Thermal Imaging for Building Fabric Insulation Compliance

Programme

10:00	Registration/Tea & Coffee	
10:30	Welcome	P. Quested
10:40	Energy Performance of Buildings Directive	B. Anderson (BRE)
11:00	Thermographic Method to meet new UK Building Regulations	C.Pearson (BSRIA & UKTA)
11:20	Discussion	
11:35	Finnish Building Regulations	T. Kauppinen (VTT)
11:55	Building Thermography Standards for Canada	T. Colantonio (PWGS Canada)
12:15	Discussion	
12:30	Lunch	
13:30	The German approach to thermal insulation of dwellings and checking with thermography	H. Bruggemann, (Raytek)
13:50	Thermal Imaging Standards for Improved Quality	H.McEvoy (NPL)
14:10	Methods of Evaulating Reflective Insulation Systems	R.Williams (NPL)
14:30	Discussion	
15.15	Laboratory tour	

dti
FUNDED BY THE DTI
National Physical Laboratory | Hampton Road | Teddington | Middlesex | United Kingdom | TW11 0LW
Switchboard 020 8977 3222 | **NPL Helpline** 020 8943 6880 | **Fax** 020 8943 6458 | **www.npl.co.uk**

Energy Performance of Buildings Directive

Brian Anderson

23 February 2005

EPB Directive – objective

- To promote the improvement of the energy performance of buildings in the Community

  considering that:

- Buildings have a long-term impact on energy consumption
- Alternative energy supplies are not generally explored to their full potential
- Major renovations provide an opportunity

EPB Directive – main provisions

- A methodology for calculating the energy performance of buildings
- Setting of energy performance requirements (building regulations) for
  - new buildings
  - major renovations
- Energy certification of buildings
- Regular inspection of boilers and air-conditioning systems

EPB Directive – main provisions

- Methodology for calculation of energy performance
  - does not specify method
  - annex lists aspects to be taken into account
  - mentions that EN 832 and EN ISO 13790 will be further developed
- Regulations to be set, based on the methodology
- Energy performance certificate
  - based on the methodology
  - to be expressed in a transparent manner
- Boiler and AC inspections

Calculation methodology

- Calculation of overall energy use including
  - space heating
  - space cooling
  - ventilation systems
  - hot water services
  - lighting

Calculation methodology

- For dwellings – SAP
  (Standard Assessment Procedure)

- For other buildings – NCT
  (National Calculation Tool)

EPB Directive – CEN standards

- Standards are being written in CEN that could eventually support the Directive

- Standards should provide common and agreed bases so far as possible for
  - Calculation methodology
  - Setting regulations
  - Energy performance certificate
  - Inspections

Starting point : published standards

- U-value calculations
- heat transfer - detailed calculations
- measurement methods (U-values, air tightness)
- insulation of building equipment
- climatic data specifications
- calculation of energy use for heating

Starting point – standards needed

- Calculation of energy needs for
  - space heating
  - space cooling
  - ventilation systems
  - hot water services
  - lighting

- Combining these to give overall energy performance
  - space heating largely done, others not

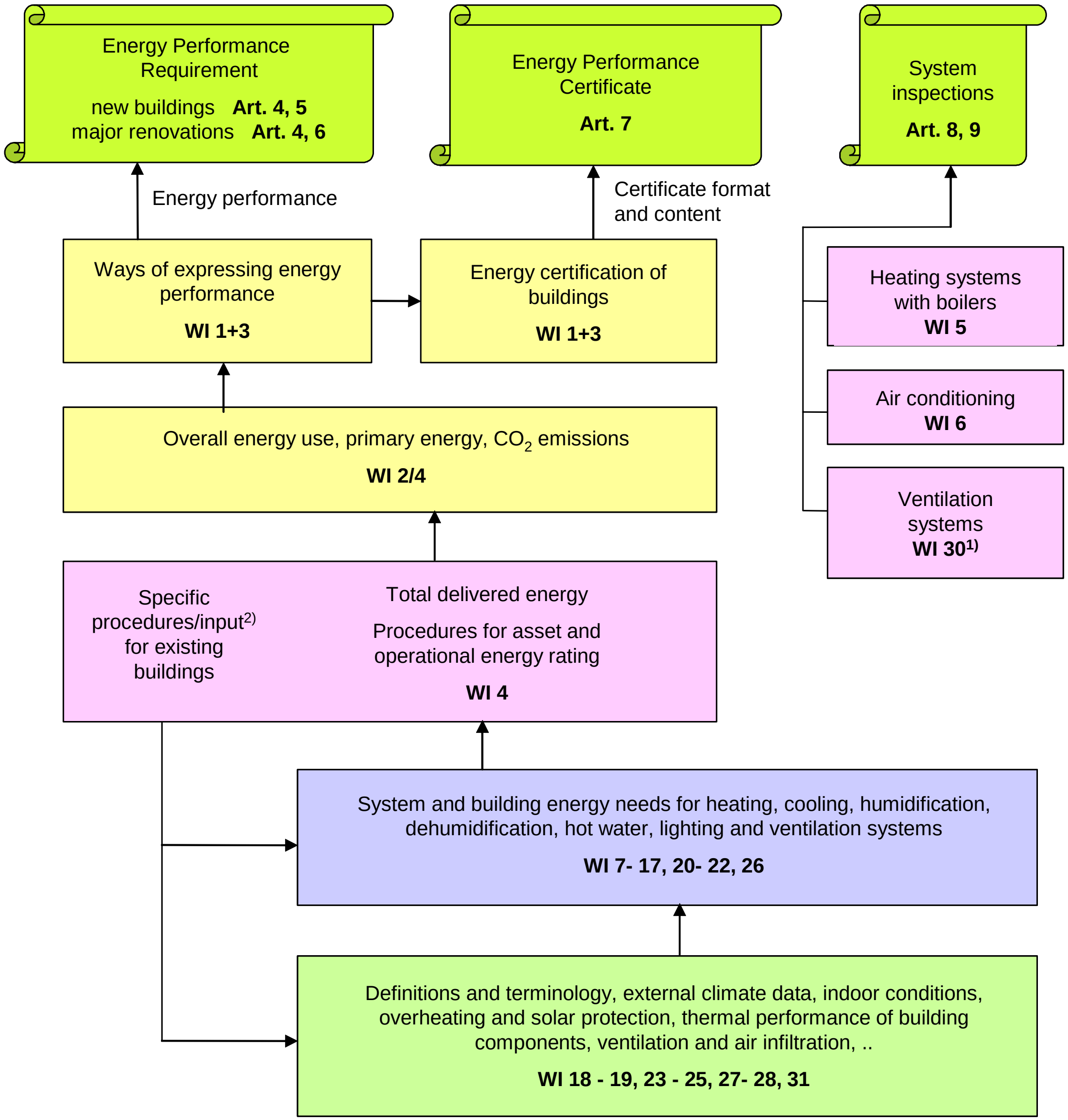
bre

Time scale for standards

- CEN rules - 3 years to produce a new standard
  - up to 4½ years if necessary
  - work item deleted if timetable not achieved
- 3 years from 2004 is 2007
- Half-way stage is CEN Enquiry (draft for public comment)
- Draft standards by end 2004
- Enquiries during 2005

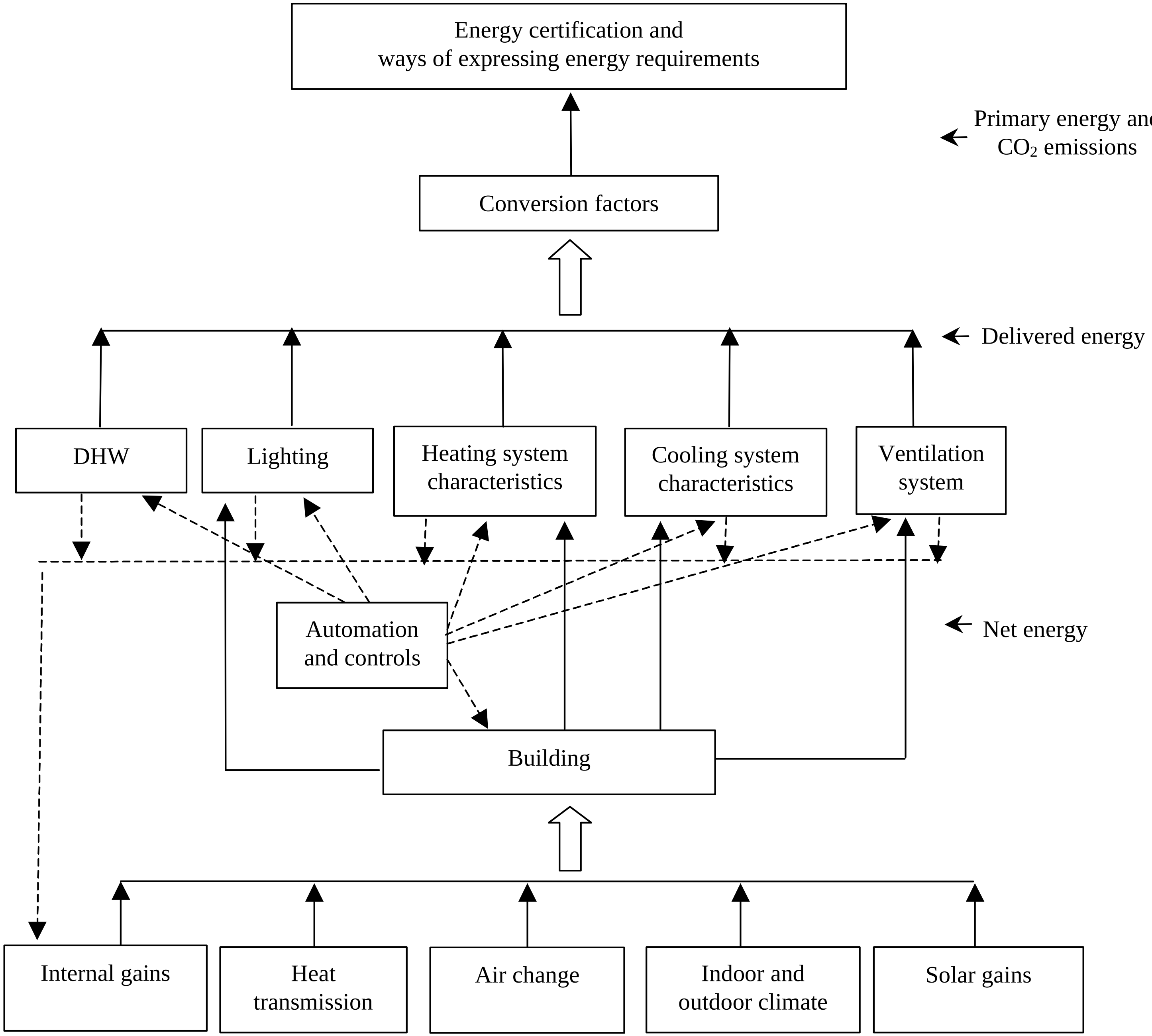
bre

Methodology for calculating energy performance (Article 3 and Annex)



1): Not explicitly mentioned in the Directive

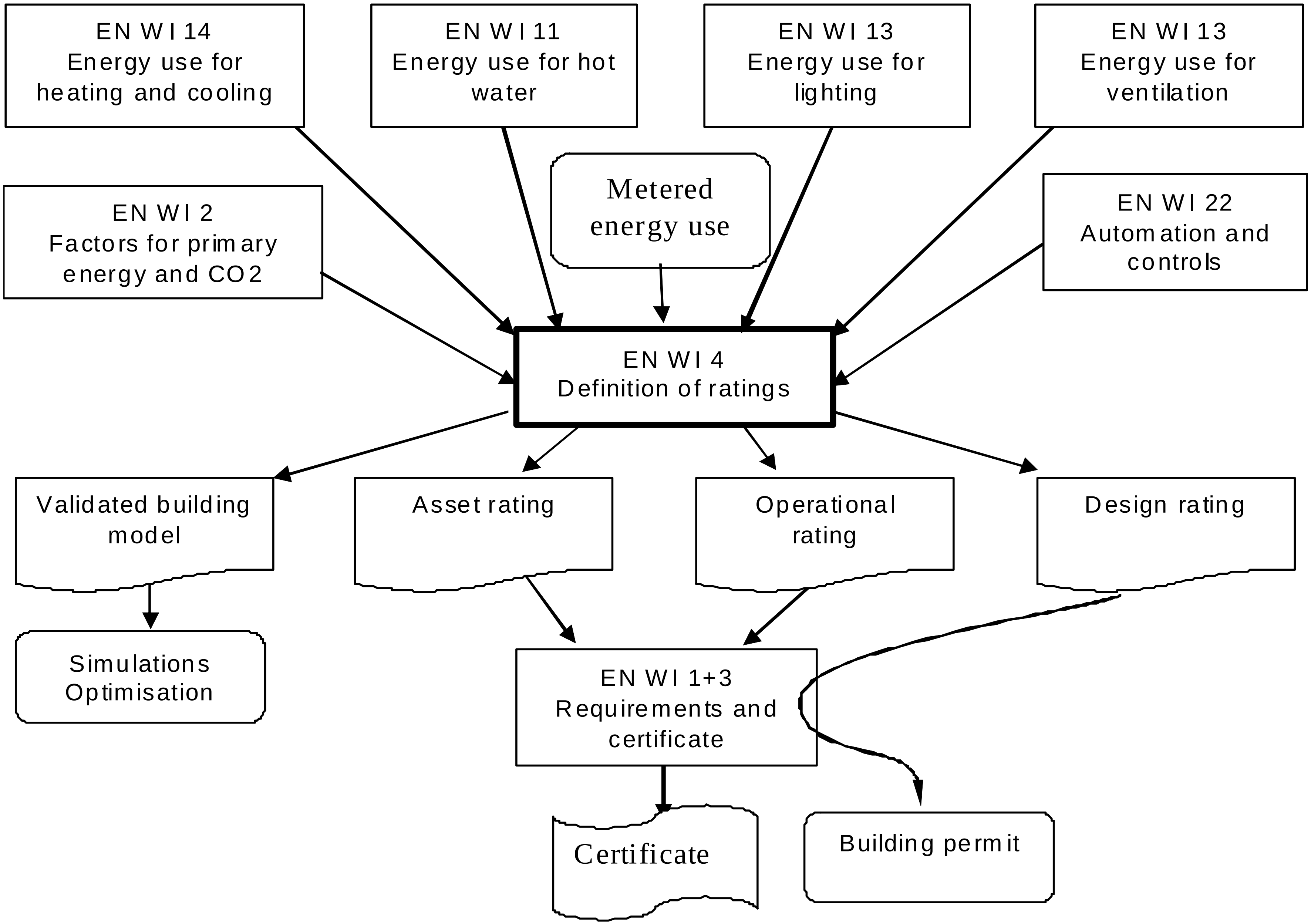
2): Unless already covered by WI 7-28



Energy certification and
ways of expressing energy requirements
Primary energy and
CO_2 emissions
Conversion factors
Delivered energy
DHW
Lighting
Heating system
characteristics
Cooling system
characteristics
Ventilation
system
Automation
and controls
Net energy
Building
Internal gains
Heat
transmission
Air change
Indoor and
outdoor climate
Solar gains

Energy performance indicator

- Asset rating (calculated)
  - Design rating
  - Tailored rating
- Asset rating can be based on
  - Delivered energy (weighted)
  - Primary energy
  - CO_2 emissions
  - Energy costs
- Operational rating (from metered energy)



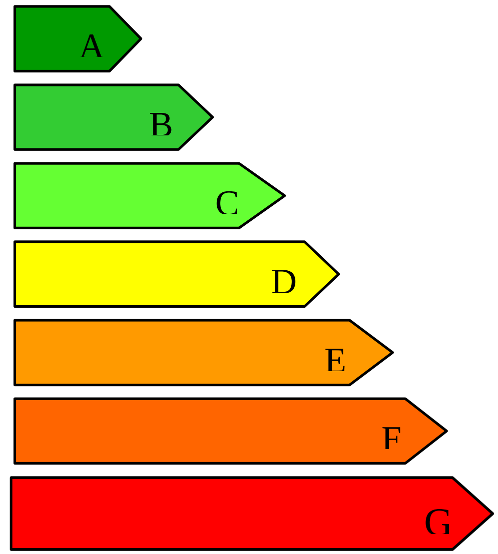
EN WI 14
Energy use for heating and cooling
EN WI 11
Energy use for hot water
EN WI 13
Energy use for lighting
EN WI 13
Energy use for ventilation
EN WI 2
Factors for primary energy and CO2
Metered energy use
EN WI 22
Automation and controls
EN WI 4
Definition of ratings
Validated building model
Asset rating
Operational rating
Design rating
Simulations
Optimisation
EN WI 1+3
Requirements and certificate
Certificate
Building permit

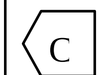
Energy certificate

Building Energy Performance | As built

Space to make reference to the certification scheme used | Asset rating

Very energy efficient





Not energy efficient

calculated

Name of the indicator used Unit

130

Standards – next stages

- January to March 2005 - translations
- April 2005 - Enquiries start
  - national activity
  - some CEN work continues
  - drafts stable for 9 months
- September 2005 - Enquiries close
- Autumn 2005 to Spring 2006 - revisions
- Summer 2006 - Final editing
- Autumn 2006 - Formal votes
- by mid 2007 - published standards

Energy performance regulations

- Overall energy performance criterion, based on Asset Rating obtained from (weighted) Delivered Energy, Primary Energy or CO_2 emissions

- Can be set as
  - a target value (as proposed for AD L1A), or
  - by reference to a notional building with defined elemental characteristics (as proposed for AD L2A)

- Extensions, renovations, etc can be regulated by elemental provisions for building and services

bre

EPB Directive - implications

- New buildings - regulations
  - Pass level based on overall emissions

    (instead of elemental provisions like U-values and heating efficiency)
- Existing buildings – regulations
  - Similar to existing: can set requirements for components

bre

EPB Directive – implications

- Energy performance certificates
  - New buildings
  - When buildings sold or rented
- Certificates to provide overall energy indicator
  - CO_2 emissions, kg/m²
  - SAP rating for dwellings
- ‘Operational’ rating certificates in public buildings

EPB Directive - implications

- Boiler inspections (> 20 kW)
  - Regular inspections of boilers
  - Leading to advice on efficiency and sizing
  - Inspection of whole system if > 15 years old
  - Alternative of advice about boiler replacement and modifications to system
- Air-conditioning inspection (> 12 kW)
  - Regular inspections
  - Leading to advice on efficiency and sizing

bre

EPB Directive – implementation

- Mostly through Part L of the building regulations
- Other regulations for energy performance certificates, boiler and AC inspections
- Likely to be phased implementation 2006 – 2008
- New buildings from 2006 – new Part L etc
  - Part L is raising standards as well

Checking compliance with Building Regulations – England & Wales

Colin Pearson

Head of Condition Monitoring – BSRIA

General Secretary - UKTA

UKTA

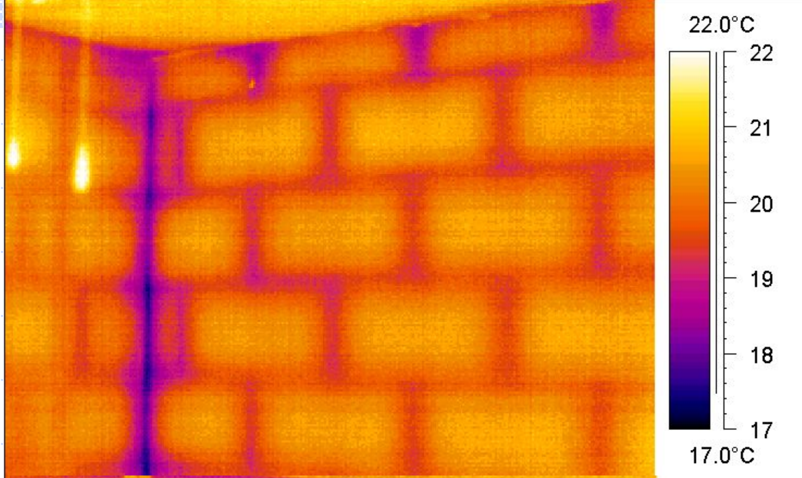
Why check thermal insulation?

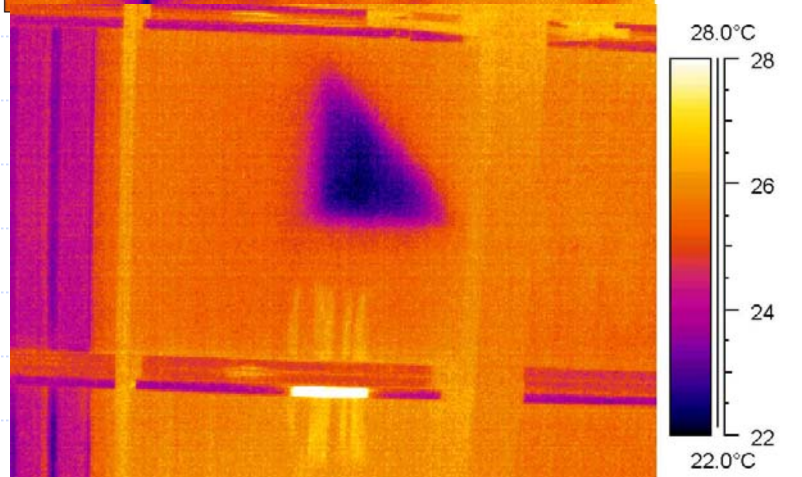
- Quality Assurance
- Energy efficiency
- Contractors' liability
- Building Regulations
  - The 2001 Part L2 revision of the Building Regulations for England and Wales introduced a requirement that thermal insulation should be 'reasonably continuous' over the whole roof, wall and floor area of new commercial buildings

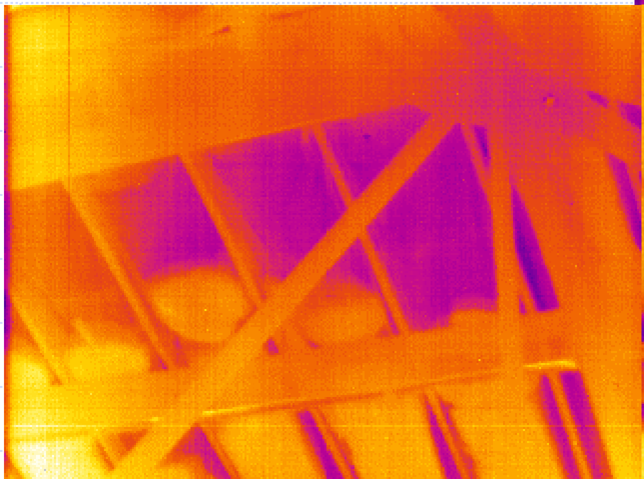
UKTA

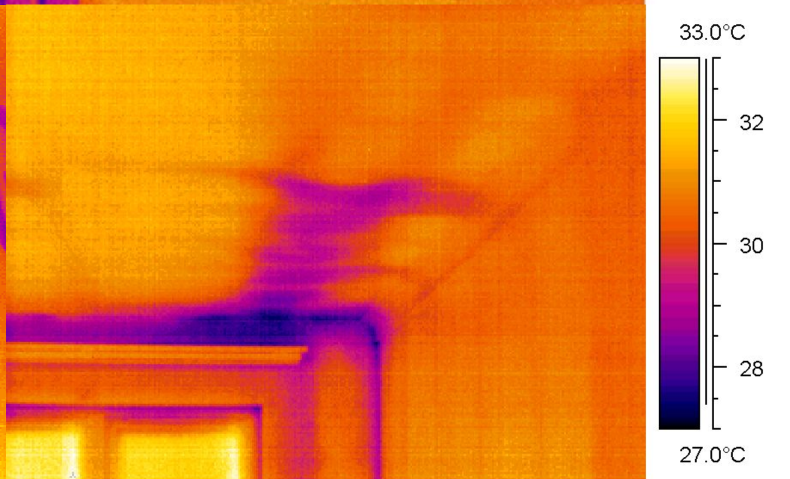
Defects

- Cold bridging
- Missing insulation
- Air leakage
- Slipped insulation









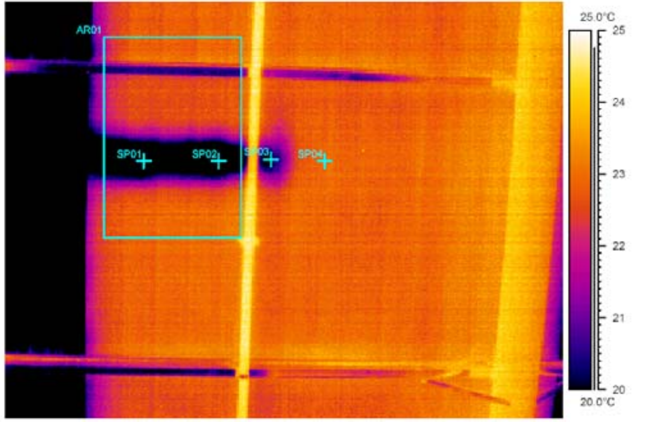
But are the buildings acceptable?

