers of hits in physiology are probably caused by the key word “core temperature”. Numerous investigations of physiological changes following exercise in different thermal environment, are the reason for a high number of publications in the field physical medicine& rehabilitation and sports medicine, respectively.

The most frequently published topic in clinical medicine was hypothermia in critical situations such as cardiac arrest,

cardiovascular surgery, stroke and liver disease. Similar to last year’s survey, cardiovascular medicine, dermatology, neurology, paediatrics, anaesthesiology remained the main fields of medical temperature measurements. Thermal imaging based diagnosis of breast disease continued to be an important task., although thermal imaging is still struggling for full scientific acceptance in this field

Due to search restrictions to applications of temperature measurements in humans, no paper of technical or industrial applications appear outside of bioengineering and medical instrumentation. The validity of infrared tympanic thermometer for fever determination is still under debate. Papers on temperature measurement in other fields of biology such as botany, entomology, crop and soil science are also not available in this selection of references, but some can be found in the more comprehensive first search. In this first search more papers are also available for basic sciences such as physics and chemistry and for applied sciences such as astronomy, geology, climatology and meteorology

European scientists are predominant in temperature related research in medicine. The number of research institutes in Europe for temperature related matters in medicine is threefold of that in the United States. The remaining research facilities are located in Japan, China, Israel, South Korea, Taiwan and Australia. Still less than 5% of temperature related research is originated from countries in Africa, South America and the Middle East.

In conclusion, this years’ literature survey was focused on temperature measurements in humans. It has demonstrated

ed a high interest in both temperature related physiology and temperature related treatment mainly in hypothermia for patients in a critical state of health. About the same number of papers on diagnostic infrared imaging were published as last year.

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# Address for correspondence

Prof Dr med Kurt Ammer PhD

Austrian Society of Thermology

Hernalser Hauptstr 209/14, A-1170 Vienna, Austria

Email: KAmmer1950@aol.com

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# News in Thermology

## MIRA Medical InfraRed Academy

Some engaged and experienced physicians dealing with thermography and infrared imaging for decades have launched an Academy focussed on Infrared Imaging in medicine and veterinary medicine. On December 2nd and 3rd, 2005, a workshop for physicians and veterinarians took place in Frankfurt, Main. More than 30 participants attended the meeting and presented a number of papers discussing the most actual developments in breast cancer prevention, whole body thermal scanning, regulation thermography and equine thermography.

Colleagues interested in Infrared Imaging are invited to join the MIRA which is associated with the German So-

ciety of Thermography and Regulation Medicine, founded 1954.

[www.inframedic.de](http://www.inframedic.de) goto MIRA  
[www.thermomed.org](http://www.thermomed.org)

Prof. Dr. med. Reinhold Berz, MD  
 Harbach 5  
 D-36115 Hilders/Rhön

Phon +49 (0) 66 81 - 72 70  
 Fax +49 (0) 66 81 - 85 51  
 mobile D +49 (0)160 - 96 71 29 89  
 E-Mail [reinhold.berz@inframedic.de](mailto:reinhold.berz@inframedic.de)

## Meetings

April 17–21, 2006

**SPIE Defense & Security Symposium** at Gaylord Palms Resort and Convention Center; Orlando (Kissimmee), Florida USA including

Thermosense XXVIII (OR37)

Infrared Technology and Applications XXXII (OR38)

Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XVII (OR 39)

Technologies for Synthetic Environments:  
 Hardware-in-the-Loop Testing XI (OR40)

**Exhibition:** 18-20 April 2006

The largest collection of infrared imaging equipment

### Deadlines

Abstract Due Date: 3 October 2005

Manuscript Due Date: Week of 20 March 2006

On-Site Proceedings Manuscript Due Date: 23 January 2006

Further Information:

SPIE • P.O. Box 10, Bellingham, WA 98227-0010 USA

TEL: +1 360 676 3290 FAX: +1 360 647 1445

Email: [spie@spie.org](mailto:spie@spie.org) [www.spie.org](http://www.spie.org)

Website: [www.spie.org](http://www.spie.org)

June 27-30, 2006

**8 Conference on Quantitative InfraRed Thermography (QIRT)** in Padova - Italy,

### Scientific Committee

D. Balageas, ONERA, France

### QIRT Steering Committee

D. P. Almond, University of Bath, United Kingdom

J. M. Buchlin, Von Karman Institute, Belgium

G. Busse, University of Stuttgart, Germany

G. M. Carlomagno, University of Napoli, Italy

X. Maldague, Laval University, Canada

S. Svaic, University of Zagreb, Croatia

V. P. Vavilov, Tomsk Polytechnic, Russia

B. Wiecek, Technical University of Lodz, Poland

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J. M. Buchlin (Belgium) G. Busse (Germany)

G. Cardone (Italy) G. M. Carlomagno (Italy)

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A. Nowakowski (Poland) A. Rozlosnik (Argentina)

F. Scarano (Italy) S. Svaic (Croatia) B. Wiecek (Poland)

V. Vavilov (Russia)

### Organizing Committee:

Ermanno Grinzato (local chairman)

Antonella Barizza; Paolo G. Bison; Sergio Marinetti

### Deadlines:

November 7, 2005 Abstract submission

January 31, 2006 Notification of abstract acceptance

April 31, 2006 Paper submission

### Conference fee

The conference fee is € 450 (early bird by May 15, 2006) and € 500 (late/on site after May 15, 2006) for authors presenting papers and posters.