- Normally rely on skill and experience of thermographer
- No guidance on what is acceptable
- Standards and Guides do not set criteria

What is required?

- Show thermal anomalies
- Differentiate between real thermal anomalies and confounding factors
  - such as localised differences in air movement, reflection and emissivity
- Quantify affected areas and their severity
- State whether the anomalies and the building thermal insulation are acceptable

Approach



- Select critical temperature parameter
- Select acceptable defect area limit
- Measure surface temperature difference caused by each anomaly
- Measure area of the defects

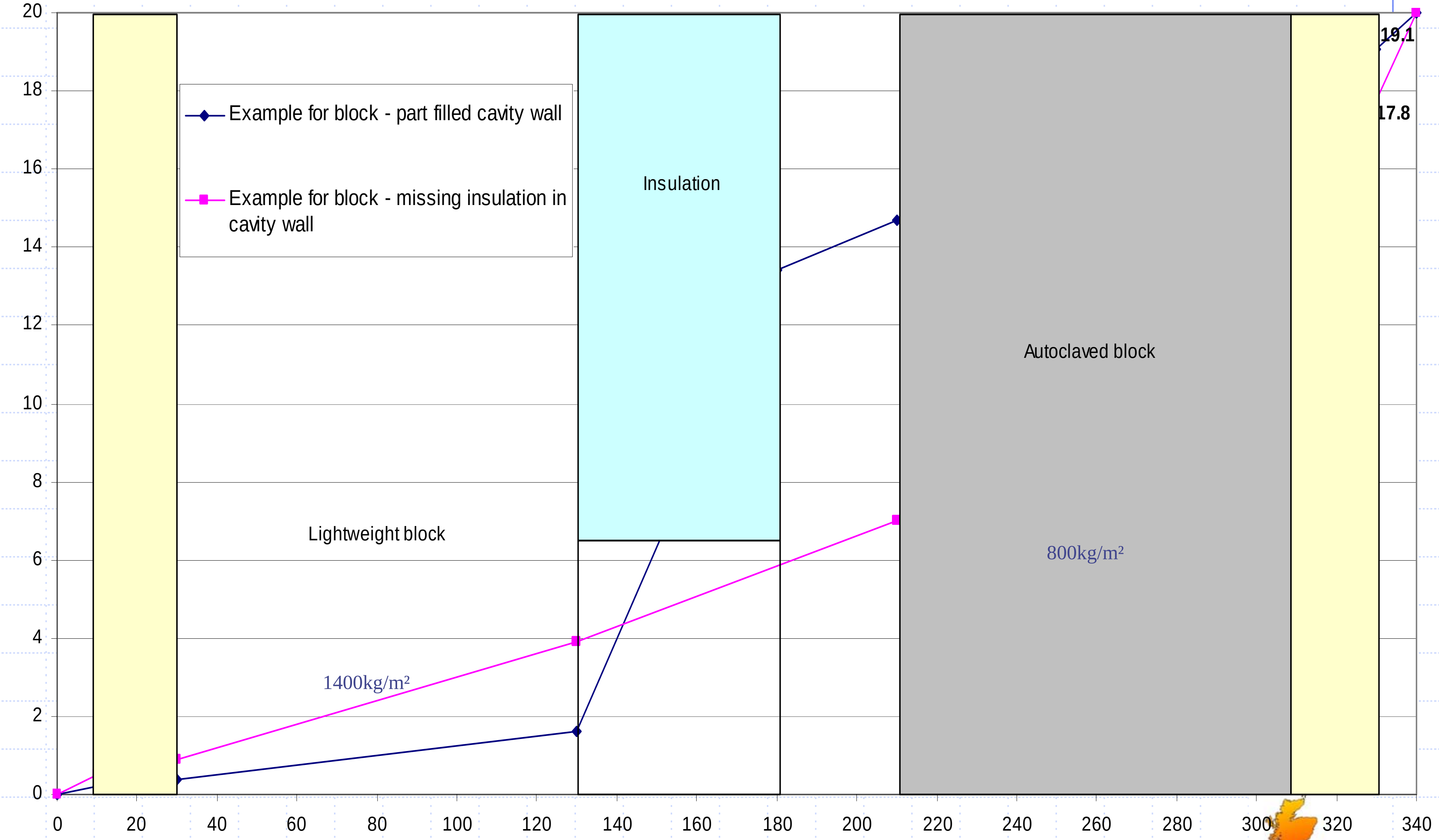
Critical temperature parameter

- Risk of condensation and mould
- Surface temperature factor, f_{Rsi}

$$f_{Rsi} = \frac{T_{si} - T_e}{T_i - T_e}$$

- Critical surface temperature factor f_{CRsi}
  - Proportion of temp. diff. across fabric rather than internal boundary layer that will lead to condensation or mould in lowest design temperature

The effect of missing insulation



What change in insulation causes a critical defect?

Surface resistance	$0.12 m^2K/W$
Surface temperature	19.4°C
Surface temperature for f_{CRsi} of 0.75	14.55°C
Surface temperature for insulation reduction of 25%	19.2°C
33%	19.1°C
50%	18.8°C
75%	17.6°C
80%	17°C
85%	16°C
88%	14.55°C

Allowable area

- Must maintain high standards without alienating construction industry by failing too many buildings
- 0.1% has been found to cause one building in four to fail
- 0.1% is suggested as suitable for large commercial and retail buildings

UKTA

Measure surface temperature and area

- Temperature measurement is common feature of a thermographic survey
- Area measurement is often a feature of analysis software requiring:
  - Object distance
  - Angular field of view
  - Setting threshold temperature in software
  - Pixel counting
  - Computation of area below threshold temperature

Conditions and equipment

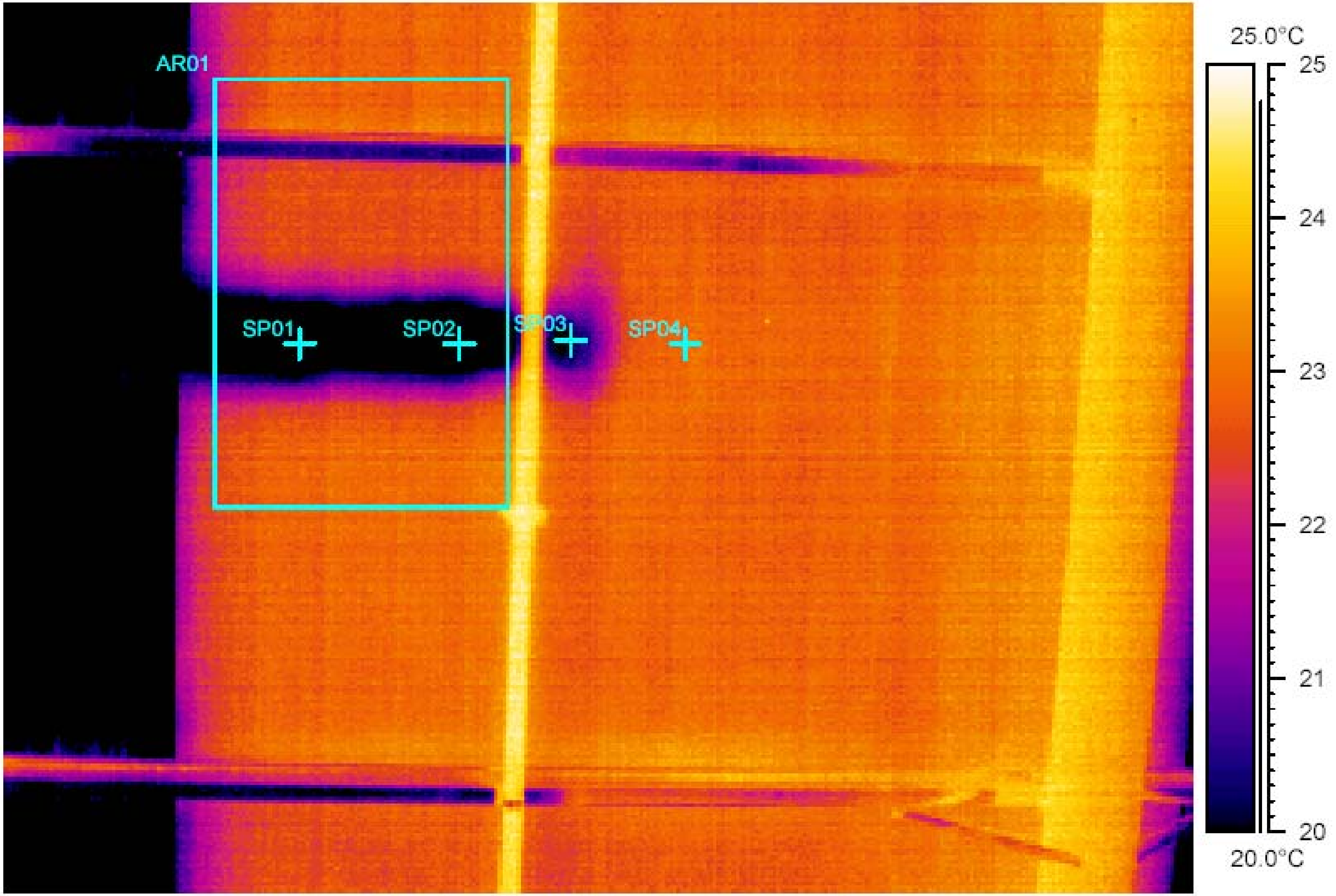
- Suitable conditions, equipment and repeatable method required
- Follow existing standard
  - eg BS EN 13187:1999, Thermal Performance of buildings – Qualitative detection of thermal properties in building envelopes – Infrared method (ISO 6781:1983 modified)

Method

- Internal survey usually best
- Requires image of every anomaly
  - image square to any features of the wall or roof.
  - viewing angle perpendicular to surface imaged
  - interfering sources of infrared radiation such as lights, heat emitters, electric conductors, reflective elements minimised
- Requires calculation of building surface area

UKTA

Analysis



Limitations

- This method may not be suitable for:
  - Heavyweight structures, particularly where the main insulating element is near the outside surface
  - Buildings where much of the internal surface is obscured, eg by false ceilings.

Building Regulations Part L2

"The person responsible for achieving compliance should (if suitably qualified) provide a certificate or declaration that the provisions meet the requirements of Part L2(a);

or they should obtain a certificate or declaration to that effect from a suitably qualified person. Such certificates or declarations would state:

a) that appropriate design details and building techniques have been used or

b) that infra-red thermography inspections have shown that the insulation is reasonably continuous over the whole visible envelope"

from April 2002

UKTA

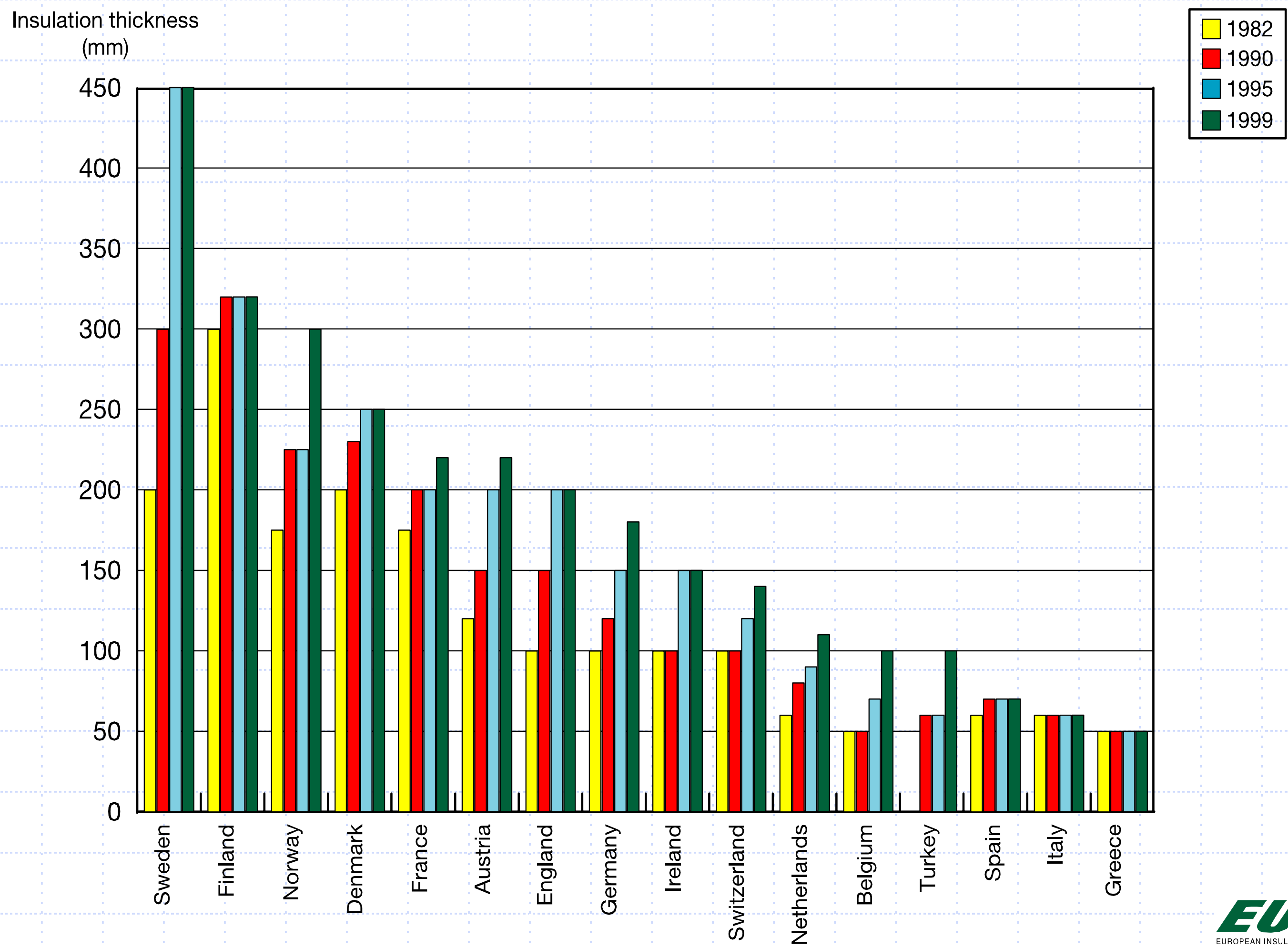
New Building Regulations Part L from 2006

- May not mention thermography at all
- May include reference to UKTA Application Guide
- May require existing buildings to comply when sold or leased
- Will implement European Energy Performance of Buildings Directive

INSULATION THICKNESSES IN EUROPE

STANDARDS AND/OR IN-USE

ROOFS

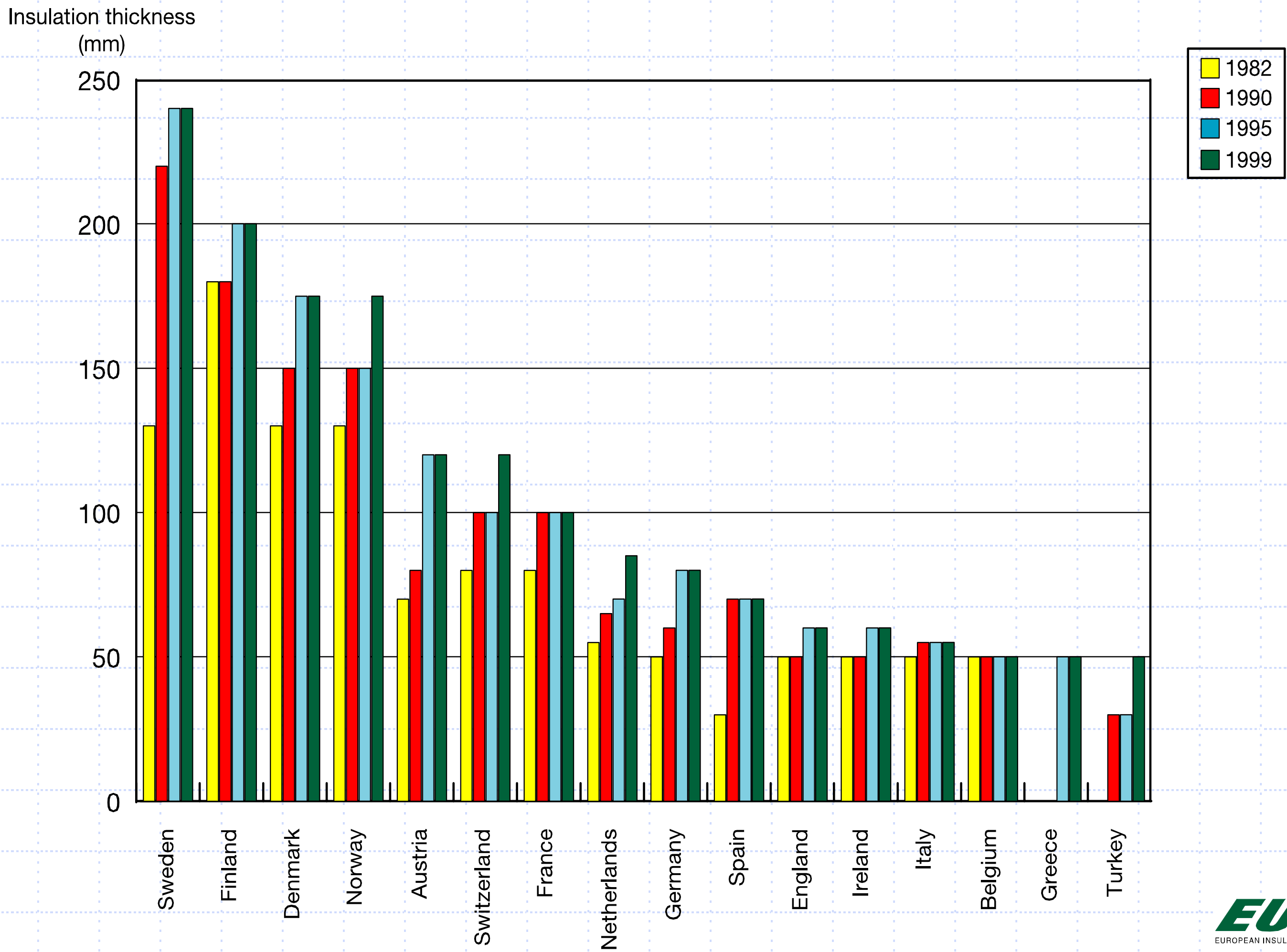


June 199

INSULATION THICKNESSES IN EUROPE

STANDARDS AND/OR IN-USE

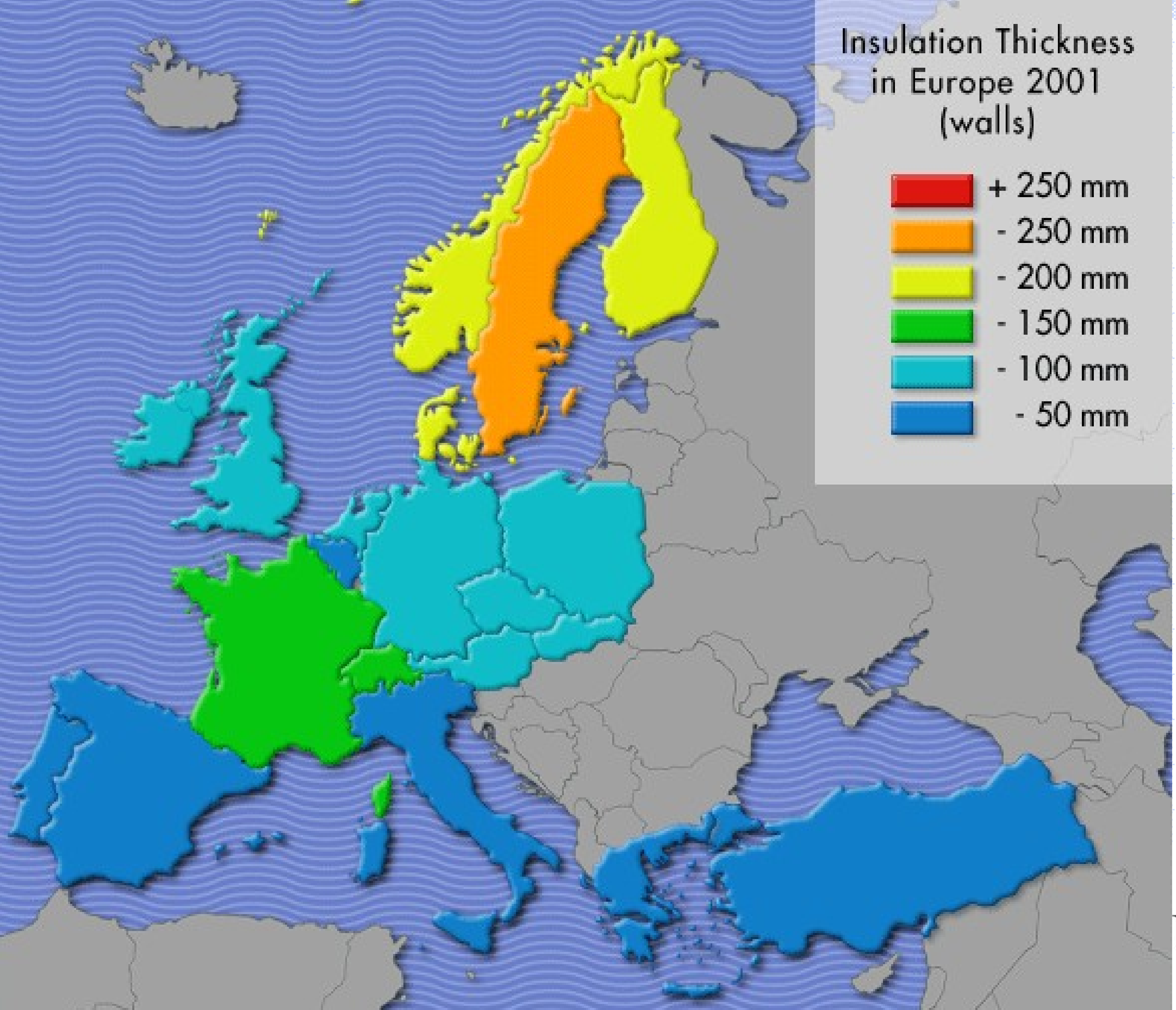
WALLS

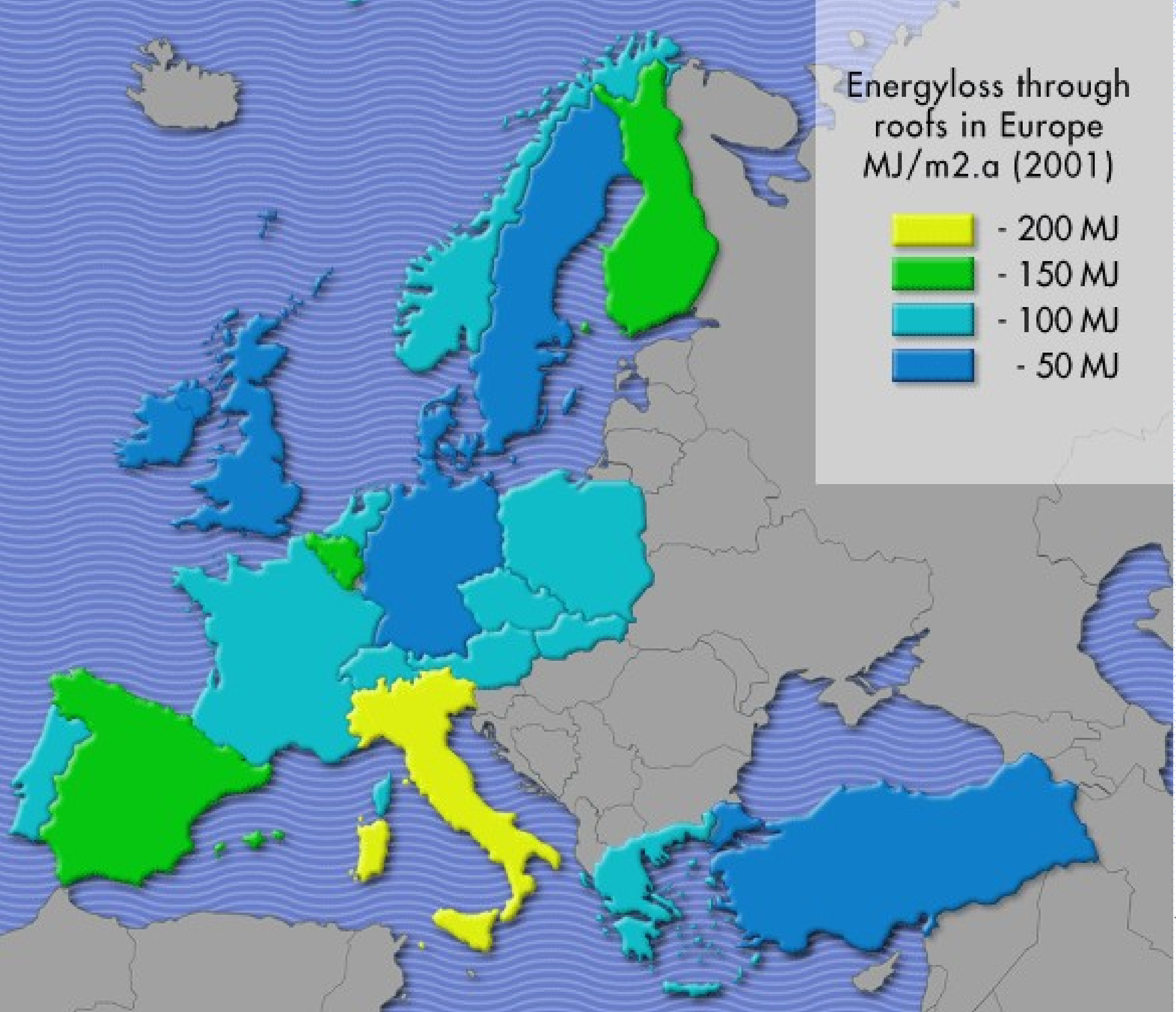


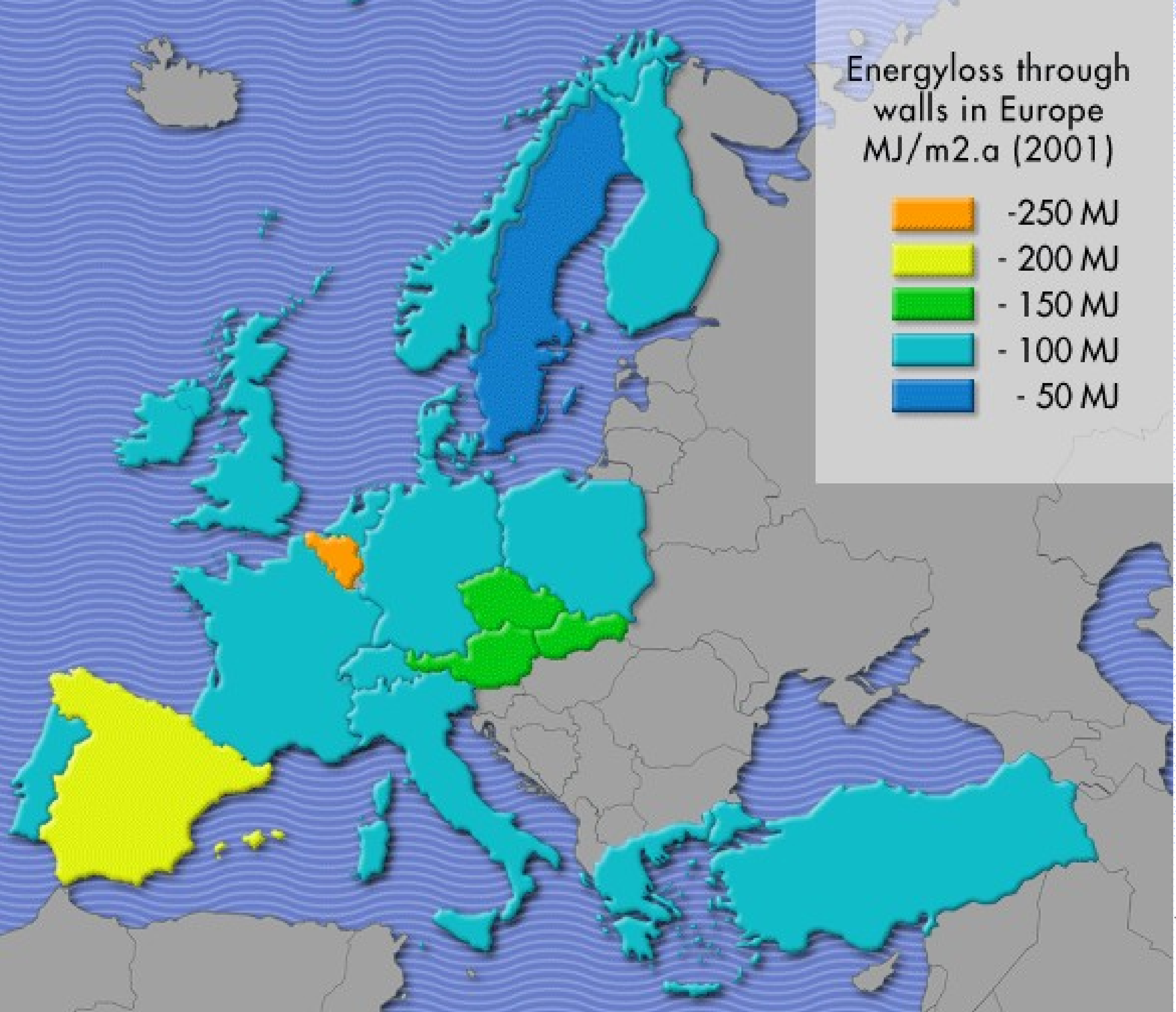
EURIMA
EUROPEAN INSULATION MANUFACTURERS ASSOCIATION

June 1999

UKIA


Insulation Thickness
in Europe 2001
(walls)
+ 250 mm
- 250 mm
- 200 mm
- 150 mm
- 100 mm
- 50 mm


Energyloss through
roofs in Europe
MJ/m2.a (2001)
- 200 MJ
- 150 MJ
- 100 MJ
- 50 MJ


Energyloss through walls in Europe MJ/m2.a (2001)
-250 MJ
- 200 MJ
- 150 MJ
- 100 MJ
- 50 MJ

UKTA

Conclusions

- There is a practical, repeatable quantitative method of assessing thermal insulation performance
- It may be used to show compliance with Building Regulations
- Quantifying thermal insulation performance is becoming more important
- There are different standards across Europe and Worldwide

Thank-you

UKTA

FINNISH BUILDING REGULATIONS
The use of thermography for the evaluation of building performance

Timo Kauppinen

VTT IN BRIEF

Jnits:

/TT Electronics
/TT Information Technology
/TT Industrial Systems
/TT Processes
/TT Biotechnology
/TT Building and Transport

/TT Information Service
/TT Corporate Management
and Services

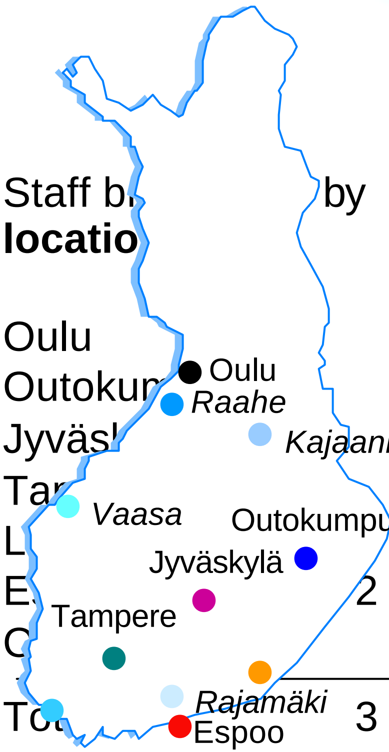
Staff: 3 012

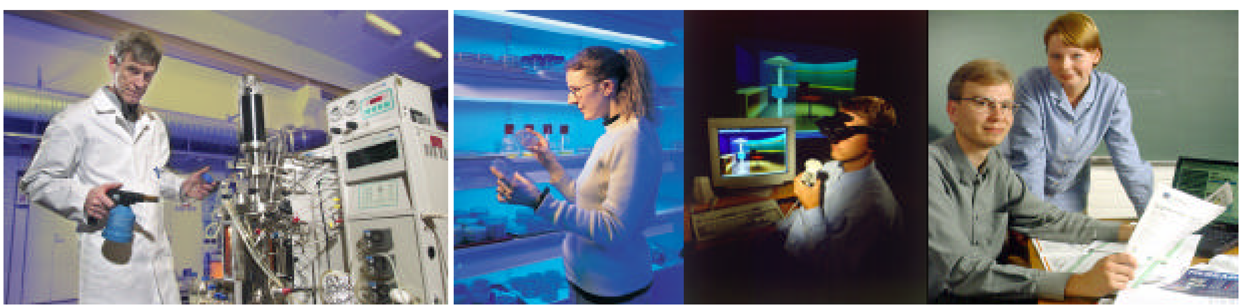
Turnover: 214 M€

- Basic govern. funding to R&D on VTT's own initiative 34 M€
- Jointly funded projects 92 M€
- Commercial activities 88 M€

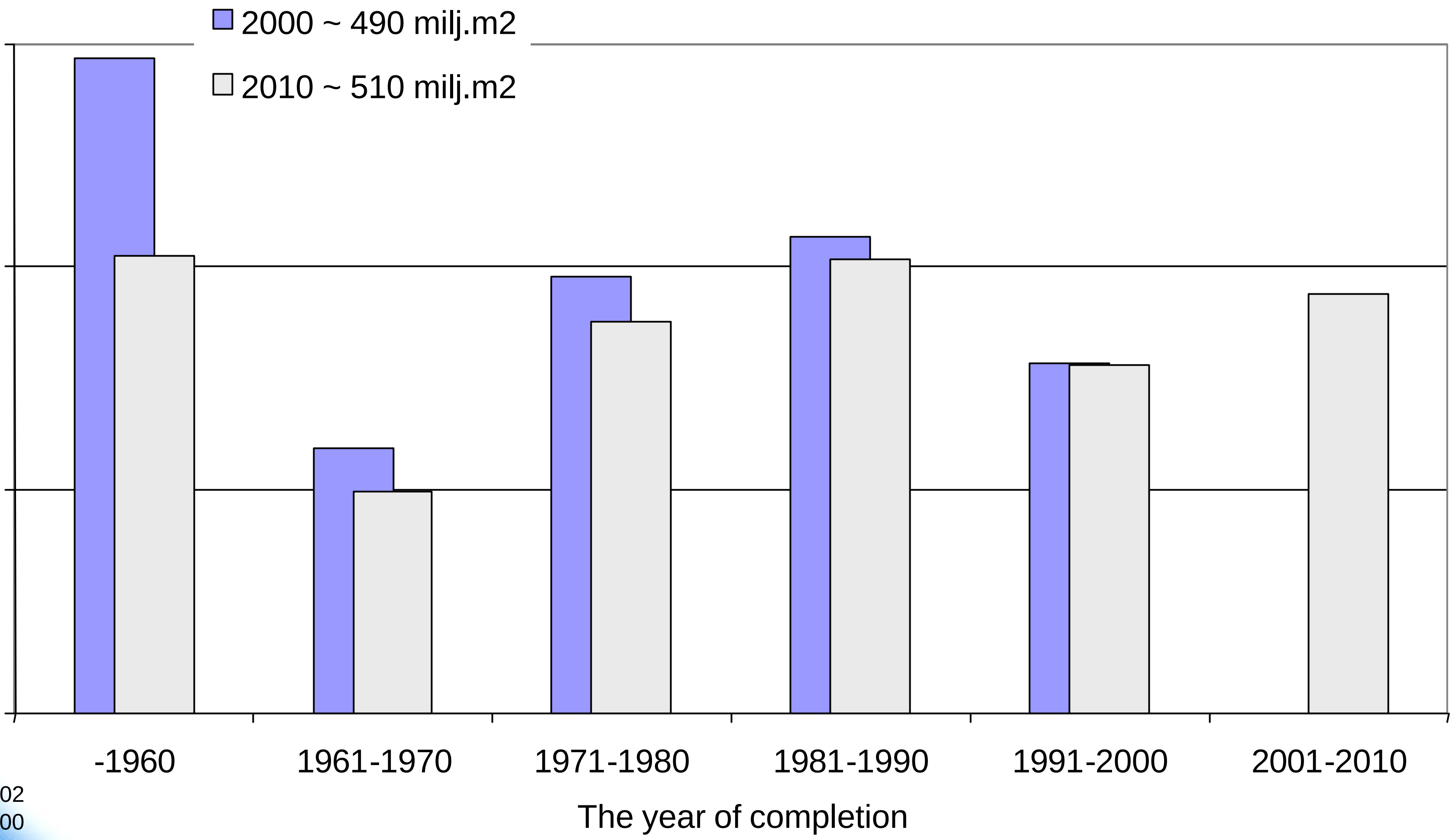
Staff b… by **locatio…**

Oulu	323
Outokun…	37
Jyväs…	128
Ta…	332
L…	12
E…	2 159
C…	21
To…	3 012



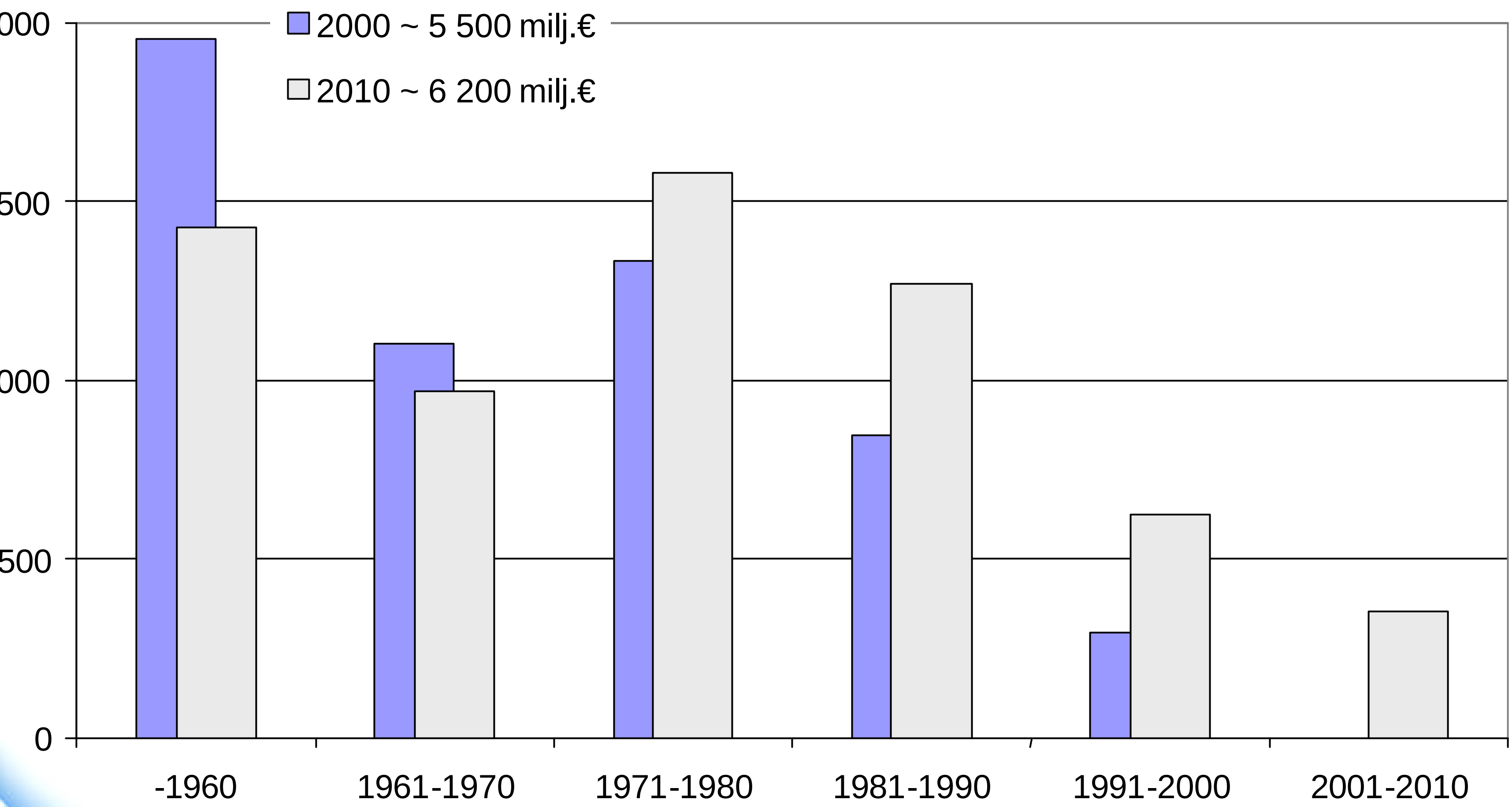


The building stock in the years 2000 and 2010

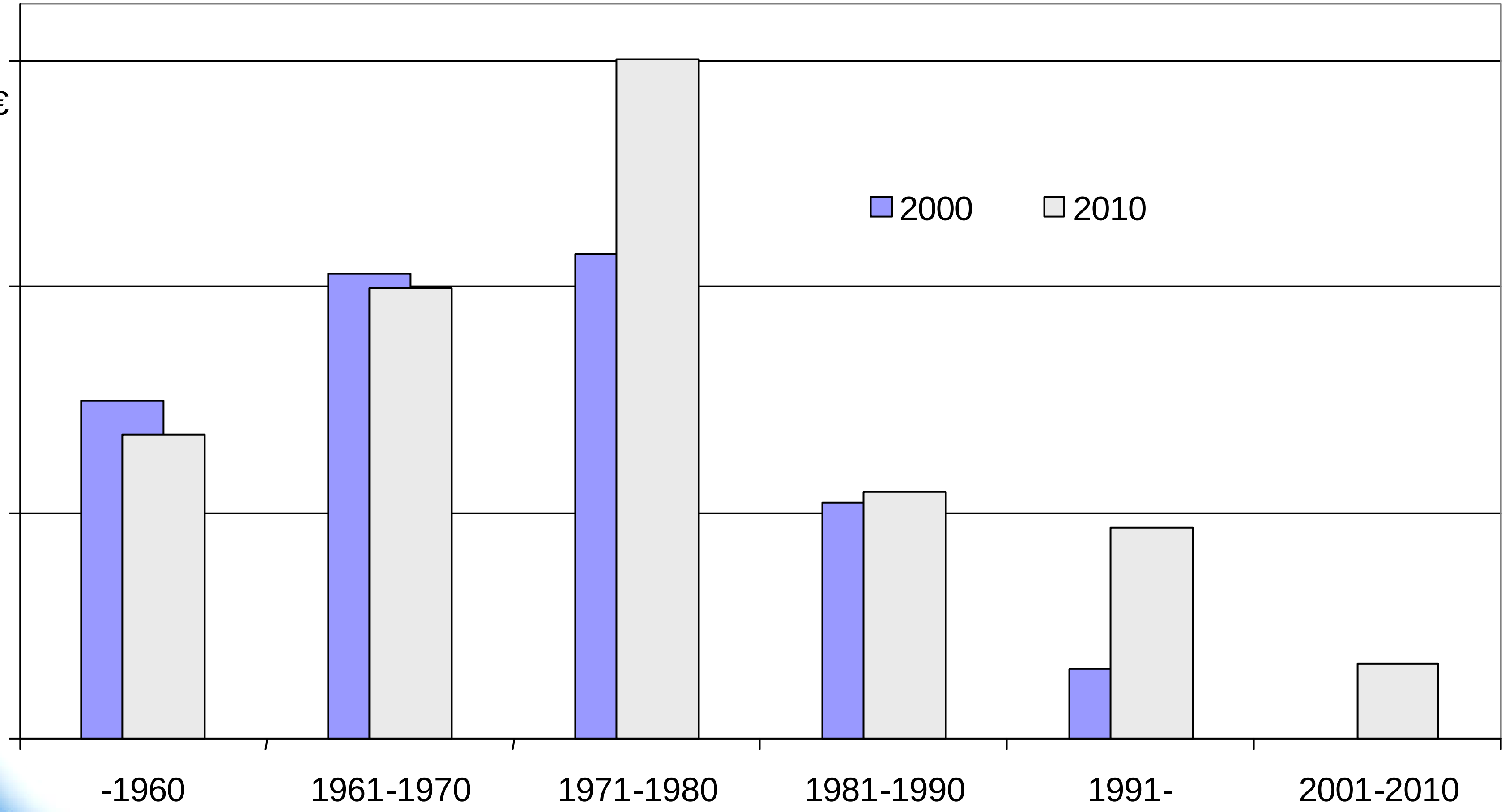


002
000

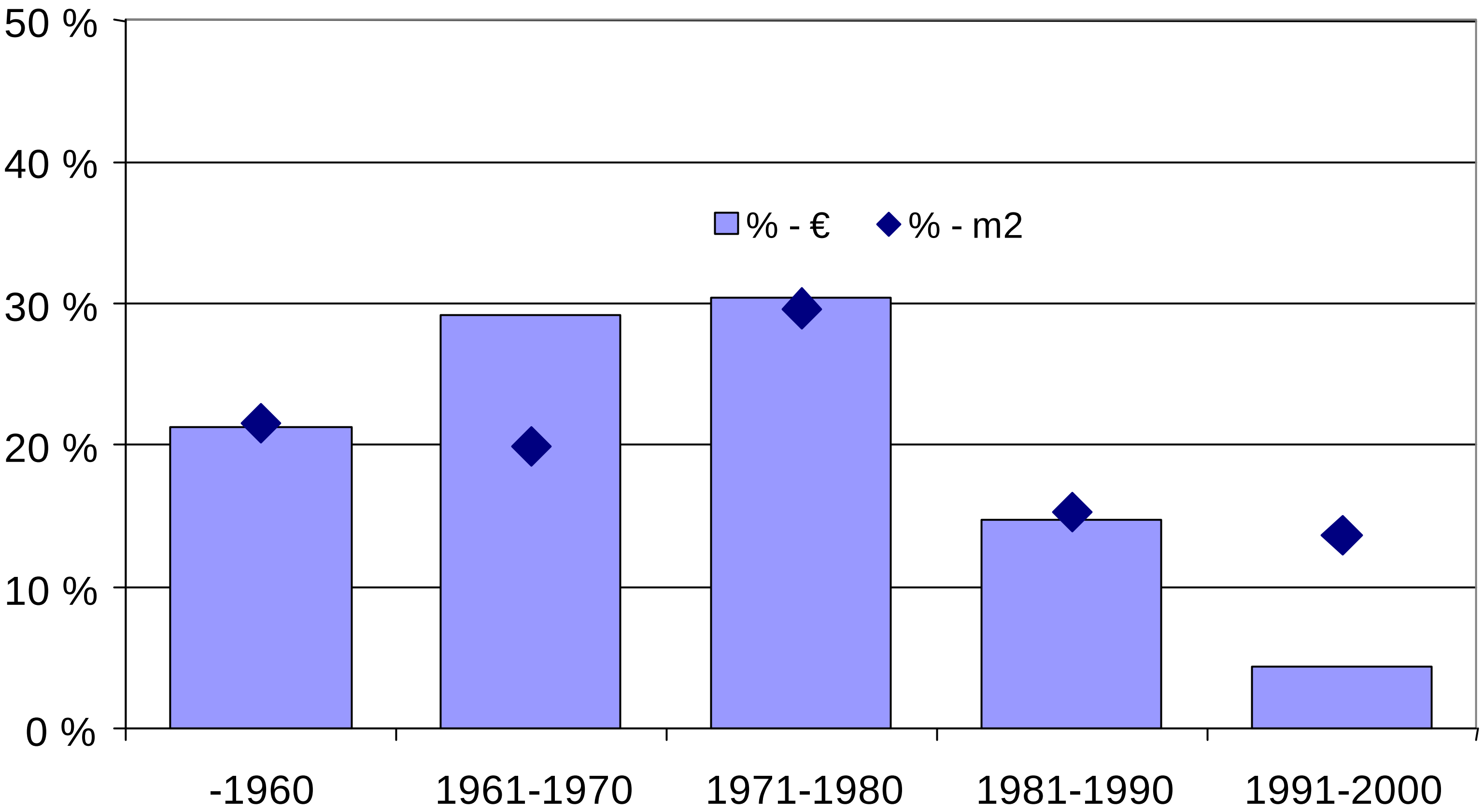
Renovation of buildings in the years 2000 and 2010