The conference fee for all other participants is € 500, earlybird by May 15, 2004 or € 550 late/on site after May 15, 2006.

The fee includes: sessions, lunches, welcome reception, conference dinner and a free subscription to the Journal of QIRT for two years

**Information:**

CNR-ITC, C.so Stati Uniti, 435127 PADOVA - Italy

phone +39 049 8295722 fax +39 049 8295728

email: info.qirt2006@itc.cnr.it

Website: <http://qirt2006.pd.cnr.it>

July 5 - 7, 2006

**7th Course on the Theory and Practice of Infra Red Thermal Imaging in Medicine,**

University of Glamorgan. Pontypridd CF37 1DL, UK

**Preliminary Programme (subject to change):**

Day 1 (Wednesday, 5 July):

Theoretical and Historical Basis of Thermal Imaging in Medicine

11.00-12.15 Registration in the (also known as 'Tâf' Building) next to 'Bytes' cafeteria

12.30-13.30 **Lunch**

13.30-14.30 History and development of IR imaging (FR)

14.30-14.40 Physical principles of heat transfer (FR)

14.40-15.20 **Break** and **check-in** to University accommodation

15.20-16.15 Principles of thermal physiology 1 (KA)

16.15-16.30 Film (cold and warm exposure)

16.30-17.20 Principles of Thermal Physiology 2 (KA)

Day 2 (Thursday, 6 July):

**Clinical Applications of Thermal Imaging**

09.00-09.45 Standard protocols for image capture (FR)

09.45-10.15 Provocation tests 1 (FR)

10.15-10.45 Provocation tests 2 (KA)

10.45-11.15 **Break**

11.15-12.15 Detector and camera systems (RT)

12.15-12.45 CTHERM software introduction (PP)

13.00-14.15 **Lunch**

14.15 15.15 Parallel sessions, two groups:

Film (Living body- thermoregulation)

Practical Lab image capture

15.15-15.30 **Break**

15.30-16.30 Causes of temperature increase (KA)

16.30-17.15 Causes of temperature decrease (KA)

19:00 **Course Dinner**

Day 3 (Friday, 7 July):

Practical session capturing and analysing images

09.15-09.50 Producing a thermographic report (KA)

09.50-10.10 Discussion

10.10-10.25 Break

10.30-12.30 Practical Session:

Using CTHERM software on images taken on day 2 and guided image analysis (FR/KA)

12.30-12.45 Reliability and Limitations of IR measurements

13.00-14.00 **Lunch** - Gallery Suite ("Conservatory Restaurant")

14.00-15.00 Future developments of thermal imaging in medicine

1. Image databases and image exchange (FR)

2. Integration into hospital DICOM systems (FR)

3. Medical Education, Journals and conferences (KA)

15.00 **Close**

**Registration Fee**

£365 (students £200). Cheques should be made payable to The University of Glamorgan. Prior reservation is essential. Booking form below.

The fee includes:

lunch and refreshment breaks,

book on thermal imaging in medicine,

searchable CD of archived "IR Imaging in Medicine" publications.

Accommodation

Inexpensive campus accommodation is available for participants without own transport who would like to stay at the University. Check-in after 14:00. If you plan to arrive late in the evening, please let us know.

There are also some Hotels and B&Bs nearby (contact details and prices on request, see ) for those with a car.

Certificate

The course is recognised by the University of Glamorgan and certificates will be issued to all who complete the course.



## EUROPEAN ASSOCIATION OF THERMOLOGY est.1974

### 10<sup>th</sup> Congress

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**ZAKOPANE POLAND 15<sup>th</sup> –17<sup>th</sup> September 2006**

#### General Information

#### Topics

Human body temperature, thermal physiology, applications of thermal imaging in medicine,  
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Infra red imaging systems, software systems for thermal image processing,  
Technological and practical standards.

#### Abstract deadline    **MAY 1 2006**

Abstract form will be found in Thermology international and on the conference website

Contact [ajung@wim.mil.pl](mailto:ajung@wim.mil.pl)

#### **Registration Fee 300 Euros** ( based on room share)

Includes full board at conference hotel, and social events

Extra night (Sunday – breakfast Monday 18 Sept). 50 Euros

Transport (groups of 5 and over) from Krakow Int. Airport – 20 Euros return

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Registration payment after August 1 2006 only on site

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#### **Local organising committee:**

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## Combined Conferences

10 **European Congress of Medical Thermology**

9 **National Congress of the Polish Association of Thermology**

19 **Thermological Symposium of the Austrian Society of Thermology**

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Abstract

Return this form not later than May 1, 2006 to:

Prof. Anna Jung  
Pediatric and Nephrology Clinic MSM  
Szaserów Str 128 00 909 Warsaw 60, POLAND Fax (48 – 22) 6816763  
e mail: [ajung@cskwam.mil.pl](mailto:ajung@cskwam.mil.pl)

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# Thermology international

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Dr. Kurt Ammer  
Österreichische Gesellschaft für Thermologie

Hernalser Hauptstr.209/14  
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This journal is a combined publication of the Austrian Society of Thermology and the European Association of Thermology (EAT). It serves as the official publication organ of the the American Academy of Thermology, the German Society of Thermology, the UK Thermography Association (Thermology Group) and the Austrian Society of Thermology. An advisory board is drawn from a panel of international experts in the field. The publications are peer-reviewed.

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