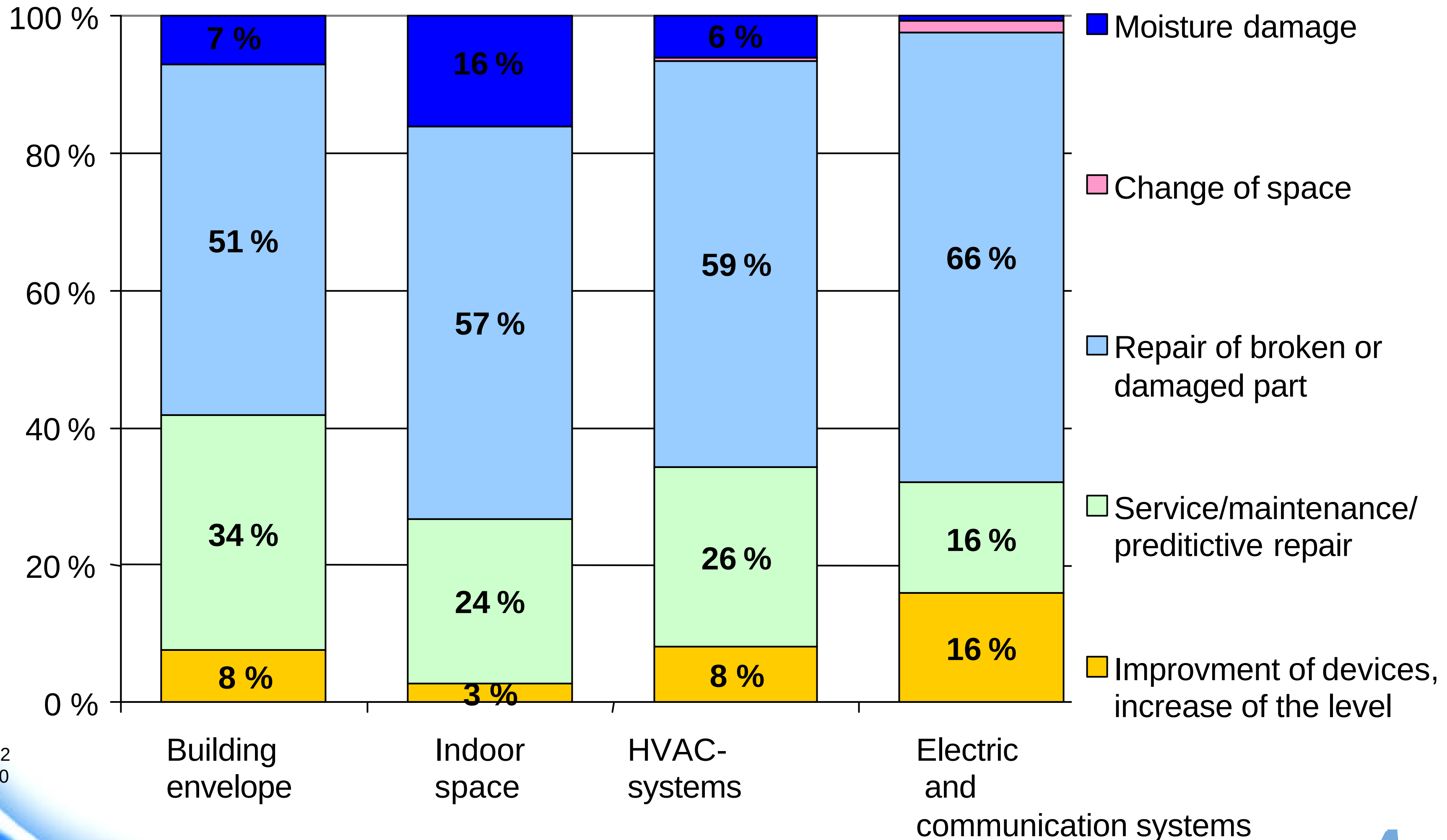
Renovation of apartment houses 2000 and 2010



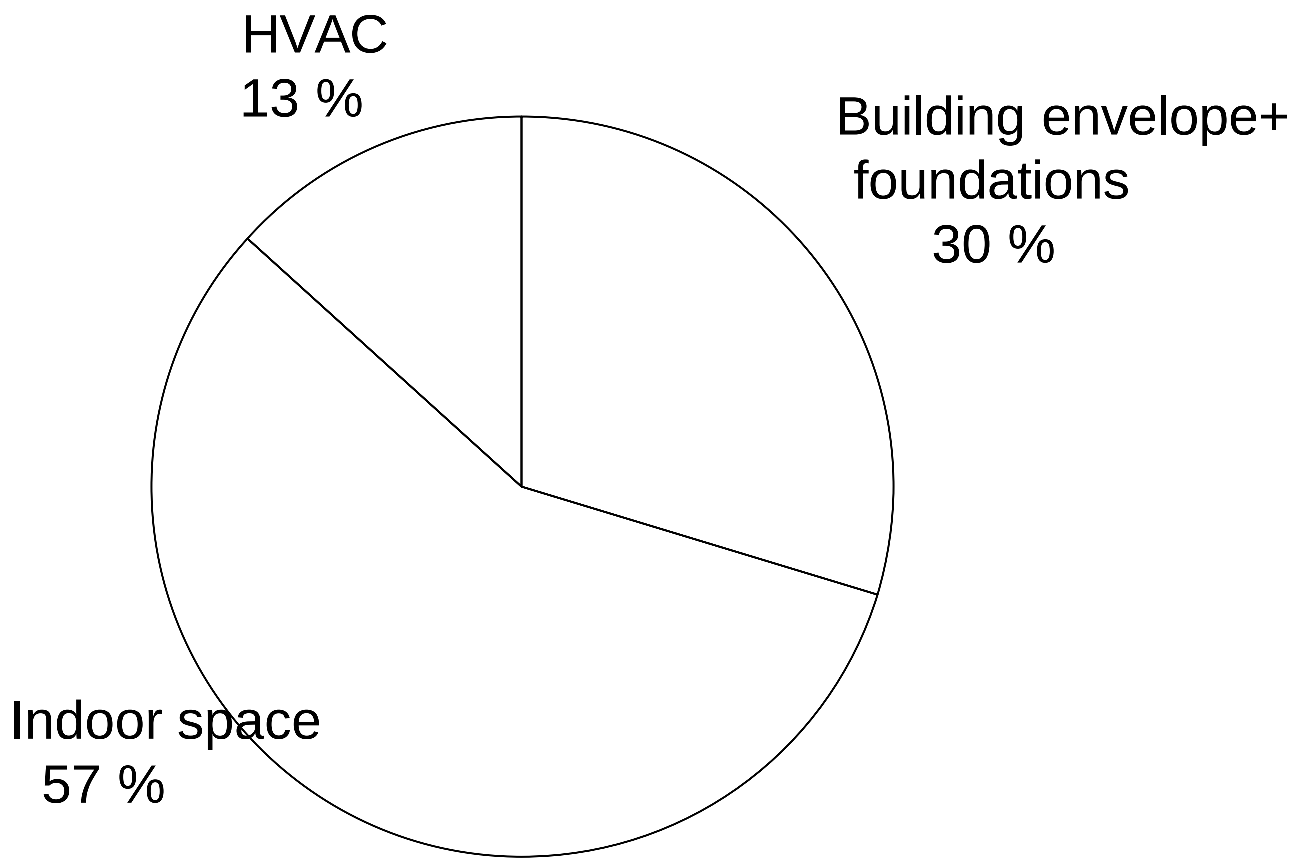
Renovation of apartment houses 1 410 milj.€, according to the age



The base for renovation of apartment houses



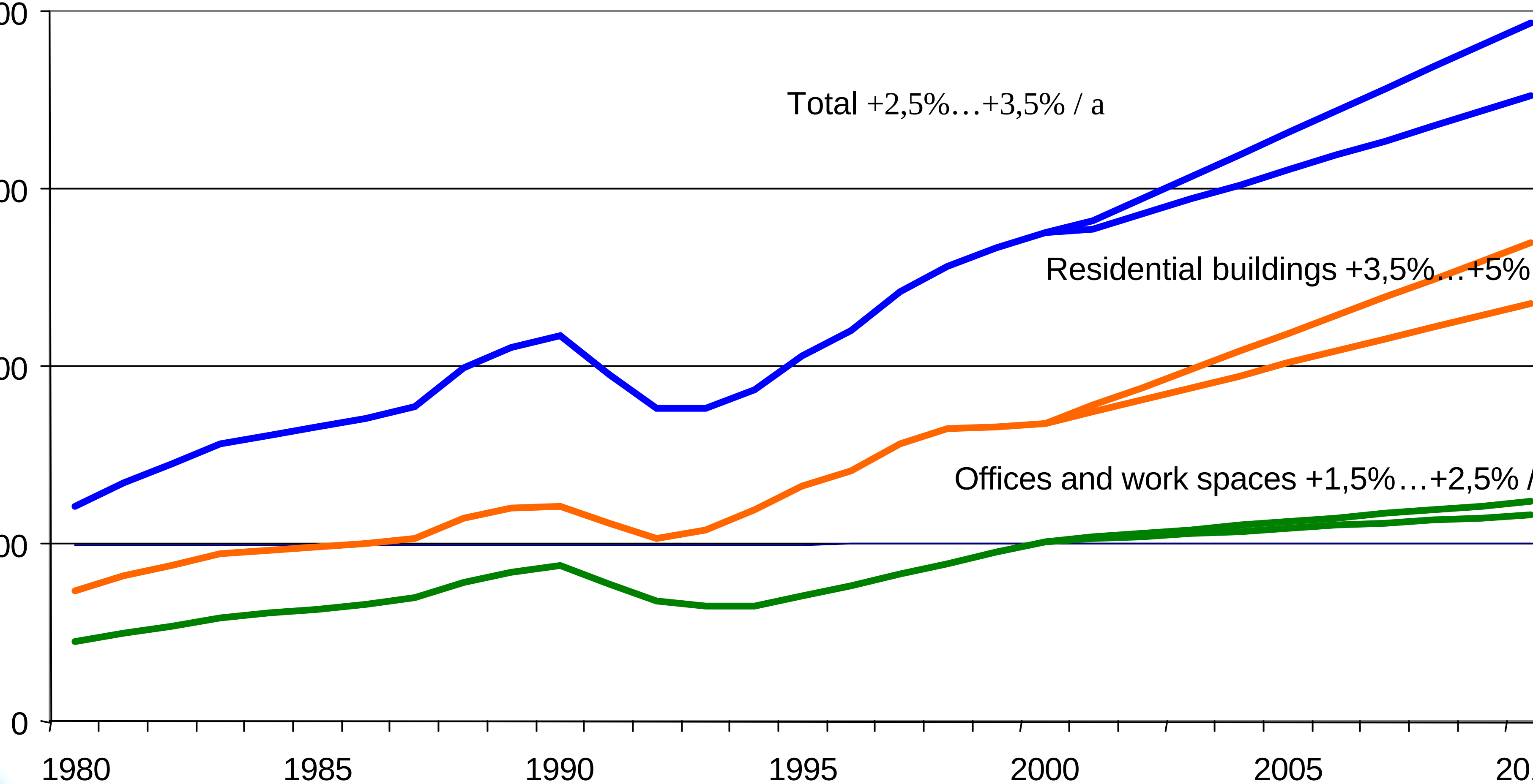
Renovation of apartment houses, 1 410 mio € total in the year 2000



5/2002
MO2000

Renovation to 2010

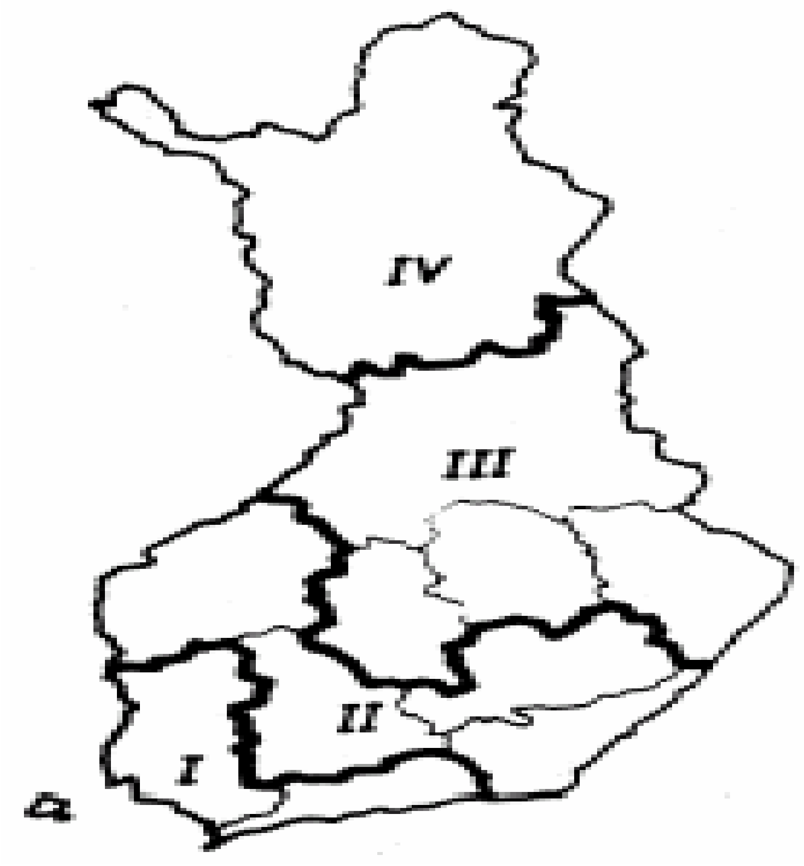
Mio €, by fixed prices year 2000



T 5/2002
MO2000

FINNISH BUILDING REGULATIONS

- Design temperatures
- Zone I: -26 °C
- Zone IV: -38 °C



FINNISH BUILDING REGULATIONS

Month	Degree day number S (20)			
	I	II	III	IV
1	800	817	879	1045
2	757	770	829	943
3	696	714	749	854
4	536	551	583	684
5	310	325	346	471
6	155	171	175	248
7	109	131	127	169
8	148	175	192	265
9	315	334	366	430
10	434	512	555	670
11	587	606	657	846
12	730	749	820	975
Year	5577	5855	6278	7600

Degree day numbers of periods colder than certain outdoor temperature

Month	outdoor temperature (°C)								
	+ 20	+ 15	+ 10	+ 5	±0	− 5	− 10	− 15	− 20
1	879	879	879	879	823	644	399	237	127
2	829	829	829	829	787	631	442	281	172
3	749	749	749	749	600	336	202	74	0
4	583	583	583	570	264	26	0	0	0
5	346	336	269	117	0	0	0	0	0
6	175	146	58	0	0	0	0	0	0
7	127	90	2	0	0	0	0	0	0
8	192	163	35	0	0	0	0	0	0
9	366	366	296	136	0	0	0	0	0
0	555	555	555	451	222	26	0	0	0
1	657	657	657	643	444	200	65	0	0
2	820	820	820	820	689	490	299	203	92
Year	6 278	6 173	5 732	5 194	3 829	2 353	1 407	795	391

FINNISH BUILDING REGULATIONS

- U-values (2002) valid from 1.10.2003 ?
- exterior walls 0.28(1983) ? **0.25** (W/m^2, K)
- roof ? **0,16**
- floor (air space) ? **0,20**
- floor (ground floor) ? **0,25**
- windows and floors ? **1,4**
- roof window ? **1,5**
- window area must be <15 % of total floor area and <50 % total area of exterior walls

- compensation: e.g. improved heat recovery of ventilation (if one single part does not fulfill requirements)

THE GUIDELINES OF THE INTERPRETATION

ndoor Air Guidelines (Ministry of Social Affairs and Health) before 2003:

The minimum surface temperatures (exterior walls, floors, joints and junctions

limitation for the use:
given minimum surface temperatures has not been fixed with
the temperature difference between outdoor and indoor

The lowest minimum temperature (in the occupation zone): 9 °C
(The dew point temperature for 21 °C, when RH = 45 %)
The conditions for measurements:

- Outdoor temperature at least -10 °C
- No unusual cold conditions
- No unusual high wind

THE GUIDELINES OF THE INTERPRETATION

The new guidelines (published in the year 2003)

Thermal indexes (TI):

Thermal index (TI) is determined by the equation

TI = (Tsp - To) / (Ti - To)*100 %

In which

TI	=thermal index
Tsp	= surface temperature °C (measured e.g. by infrared camera)
Ti	= indoor temperature
To	= outdoor temperature

THE GUIDELINES OF THE INTERPRETATION

VTT Building and Transport:

70 % thermal index for corners, edges and joints (in the building envelope)

Indoor Air Guidelines: (9 °C, when To = -10 °C and Ti = 21 °C) = **61 %** thermal index, valid in the occupation zone = 0,6 m from exterior walls

Outside the occupation zone: for performance evaluation

THE GUIDELINES OF THE INTERPRETATION

Suggestion for the following preliminary baselines of building thermography

• **TI < 60 %**	**healthy risks or hazards**
• **TI = 60 - 65 %**	**the details/structure must be checked, possibility for healthy hazards or structure risks**
• **TI = 65 – (70) 75 %**	**obvious defects or faults (thermal bridges, insulation defects etc.)**
• **TI >(70) 75 %**	**normal situation**

- Obs: Must be measured in steady-state conditions

Interpretation, T=22 °C

	k=0,28	k=0,40	k=0,50	k=0,60
Tu	Tsp	Tsp	Tsp	Tsp
0	21,2	20,8	20,5	20,2
-10	20,8	20,3	19,9	19,4
-20	20,4	19,7	19,2	18,6
-30	20,0	19,2	18,5	17,8

Interpretation, T=22 C

	TI=95	TI=90	TI=85	TI=80	TI=75	TI=70
T_u	T_{sp}	T_{sp}	T_{sp}	T_{sp}	T_{sp}	T_{sp}
0	20,9	19,8	18,7	17,6	16,5	15,4
-10	20,4	18,8	17,2	15,6	14,0	12,4
-20	19,9	17,8	15,7	13,6	11,5	9,4
-30	19,4	16,8	14,2	11,6	9,0	6,4

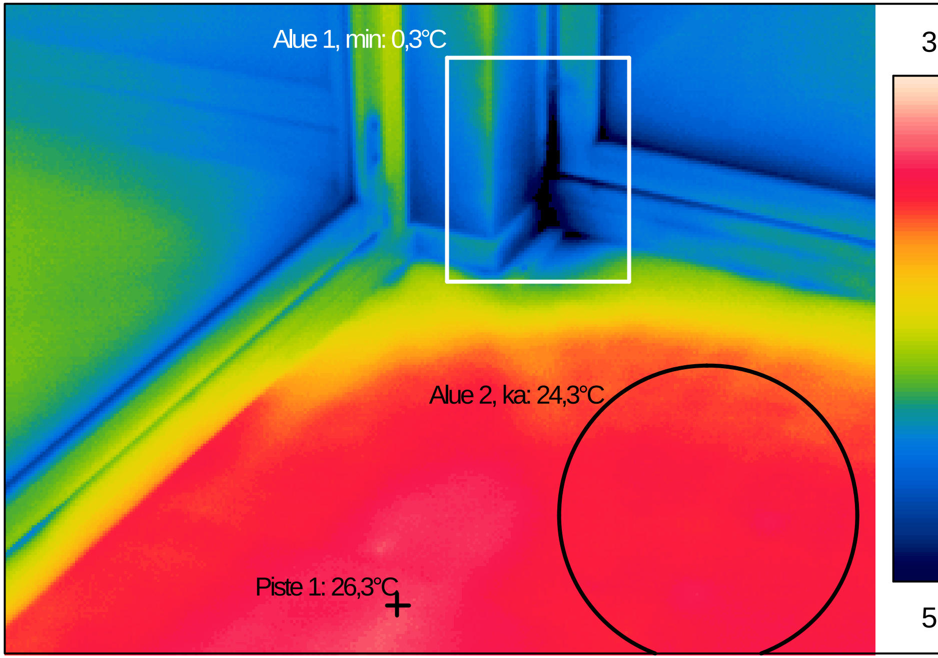
The use of thermography

e other factors:

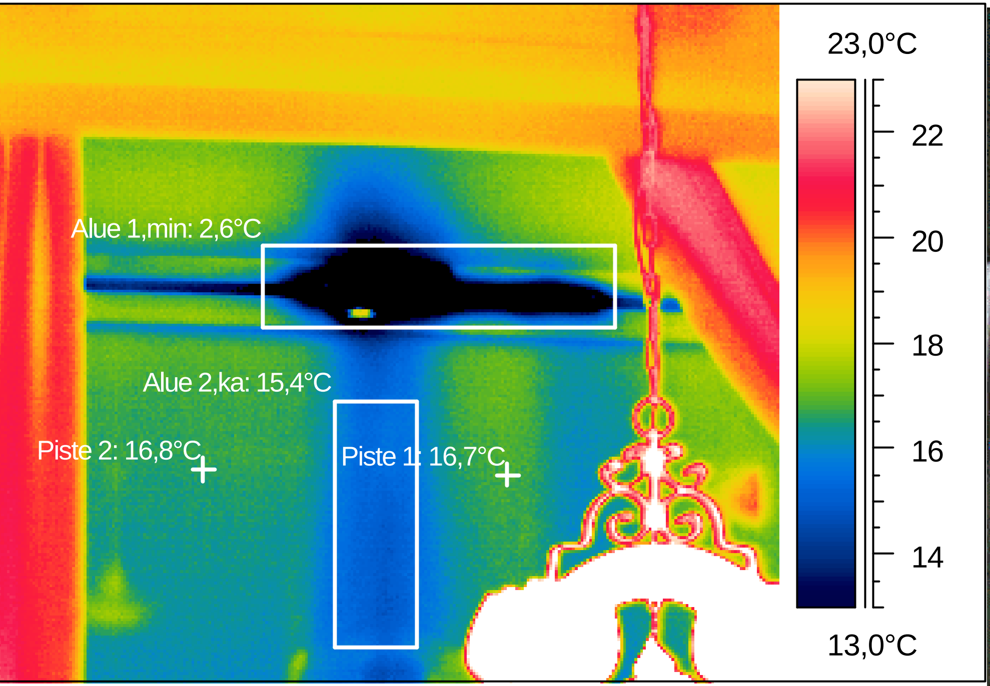
leating system

or heating

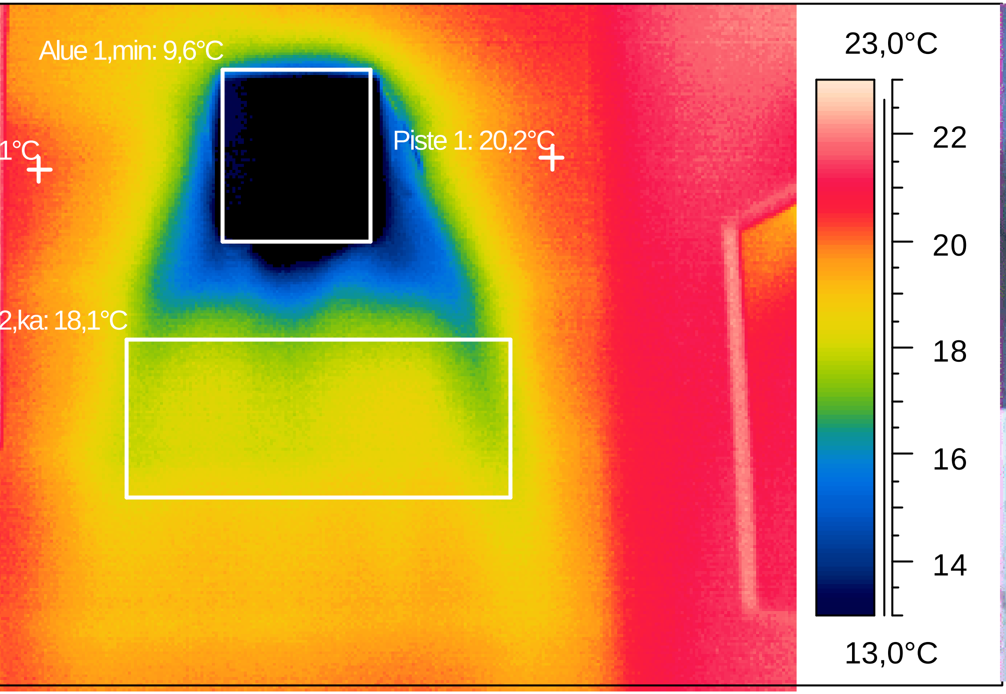
Thermal image

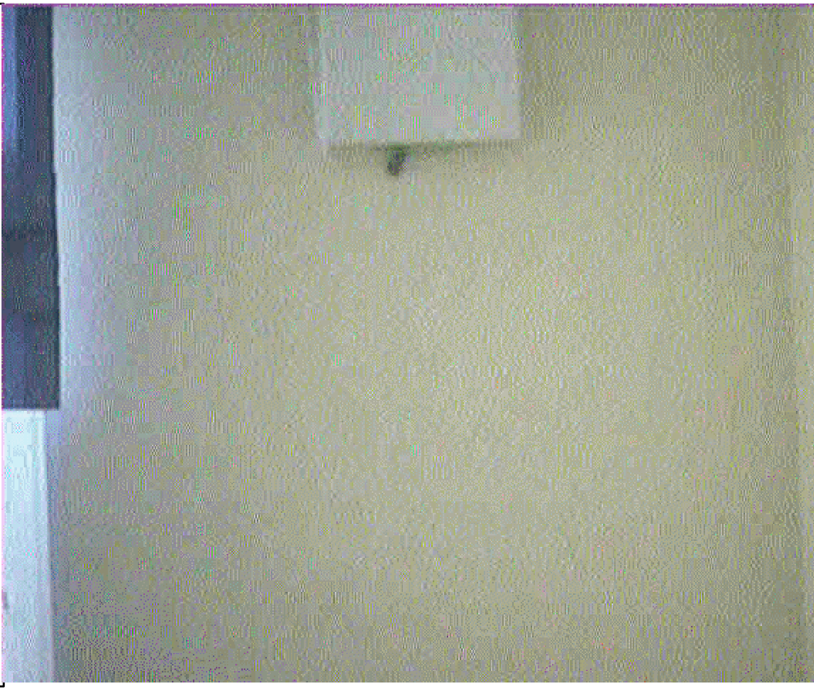


Ventilation system

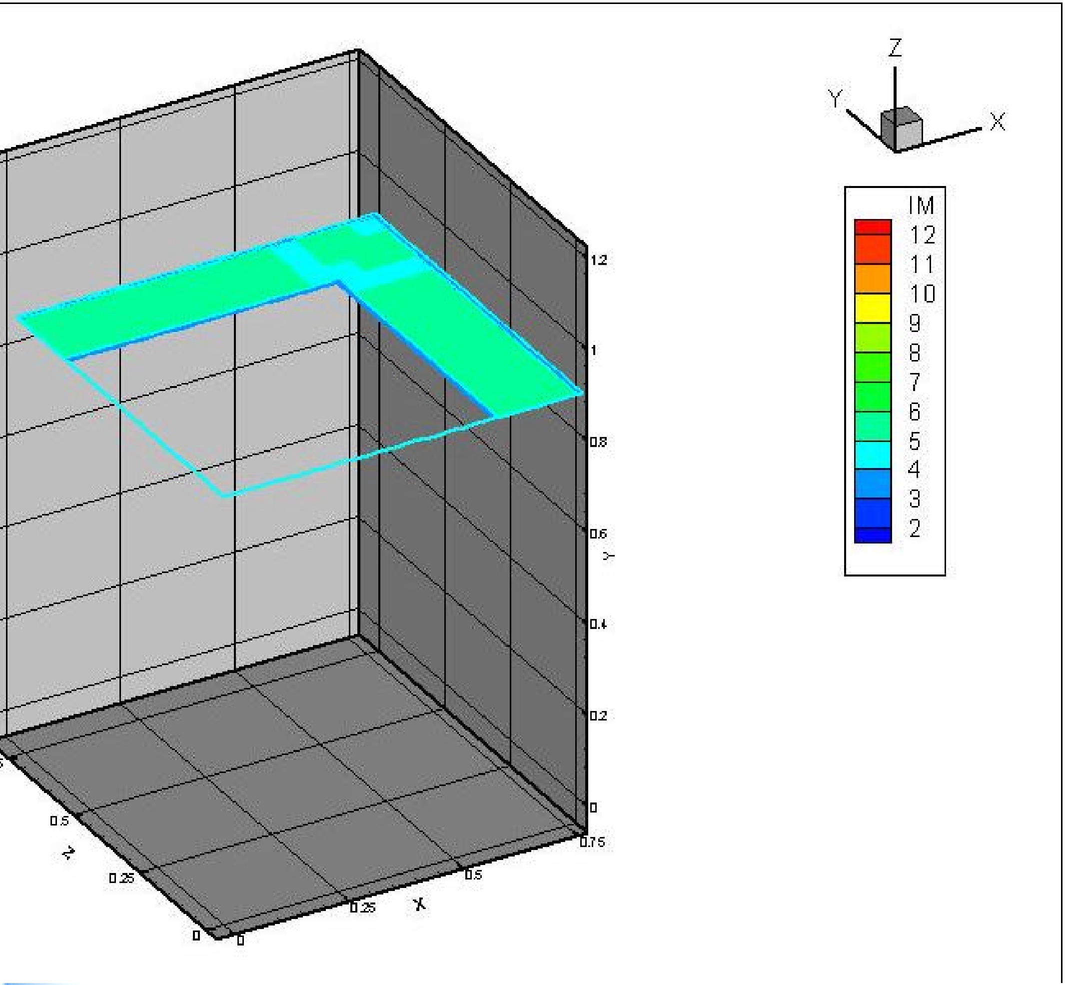


Ventilation system





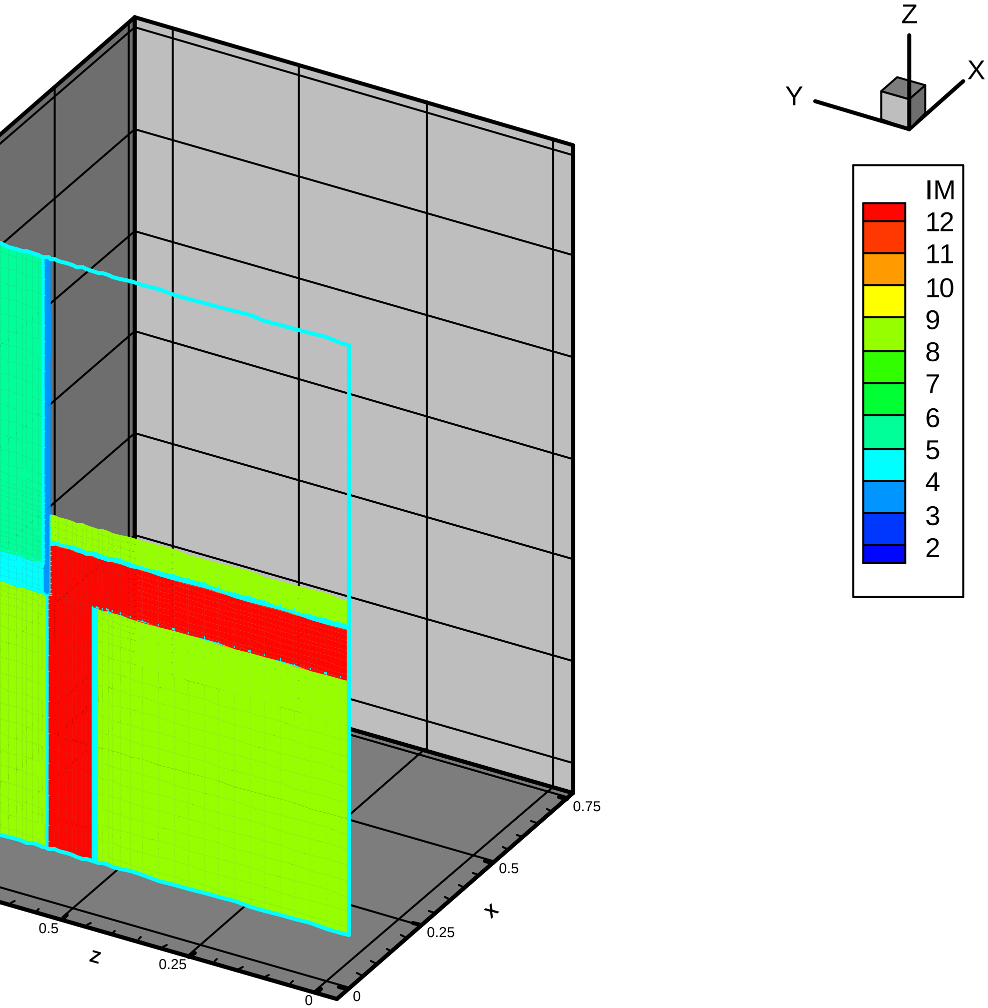
Air tightness



Calculation example

- •Surface temperatures (air leak case and no air leaks)
- •Light wall
- •Three cases
- •No leak
- •Air leak 0,25 L/s,m
- •Air leak 0,025 L/s,m.
- •Air leak 0,25 L/s,m causes for a house 150 m2 untcontrolled air exchange 0,12 1/h,
- • 0,025 L/s,m = 0,012 1/h

Air tightness



Calculation example

Green = mineral wool

Dark blue = gypsum board

Light blue = wood

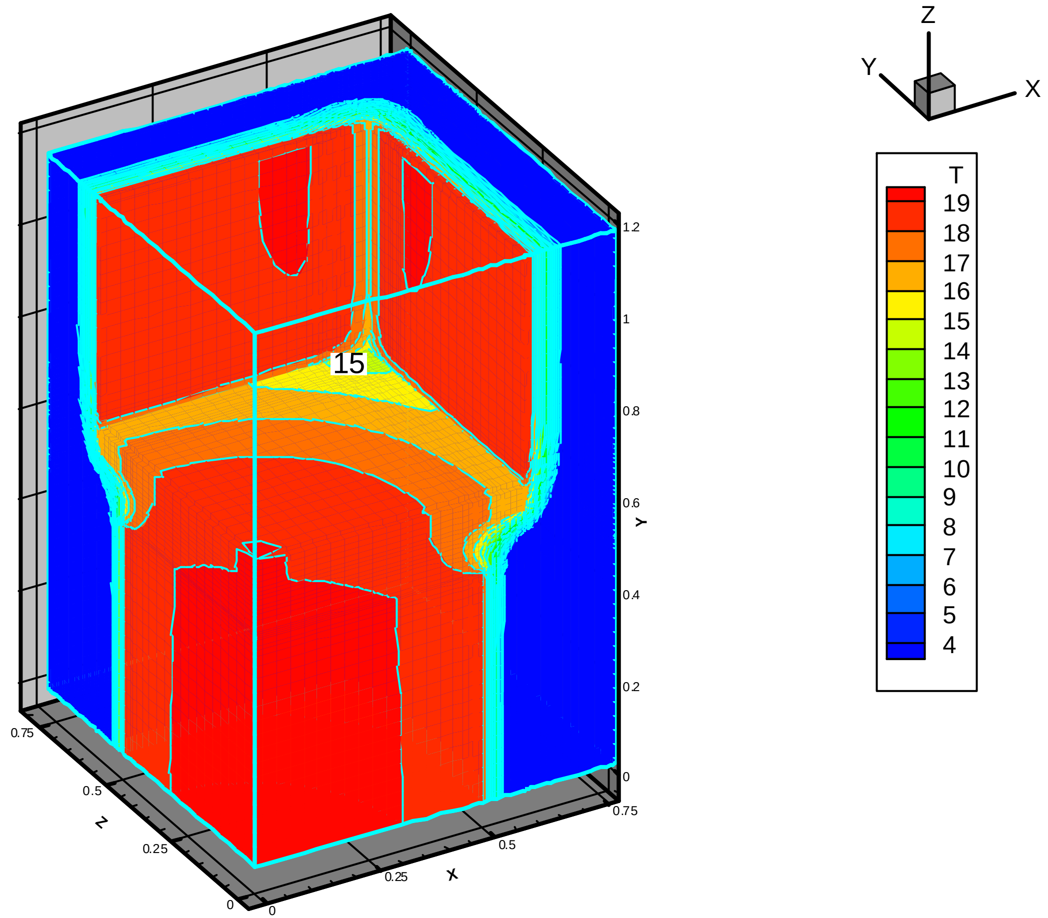
Red = EPS

Concrete = yellow green

T outdoor –20ºC

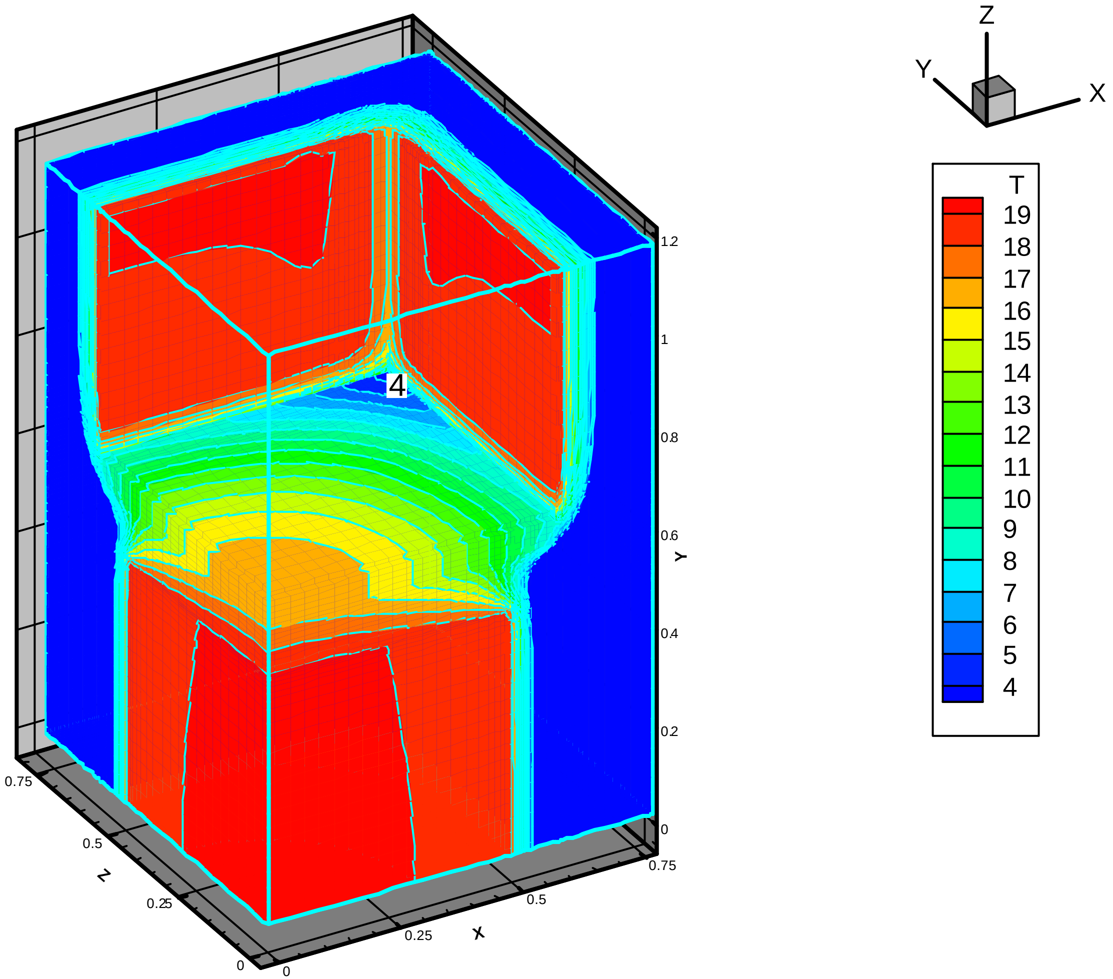
T indoor +20ºC

Air tightness



No air leaks, Tmin = 15°C

Air tightness



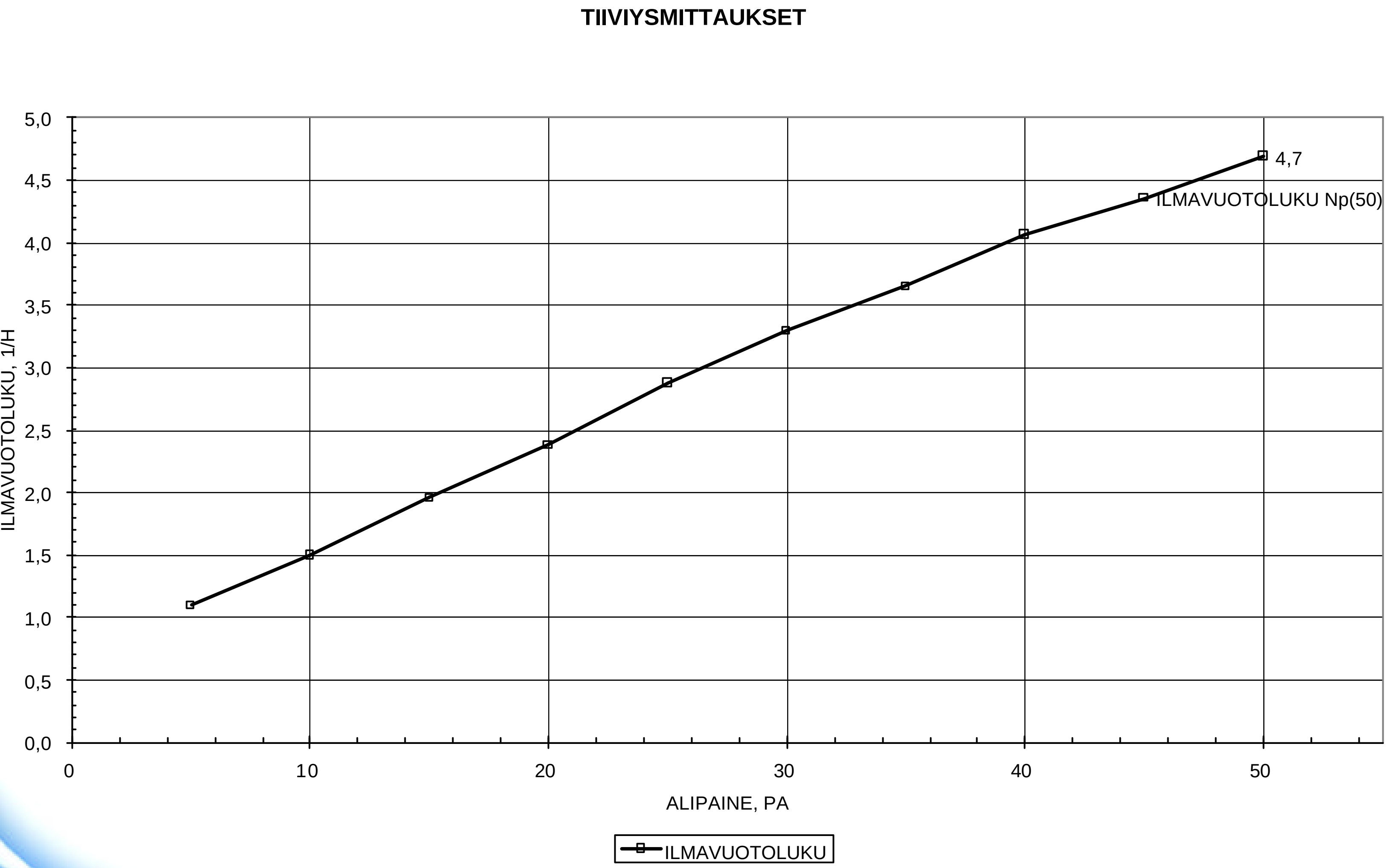
Air leak 0,25 L/s,m, Tmin = 4° C

Condition survey and performance studies
Condition survey before renovation

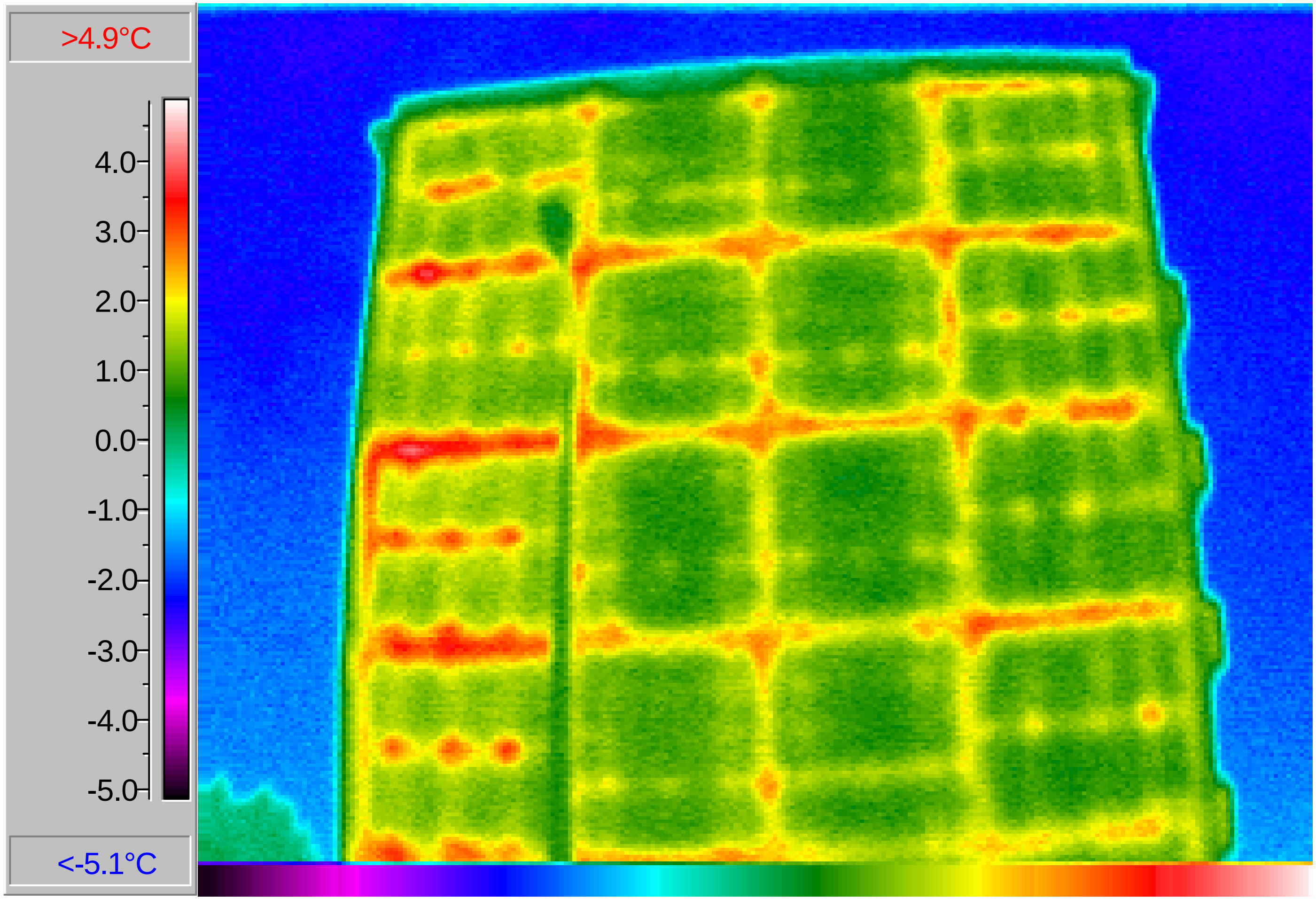
- Benchmarking of consumptions (if needed, comparison to the surrounding/same type of buildings, if information available)
- Monitoring of the thermal performance of exterior walls
    - outdoor and indoor thermography
    - blower-door tests (air tightness)
    - heat-flux measurements
    - indoor surface tempererature measurements (single/continued)
    - quality of the concrete and reinforcement/wall materials
    - checking of the windows and panel seams

Air tightness test

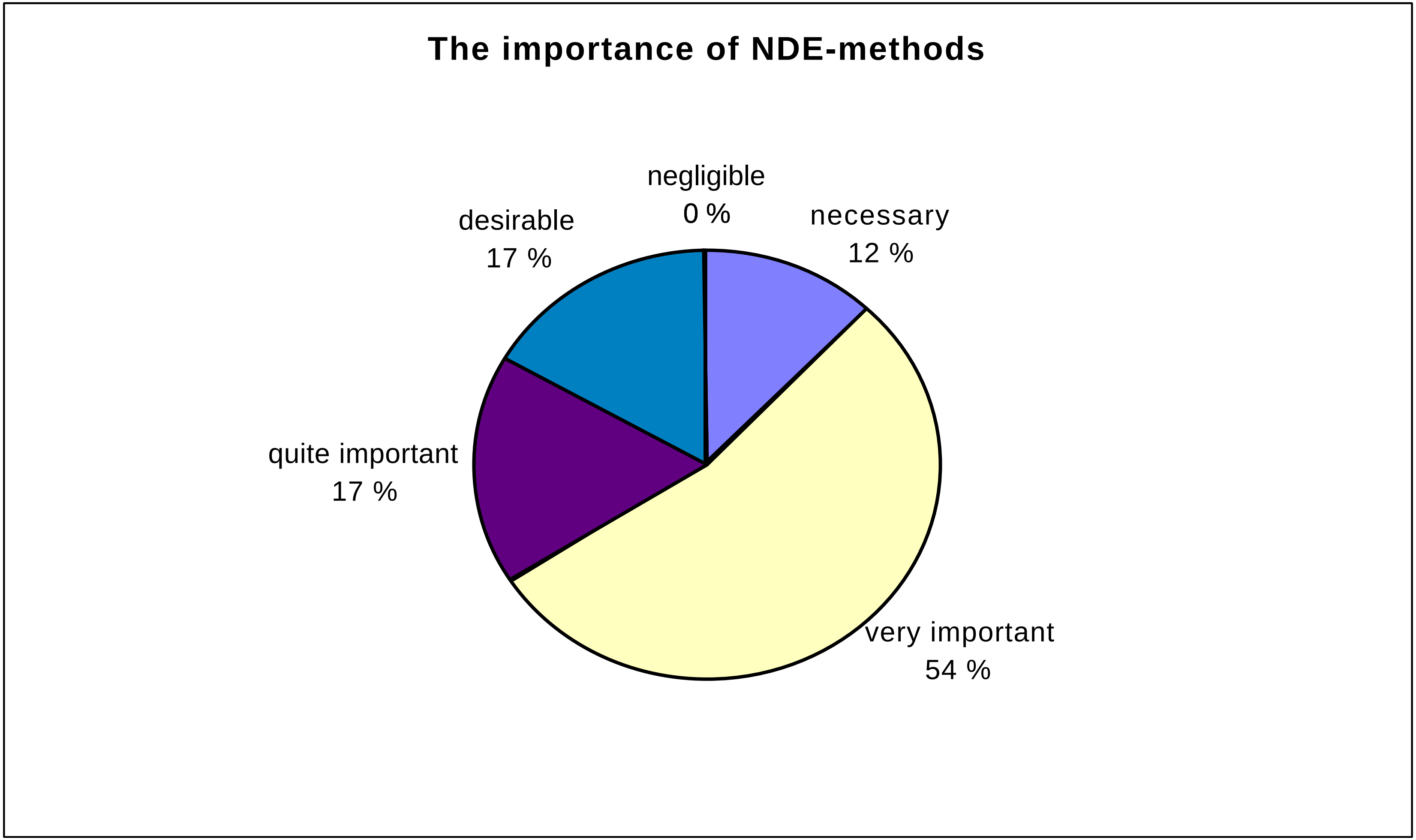
Air tightness, leak curve from 0 – 50 Pa negatyive pressure drop
Air leak number at 50 Pa negative pressure drop 4,7 1/h



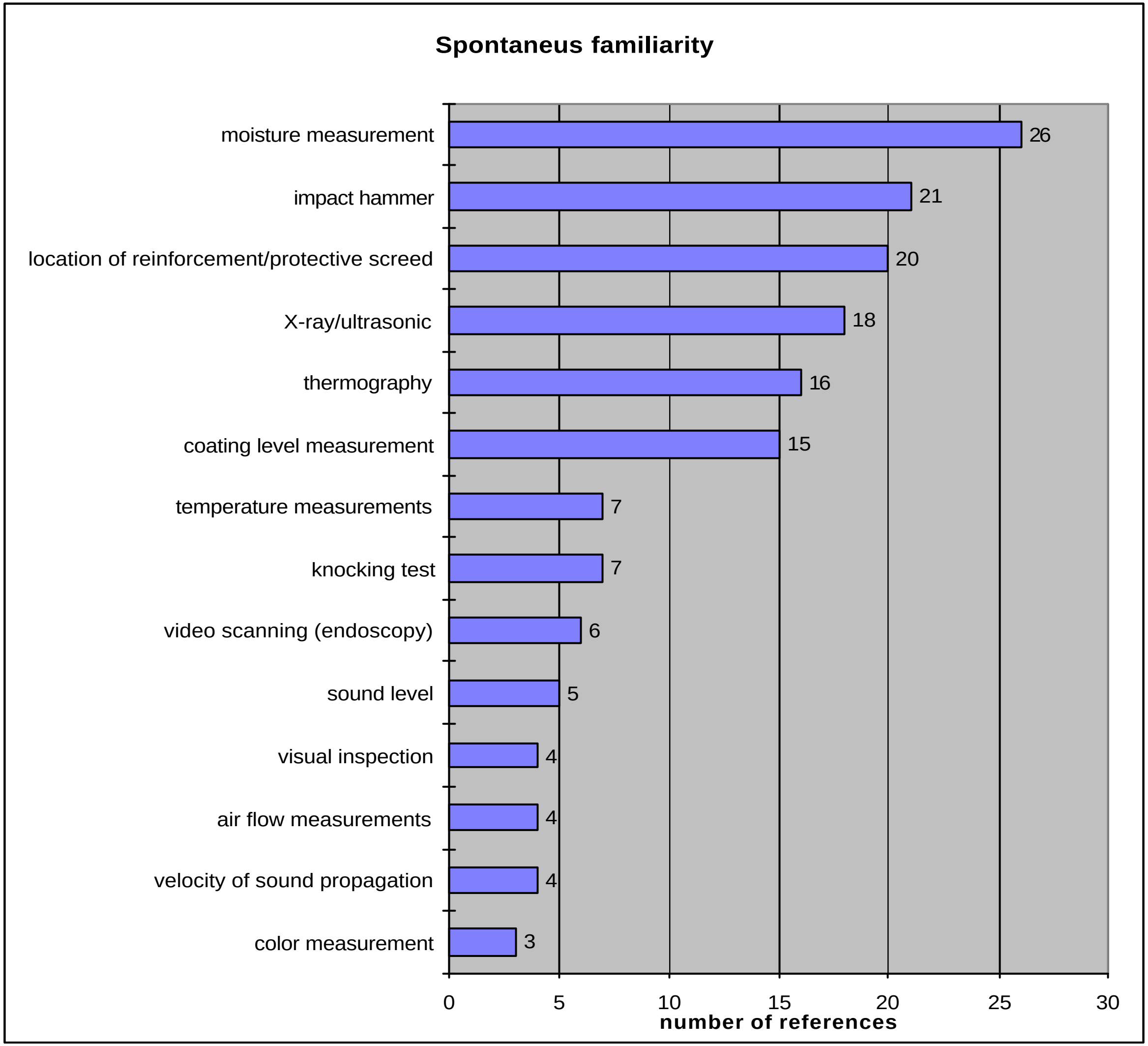
Outdoor thermography



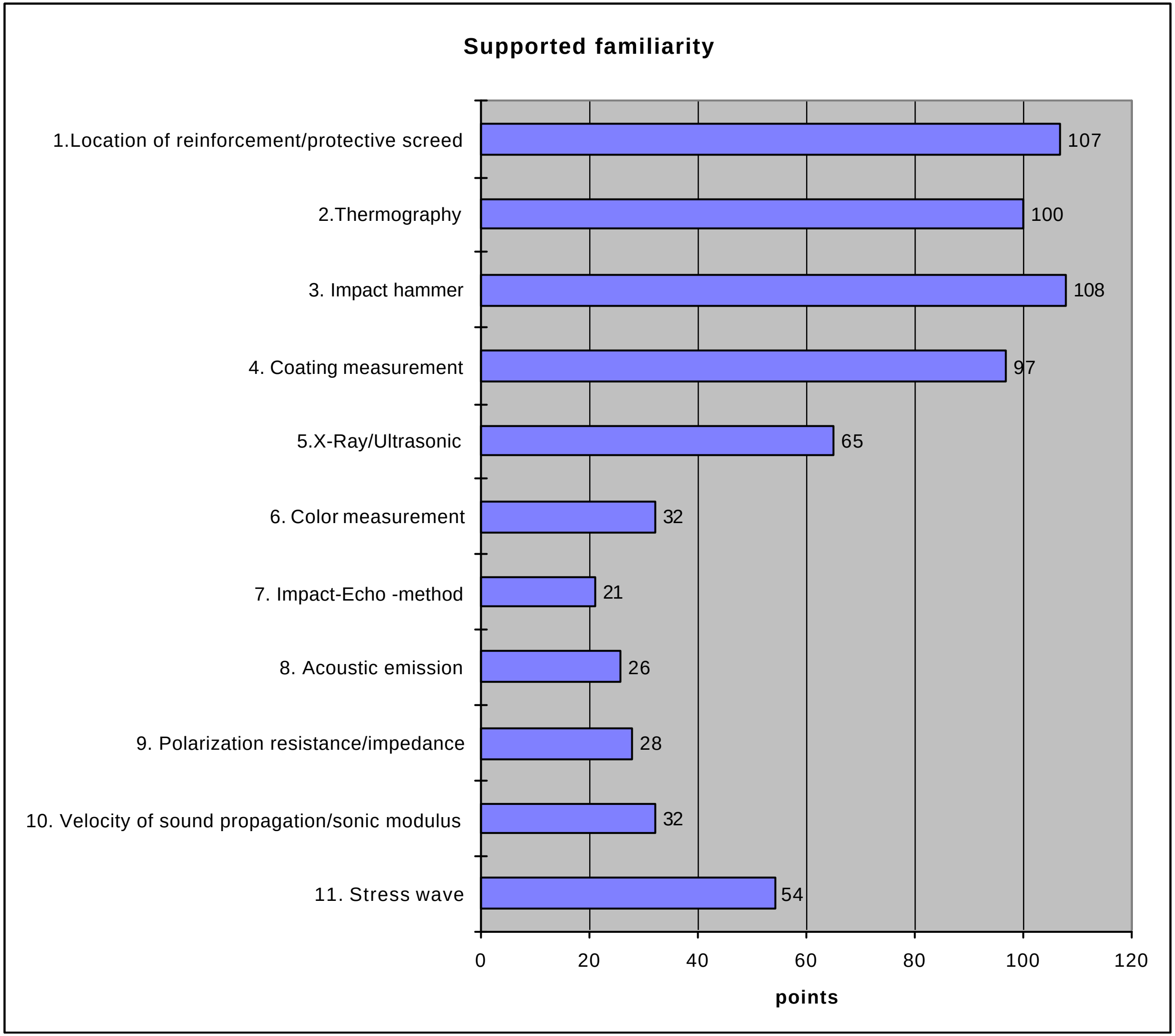
The importance of NDE-methods in construction



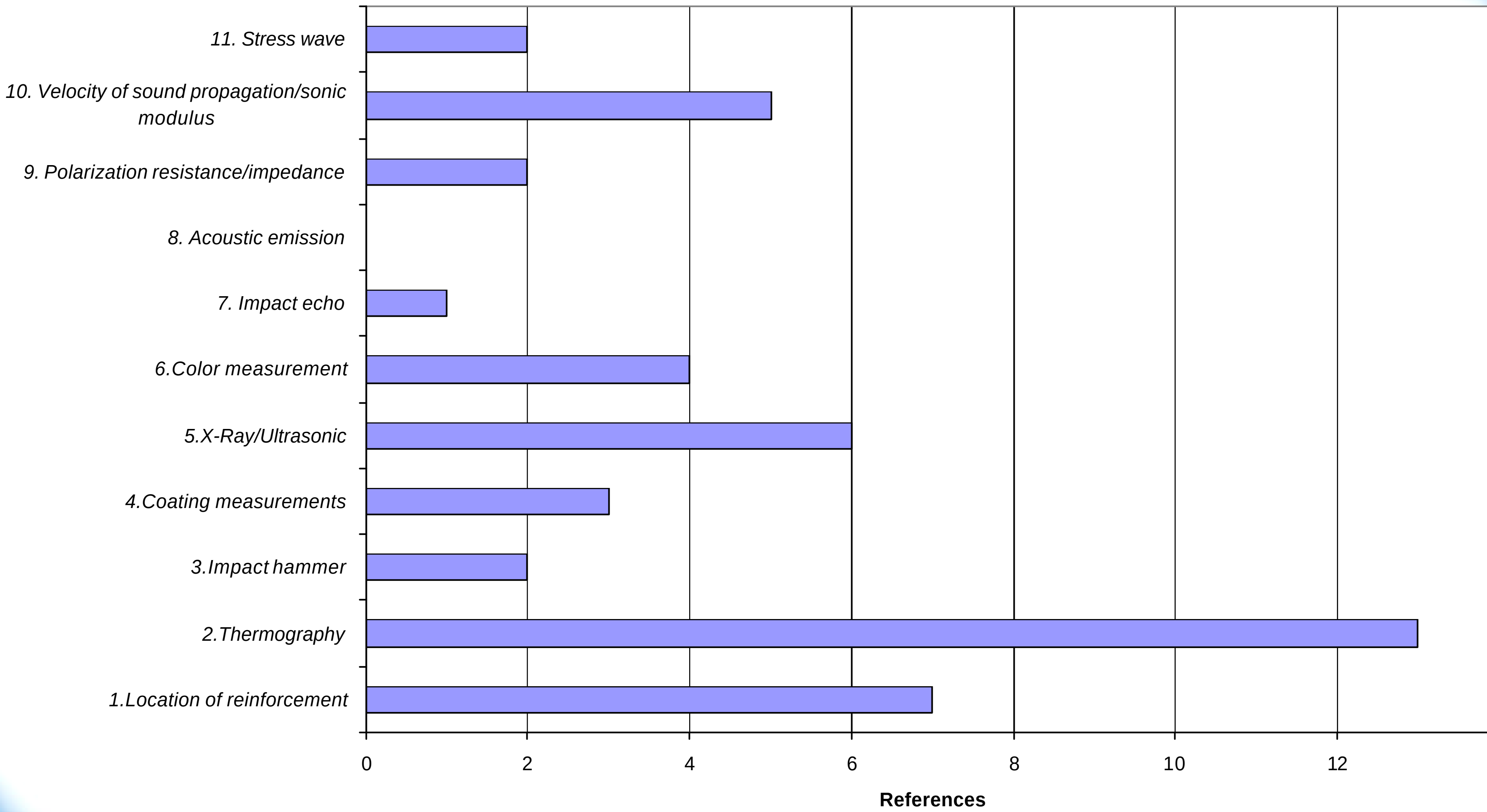
The spontaneous familiarity of different NDE-methods



Supported familiarity of NDE-methods



The use potential in commercial scale



CONCLUSIONS

The users, utilizers and thermographers would like to have

- clear and unambiguous guidelines and instructions
- base for interpretation.
- The need for generally accepted procedure for building thermography is very evident.
- This procedure should include the thermography practice and the conditions (pressure conditions, the use of ventilation system, indoor- and outdoor temperatures etc.) where thermography would be available and could be used
- also with guidelines for interpretation.

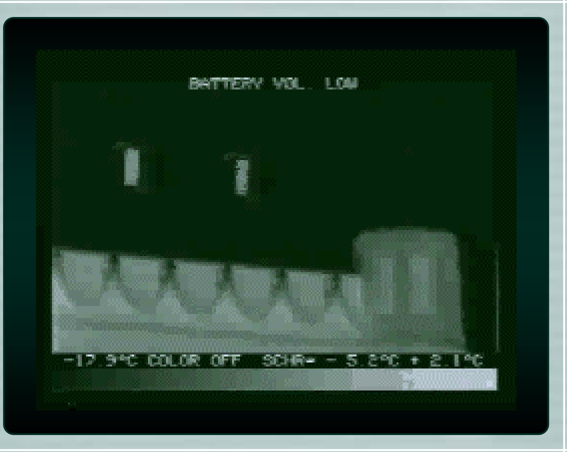
CONCLUSIONS

- In year 2004 the various organizations in building trade launched a pilot project to certificate building thermographers.
- The procedure is divided into two parts: Part 1 is Level I (the basis of thermography) and Part II (divided into two periods) thermography applications of buildings, including also information on building physics, heat and mass transfer and structures.
- Both parts will take a week, two weeks in total with the examinations. The procedure follows moisture measurement procedure - certification of building moisture measurements started a couple of years ago.

Canadian Building Thermography Standards: Creating A Level Playing Field

Tony Colantonio

Building Enclosure Architect
Public Works & Government Service Canada



History:

Infrared thermography was introduced into building applications in the late 1970’s in part to respond to the energy crisis of the day

- Thermography was implemented to detect insulation abnormalities in walls and roofs.
- In cold climates such as Canada, this technology was focused to look for air leaks and resultant moisture problems.
- It was not until the 1990’s that moisture within building envelopes was tied to IAQ investigations.

Infrared Thermography Standards.

- **ANSI - ASHRAE 101. 1981**,
  Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics
- **ISO – 6781 - 1983**,
  Thermal Insulation – Qualitative Detection Of Thermal Irregularities In Building Envelopes – Infrared Method
- **CGSB – 149 – GP –2MP - 1986**,
  Manual For Thermographic Analysis of Building Enclosures
- **ASTM – C - 1153 - 90**,
  Standard Practice for the Location of Wet Insulation in Roofing Systems Using Infrared Thermography
- **ASTM – C – 1060 - 90**,
  Standard Practice For Thermographic Inspection of Insulation Installations In Envelope Cavities of Frame Bldgs

Canadian Building Standards:

National Building Code

- Federal facilities, overall model for provincial codes.

Provincial Building Codes

- Building codes for all non federal buildings administered though Provincial Building Codes.

Federal Incentive Programs

- R-2000 (residential, air tightness specific).
- C-2000 (commercial, total energy specific).
- CBIP (financial incentives for energy design and modeling).
- NR Can Energy Audit Program (cash back for implementing energy saving recommendations).
- NR Can Energy Reduction Programs (through Utilities and private sector organizations).

- cont'd

Canadian Building Standards: *- cont'd*

Sustainable Green Building Initiatives

Sustainability Initiatives

- Employ a much broader set of objectives in evaluating energy and sustainable design objectives for new and retrofit building projects.
- Energy performance is only 25% of total evaluation criteria of total evaluation criteria.

LEED

- Primary assessment tool promoted in North America for evaluation of sustainable design to meet KYOTO objectives.
- Approved in 2004 for Canadian Building Certification
- Promotes whole building integrated design process (IDP).

How Does Thermography Fit Into the Big Picture :

- It is an NDT able to detect problems before physical symptoms appear.
- Used to optimize envelope performance from start to reduce energy costs.
- Increases building durability through timely minor repairs and reduces life cycle costs.

Thermal Comfort & IAQ
Verification and Remediation

For all buildings

- Improvements to occupant comfort and safety result in increased work productivity and reduced stress on Health Care Systems
- This level of investigation required greater knowledge of IAQ investigation presently provided by industry but one that will have a great impact on Sustainable Design and its implementation.

Infrared Thermographic Services Specifications

- Although we have standards that indicate how certain infrared thermographic inspections are to be carried out, specifications for these services are often very sketchy and not enforced since consultants do not know what they are asking for.
- Consultants do not define the specific purposes of the inspection services. They do not define the minimum equipment specifications, or operator and report writers' expertise to provide such services.

- cont'd

Infrared Thermographic Services National Master Specifications *- cont'd.*

- Presently address 4 activities of Infrared thermography for building diagnostic inspections.

- Determination of Air Leakage Through Exterior Walls and Roofs
- Determination of Thermal Irregularities
- Determination of Water Penetration & Moisture Accumulation in Exterior Walls
- Determination of Water Penetration in Low Slope Built Up Roof Assemblies.

Infrared Thermographic Services National Master Specifications *- cont'd.*

- There are many other specific procedures that the NMS should address and each needs to be addressed individually.

- Determination of Thermal Comfort Problems in Perimeter Zones of Buildings
- Identification of Concrete Reinforcement In Hollow Masonry Block Walls
- Detection of Moisture in Exterior Insulation Face Seal Assemblies.
- Detection of Biological Attack of Wood Structures
- Air Tightness Testing For Containment Assemblies in Building Interiors
- Void Detection in Concrete and Masonry Wall Assemblies.


COLOR OFF


-12.8°C IMAGE MODE IMG AVG=64 F + 7.2°C

DANAHER FLUKE Raytek A Fluke Company

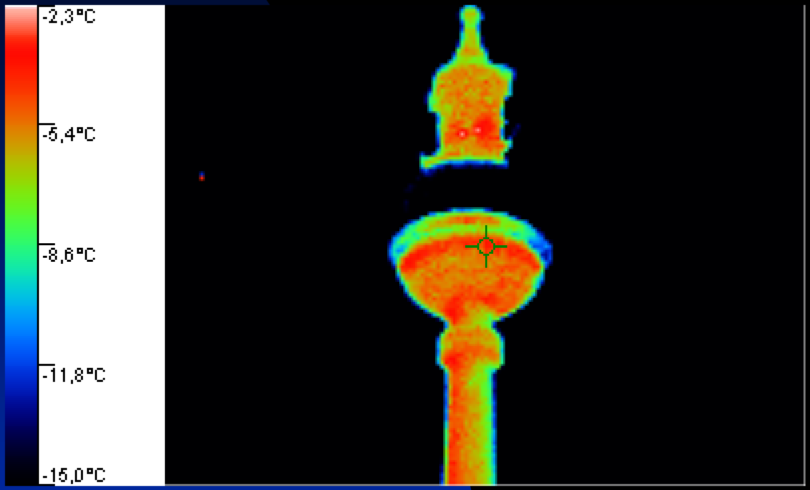
The German approach to thermal insulation of dwellings and checking with thermography

Mr. Dr.-Ing. Helge Brüggemann

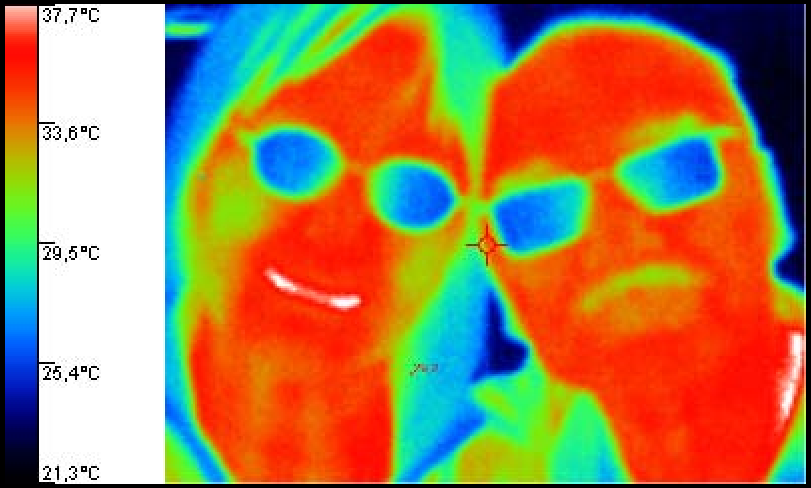
Feb 23rd 2005 UK, Teddington

Thermal Imaging for Building Fabric Insulation Compliance

I am from Berlin...



...and these are my parents.

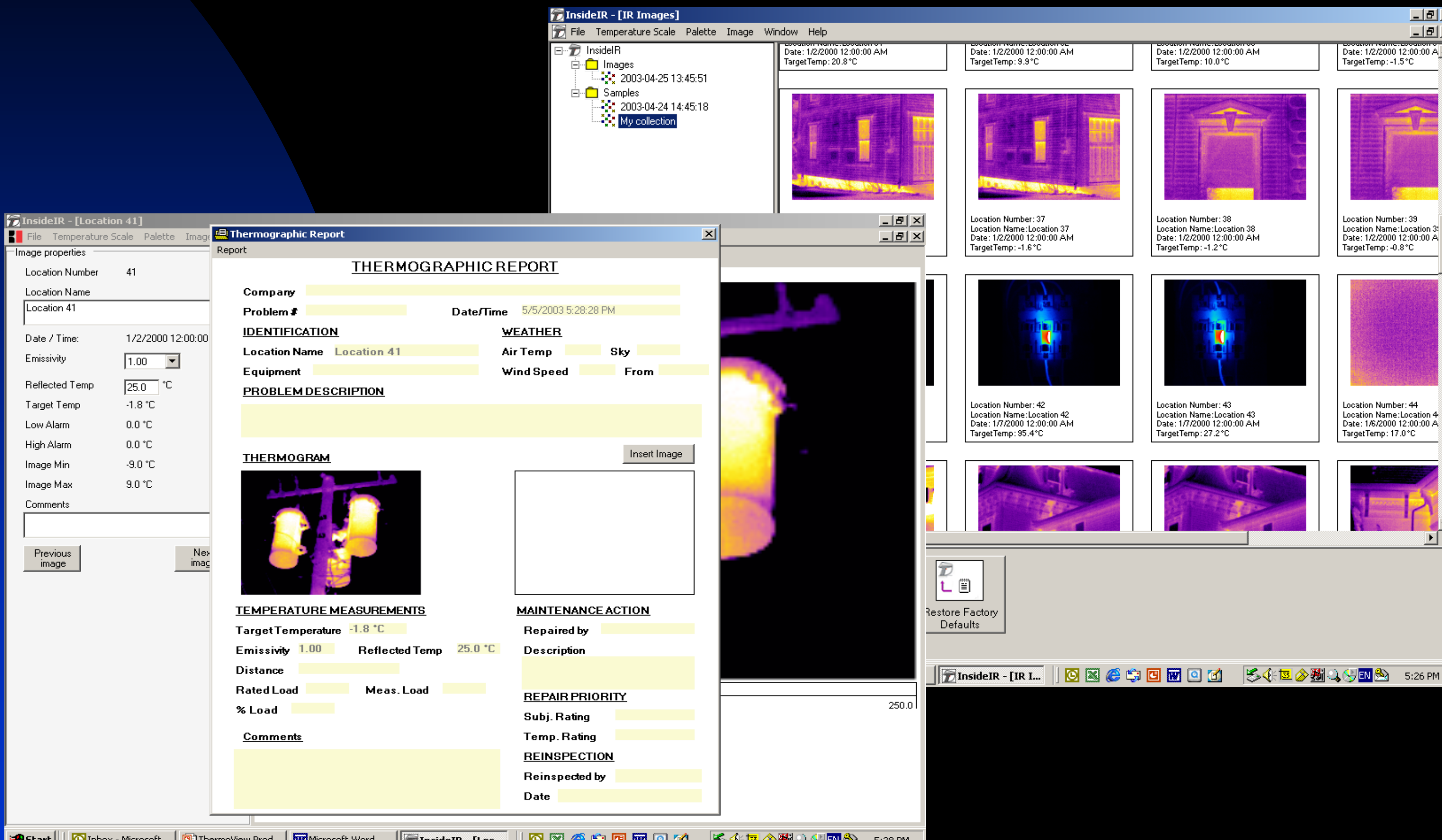


Raytek: producer of thermal imagers and world leader in noncontact temperature measurement

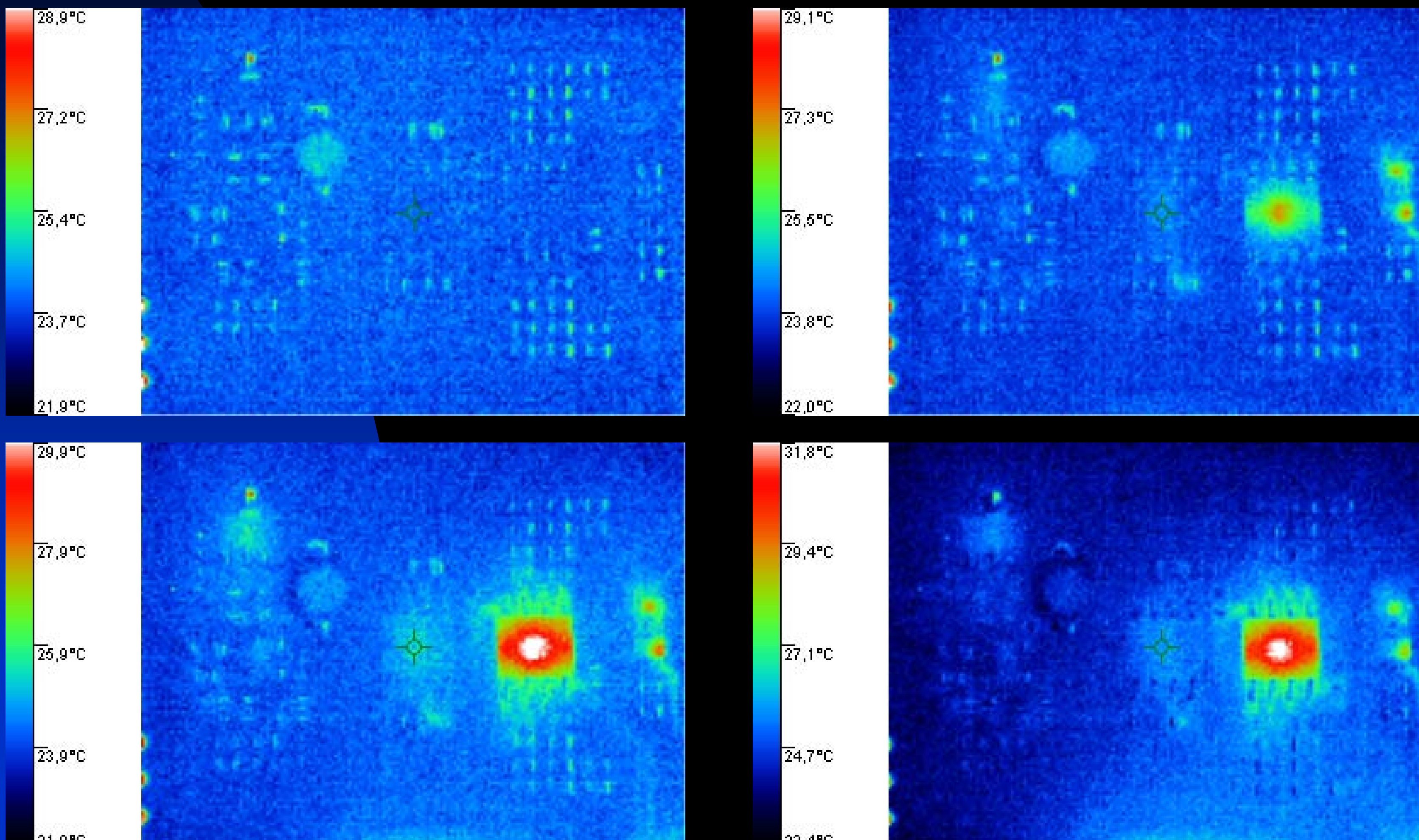
main features of Fluke Ti30 thermal imager

- complete imaging solution
- lowest cost of ownership
- designed for predictive maintenance
- 10 k€ / 10 kUS$

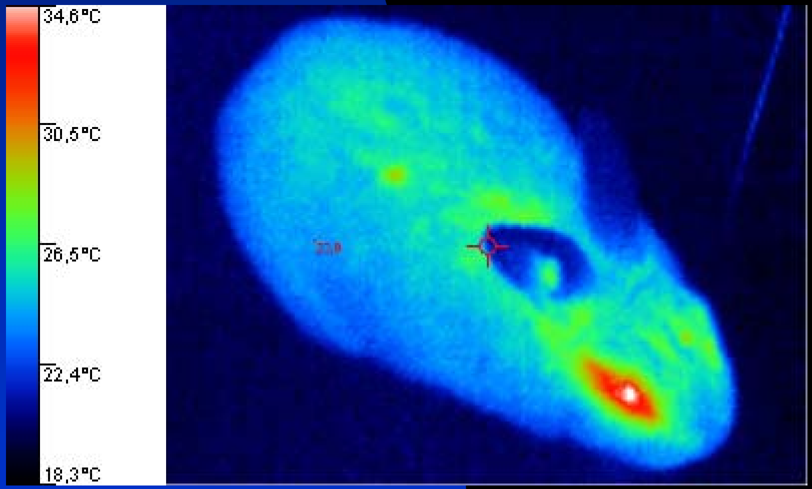
software highlights



You can check your own IC on PCB...

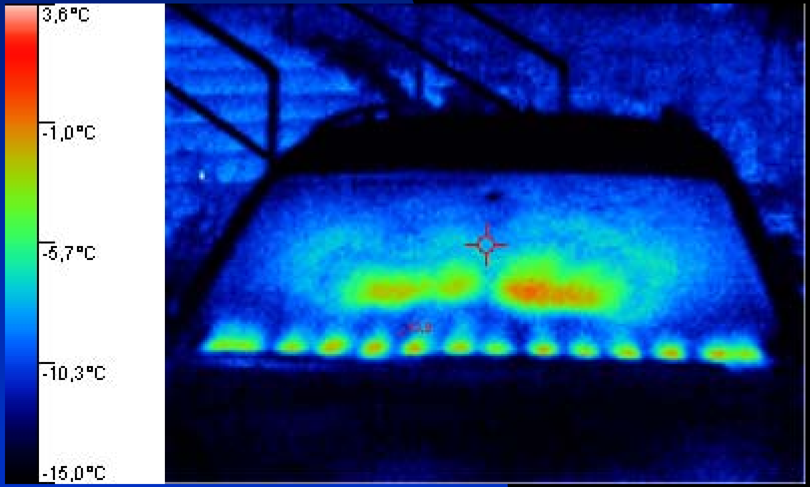


You can check your own animals...

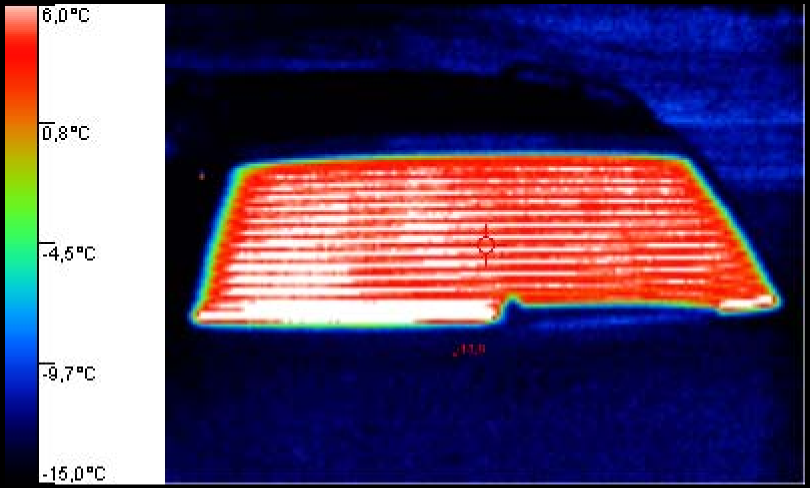


You can check your own car a/c...

warm up at front screen



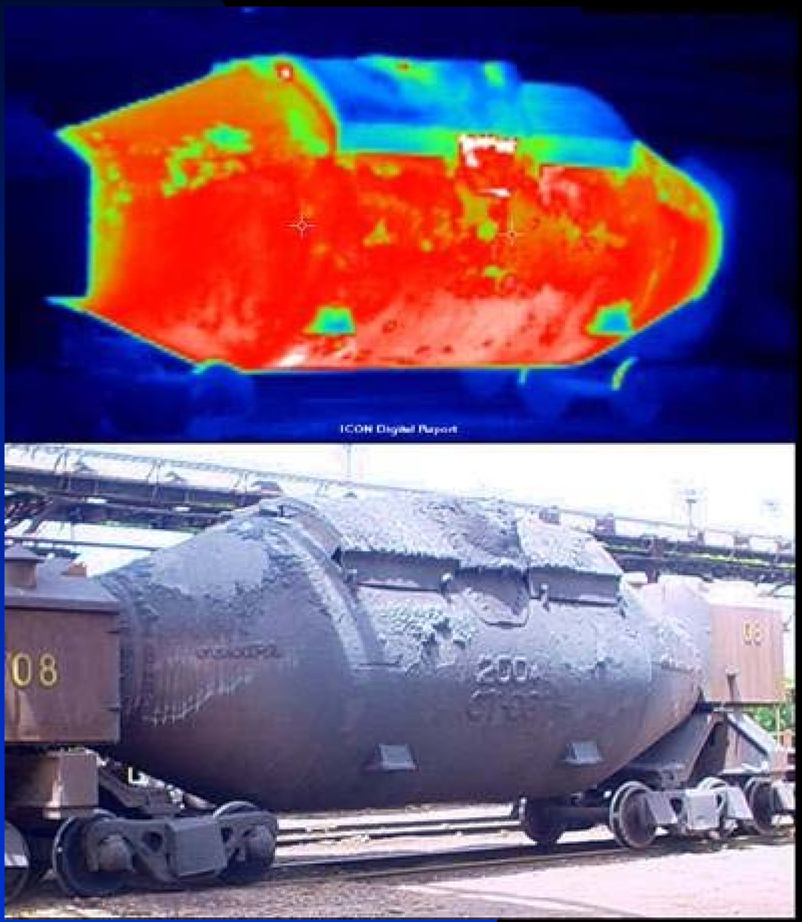
electric heat wire at back screen

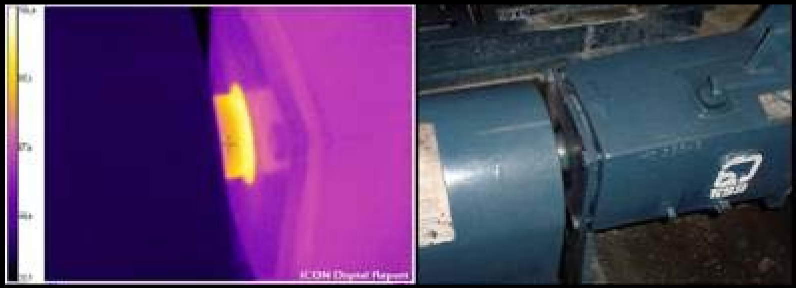


You can check your own cars or own trains...

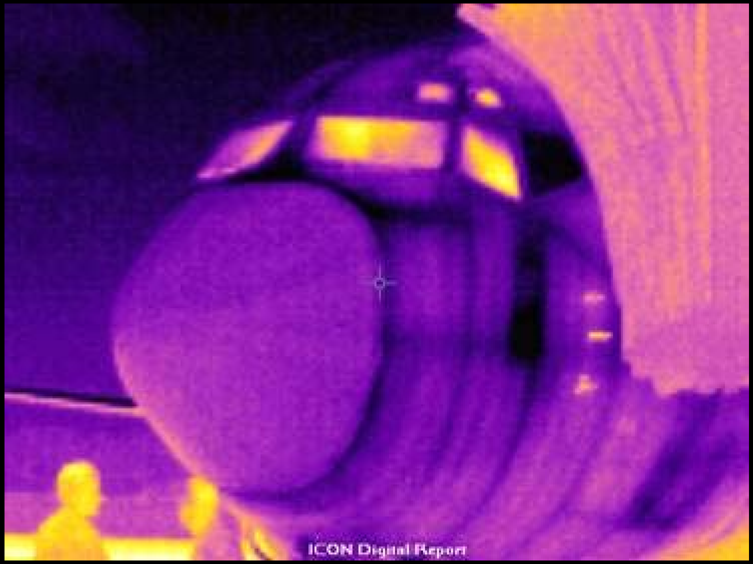
Images courtesy of ICON Tecnologia

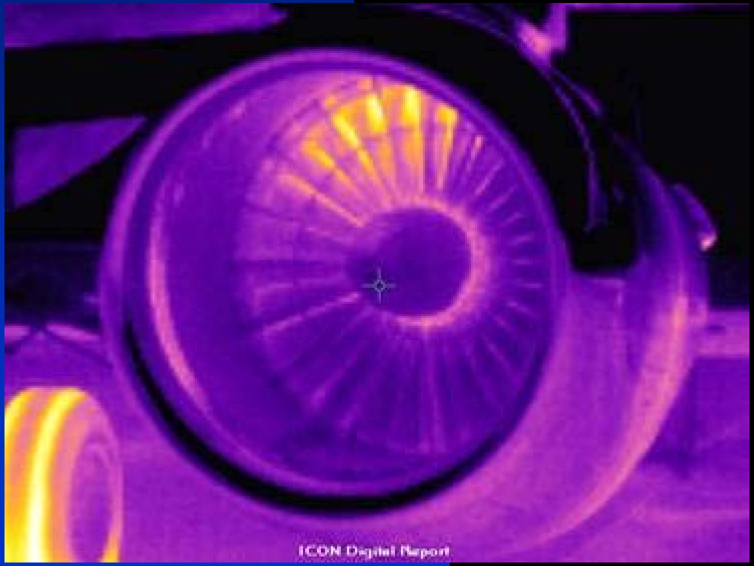
You can check your own industrial fabric...





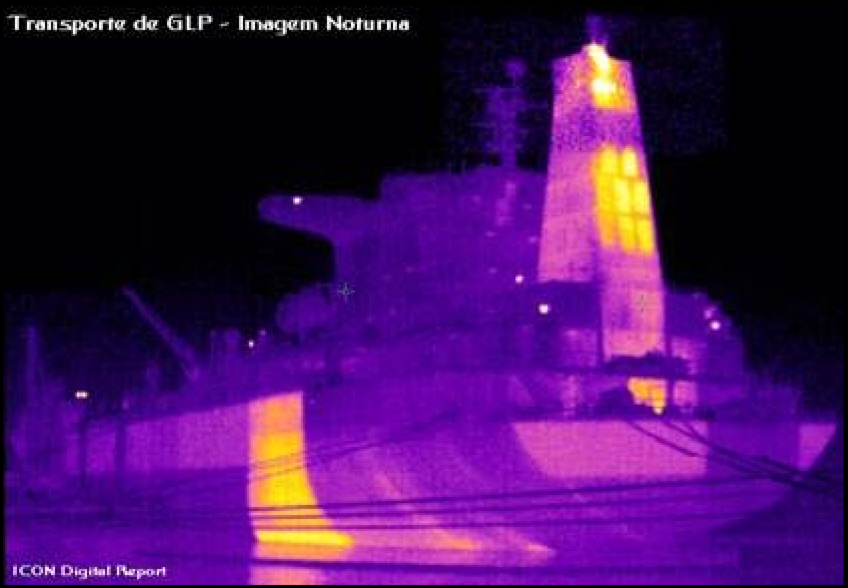
You can check your own aircraft...





Images courtesy of ICON Tecnologia

You can check your own tanker...

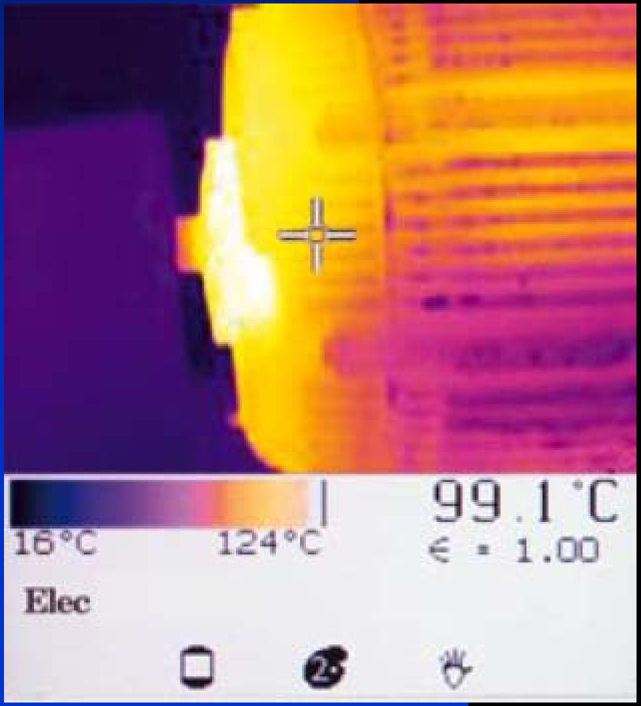


Images courtesy of ICON Tecnologia

thermal infrared –
serious samples

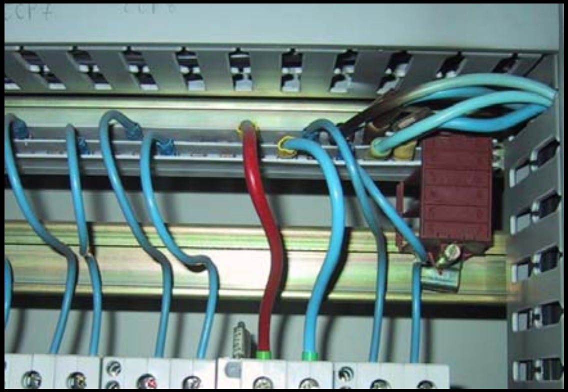
- designed for

predictive & preventive maintenence



electrical maintenence

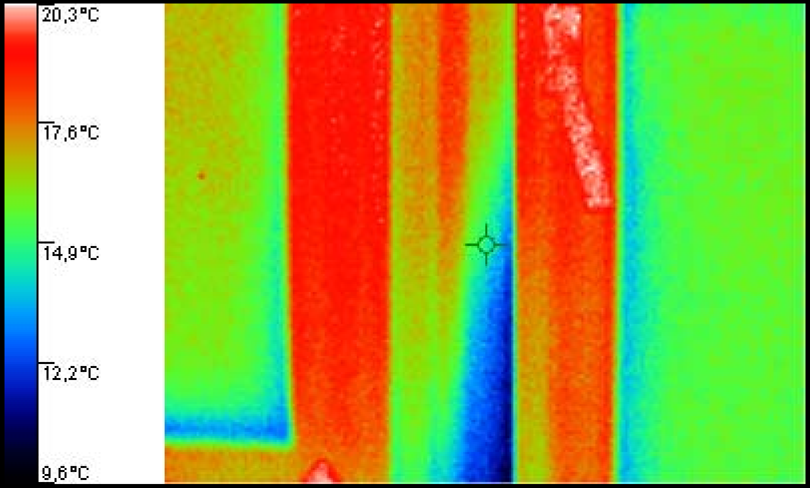
7 – 14 µm

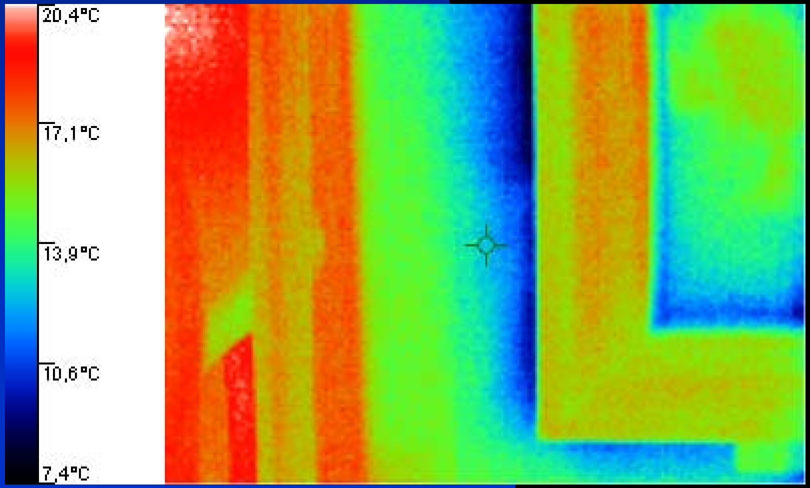


0,4 – 0,7 µm

thermal inspection of buildings

– from inside

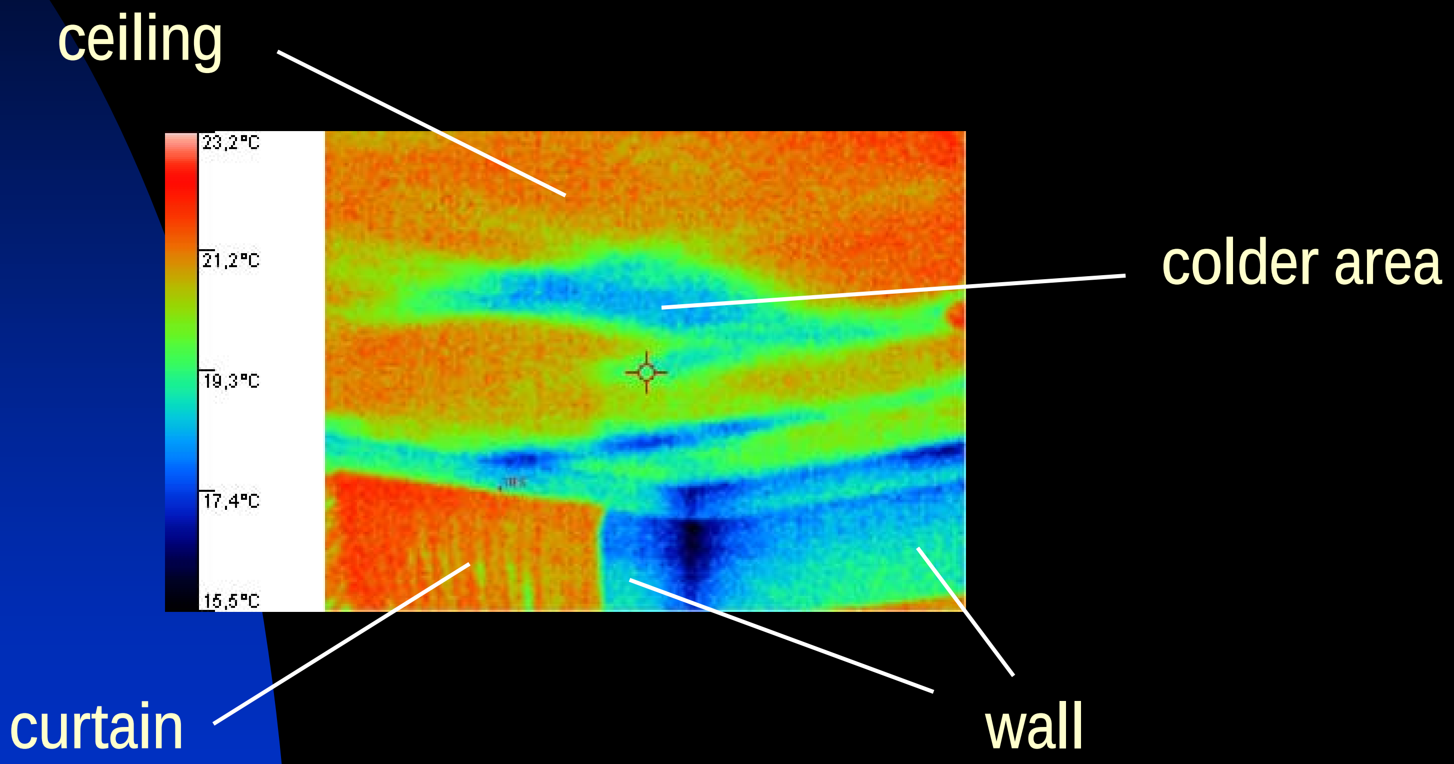




„blowing door“

thermal inspection of buildings

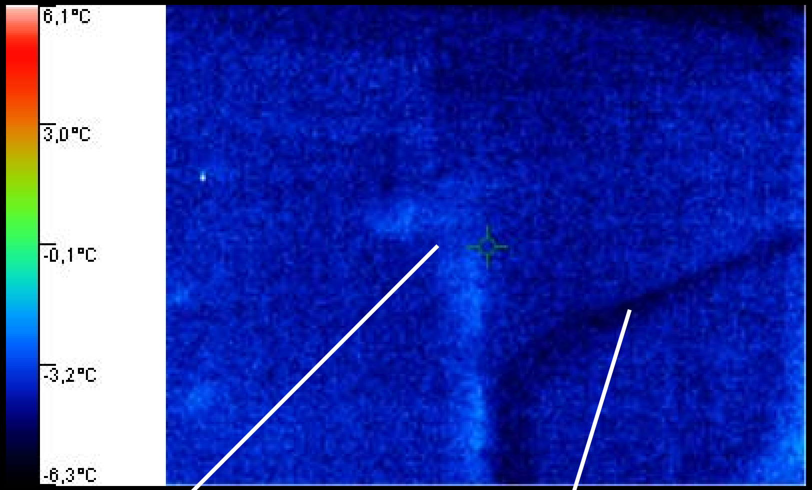
– from inside



„destroyed insulation inside roof“

thermal building inspection
– from outside

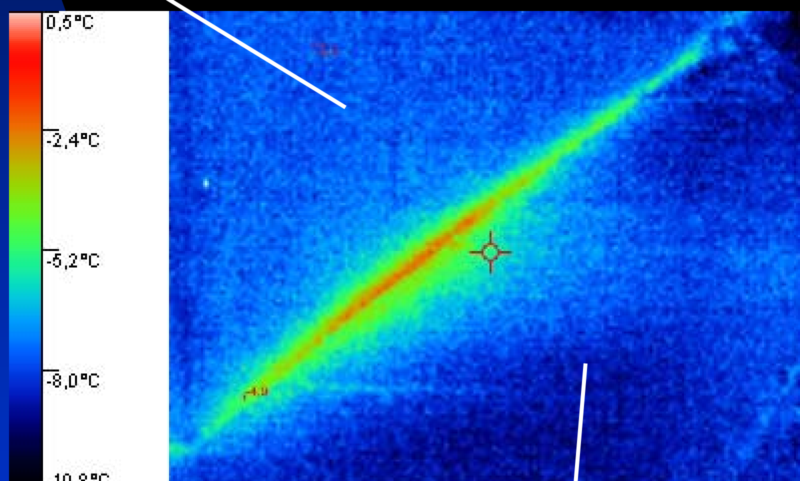
one family dwelling house
with
Styrofoam thermal protection
(60 mm thickness)



subsurface tube (air vent pipe) vs.
onsurface tube (drain tube)

thermal building inspection
– from outside

cellar area
wall

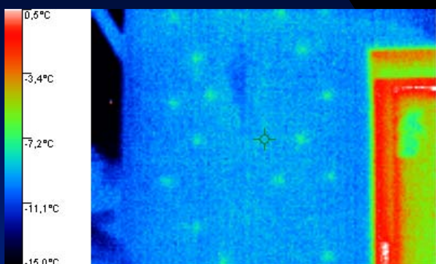


(with subsurface tube)

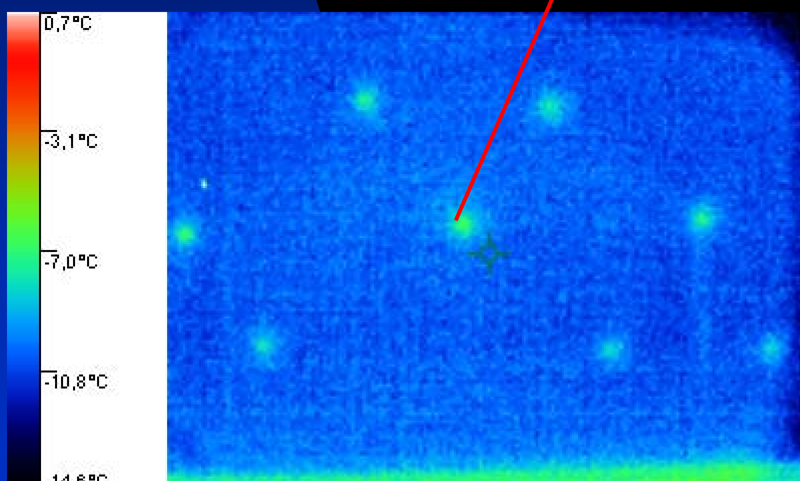
brick stone way

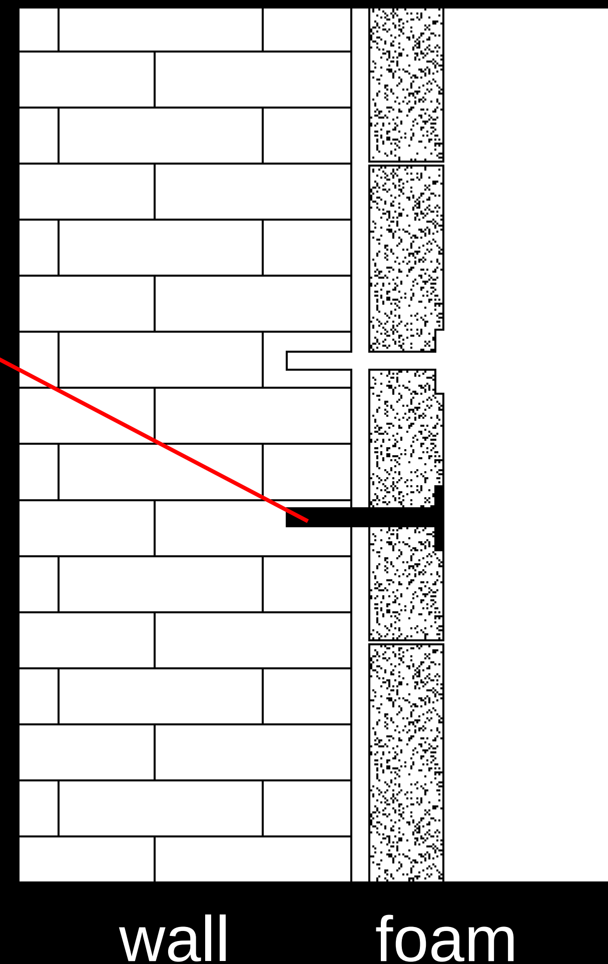
thermal building inspection

– from outside



wall plugs



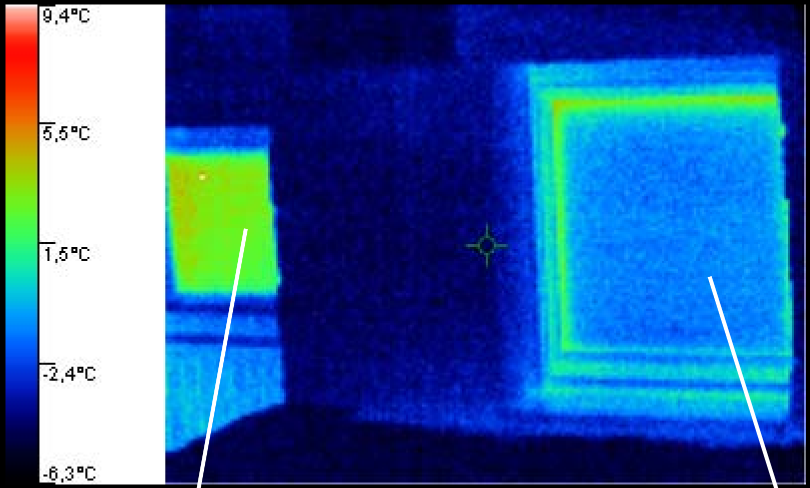


change in conductivity...

thermal building inspection – from outside

U~5,8 [W/mK]

room temperature ~ 15 °C



U~1,3 [W/mK]

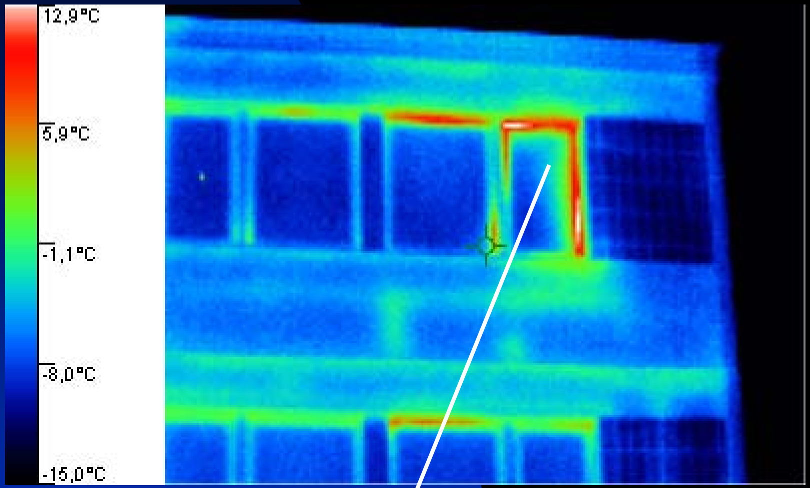
room temperature ~ 25 °C

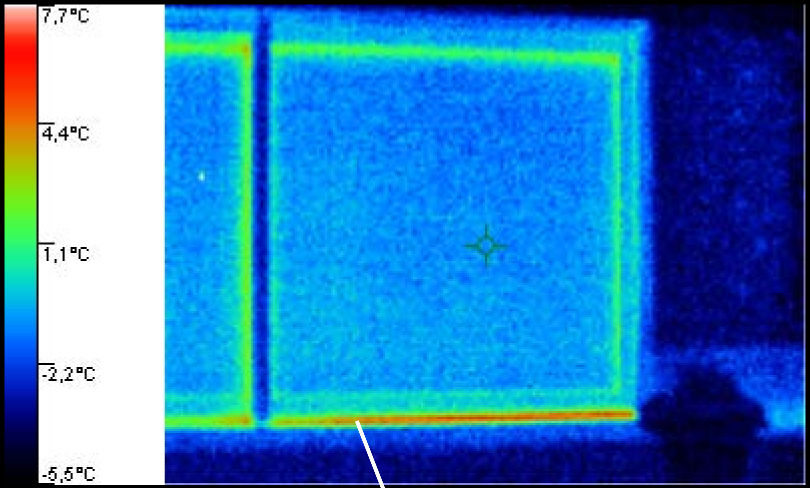
low insulating glass

vs.

high insulating glass

thermal building inspection
– from outside



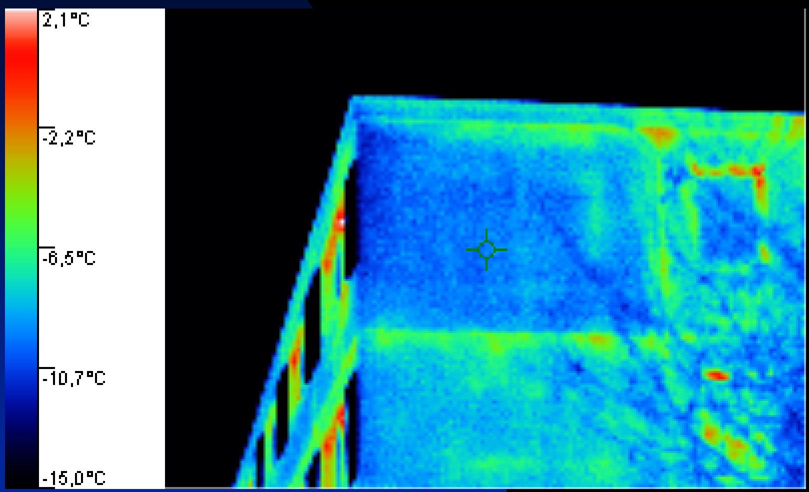


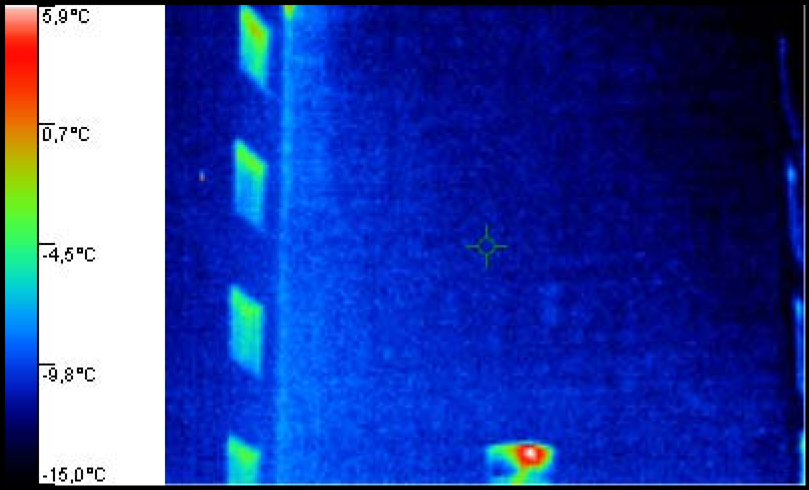
failure in window frame

failure in window seat insulation

thermal building inspection

– from outside





Comparation between

non renovatated building and

well insulated facade

What about german standards?

- Strong intention to reduce CO_2 pollution.
- ~ 70 % of german dwellings do not fulfill modern thermal insulation requirements or are heated by old heaters.

to compare – the history...

- care for best insulations (as thicker as better)
- care for k-value [W/m²K]
- use better materials (foam, wool)
  - ~ 2.5 inch for wall (to air) k=0,4
  - ~ 2 inch for wall (to ground) k=0,5
  - ~ 5 inch for roofs k=0,3
  - better glass for windows k=1,8

Former valid law:
Wärmeschutzverordnung
(law to keep energy inside)

Valid law:

- EnEV (26.05.2004)
  Energieeinsparverordnung
  (law about energy save)

Central element in energy policy and in climatic protection policy

Why important?

- don‘t care so much for best insulations or thickness
- care for a „all over brilliand result“
- only the G-value counts

How much energy needs your home per year ?

it means:
- •solar energy collectors
- •modern oven
- •heat exchangers
- •thermo windows
- •etc.

~ 2 Mio. new ovens untill 2006

the situation for designers today...

given outer area and dwelling volume

→ **A / V**

this ratio yields to a specific energy need:

88...152 MJ / m² a

What does it mean?

3...7 liter heating oil per year and square meter

the situation for designers today...

3-7 l/m²a

are

0.1 – 0.2 gallon / sqrft / year?

How ever!

the situation for designers today...

let us compare:

20-30 l/m²a	older buildings
13-19 l/m²a	Wärmeschutzverordnung '82
8-12 l/m²a	Wärmeschutzverordnung '95
3-7 l /m²a	low energy house
3-7 l/m²a	EnEV 2004
1-3 l/m²a	passiv building

How to get a 3-7 l/m²a building?

- state of the art insulation
- modernst oven technology
- small windows in north direction
  for northern hemisphere :-)
- solar collectors (voltaic)
- solar collectors (passiv)
- solar collectors (activ)
- heat exchanger
- lern to vent correct?
- reduce A/V → live in a sphere
- use vegetation as windbreaker

let‘s care – the sun always goes up again...

Thank you for listening!

Thermal Imaging Standards for Improved Quality

Helen McEvoy

23rd February 2005

NPL

Background

- Thermal Measurement Team – Temperature and Humidity Standards
- Maintenance, development and dissemination from –40 °C to 3000 °C for IR thermometry
- Calibration of:

    IR thermometers;

    thermal imagers;

    blackbody radiation sources

Introduction I

Traceability

- Demonstrable unbroken chain of calibrations to a national standard
- Reliably traceable to the international temperature scale of 1990 (ITS-90)
- If the measurement is not reliably traceable it is not measuring an internationally accepted temperature

Calibration

- Periodic calibration of instrument

Introduction 2

Concerns with using thermal cameras:

- Repeatability
- Traceability
- Standardisation

Calibration sources

- To relate imager/radiation thermometer output to temperature you need well-characterised sources of radiation

  – blackbody radiation sources

- The radiation field inside a closed, isothermal cavity depends only on the temperature and is independent of the material properties of the cavity

NPL

Blackbody calibration sources

Planck's law for spectral radiance distribution

$$L_\lambda = \frac{c_1}{\pi} \lambda^{-5} [\exp(c_2/\lambda T) - 1]^{-1}$$

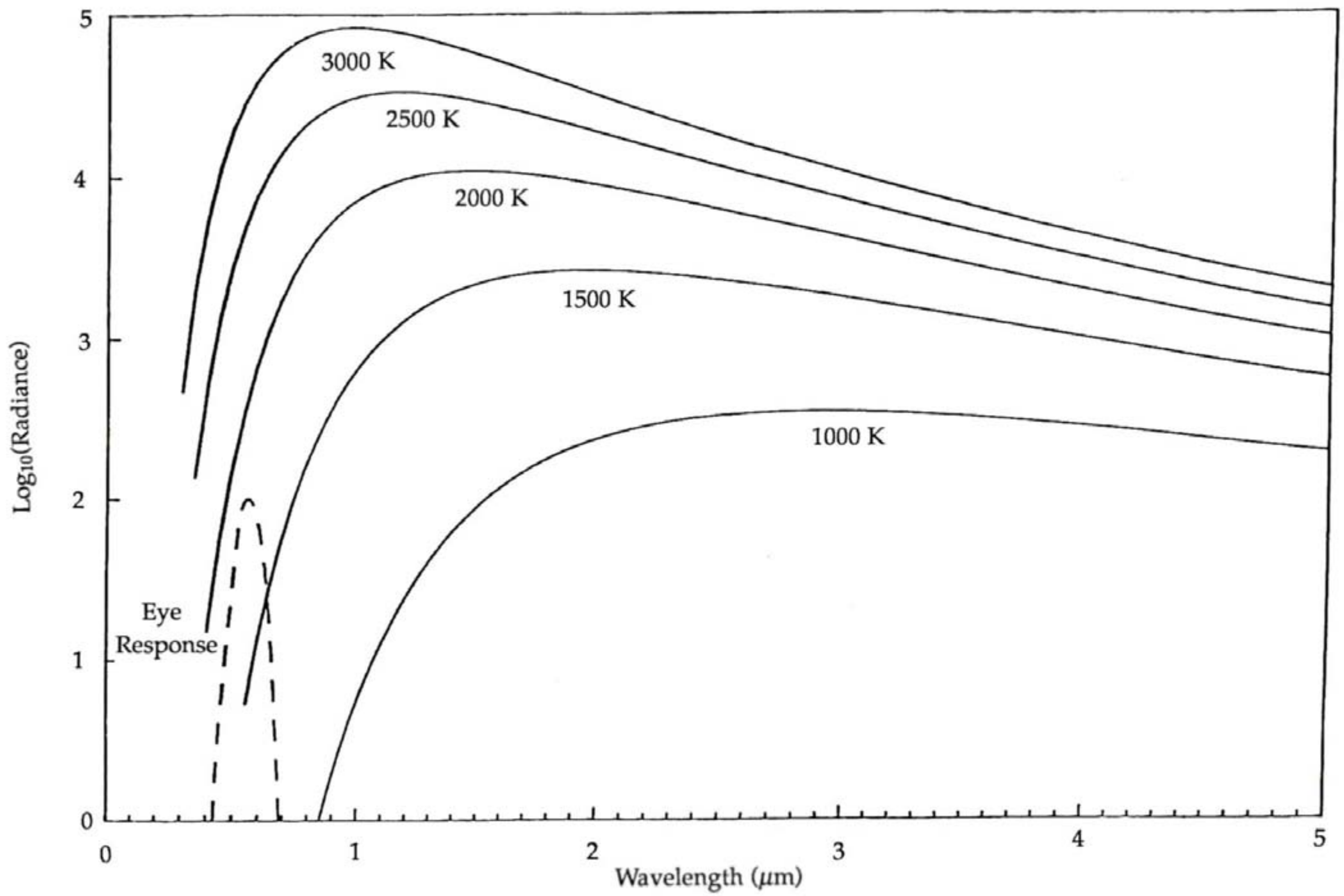
c_1 and c_2 are constants; specify λ, measure L_λ, determine T

or the Wien approximation to it:

$$L_\lambda \approx \frac{c_1}{\pi} \lambda^{-5} \exp(-c_2/\lambda T)$$

NPL

Plot of the Planck function



Calibration sources

- An aperture (hole) is used to observe the radiation in the cavity
- By careful design, the disturbance this hole creates can be minimised
- Cavity sources are therefore ideal standard sources of radiation, governed by Planck's law
- At ordinary temperatures the cavities look black; hence they are known as 'blackbodies' or 'Planckian radiators'
- For objects at ordinary temperatures most of the thermal radiation is at infrared wavelengths

Emissivity

- Radiation emitted from a surface depends on the 'emissivity' ε_λ where:

$$\varepsilon_\lambda = L_\lambda(surface) / L_\lambda(blackbody)$$

- Ideal blackbody radiators are perfect emitters of thermal radiation and also nearly perfect absorbers of it – their emissivity is 1

- Practical blackbodies are designed to have an emissivity of close to 1

NPL

NPL blackbody sources

1) Ammonia heatpipe blackbody source (- 40 °C to +50 °C)

2) Thermal imaging blackbody (TIBB): 0 °C to 80 °C

3) Water heatpipe blackbody source (+50 °C to 250 °C)

4) Caesium heatpipe blackbody source (300 °C to 600 °C)

5) Sodium heatpipe blackbody source (500 °C to 1000 °C)

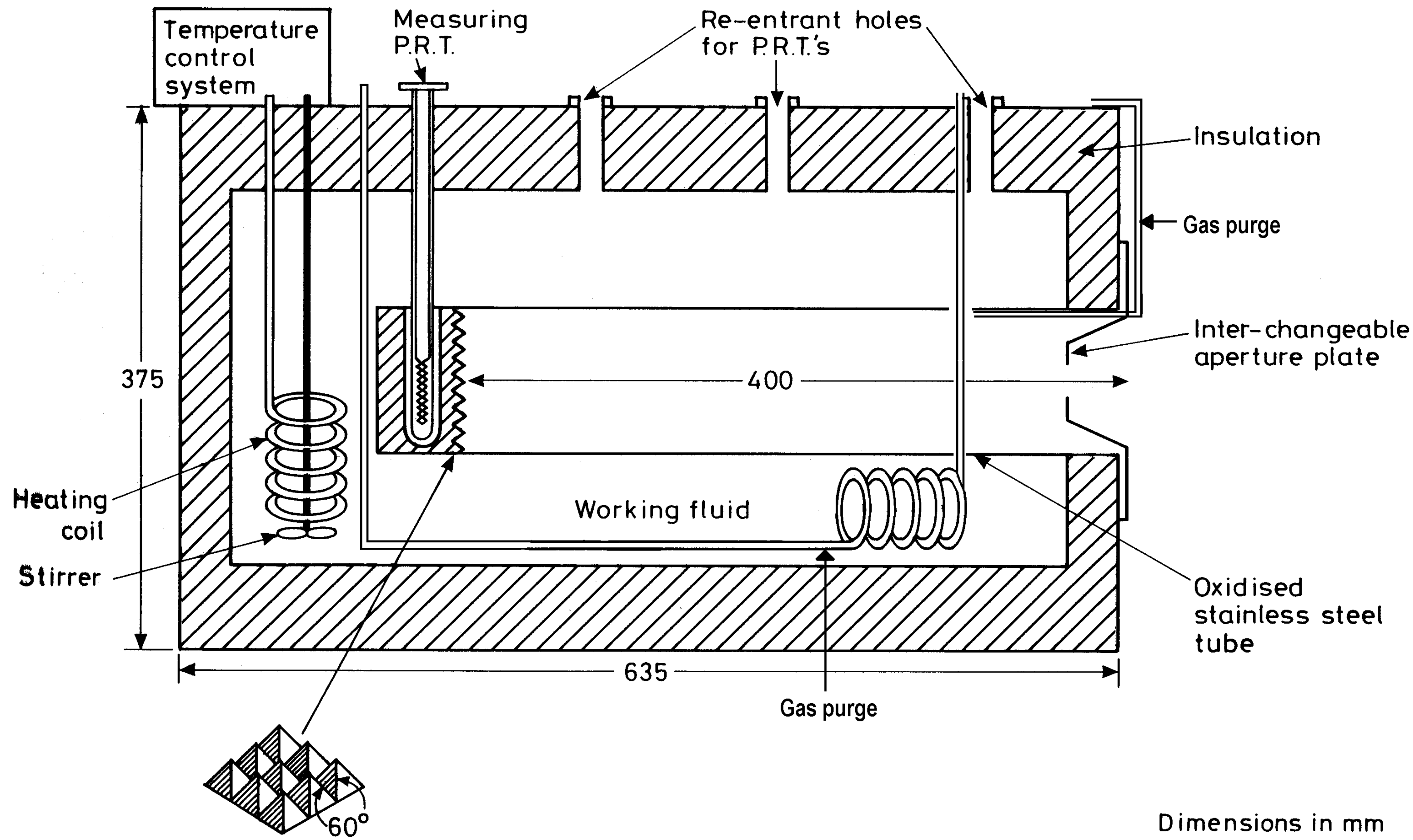
6) High temperature graphite source (1000 °C to 3000 °C)

NPL blackbody sources

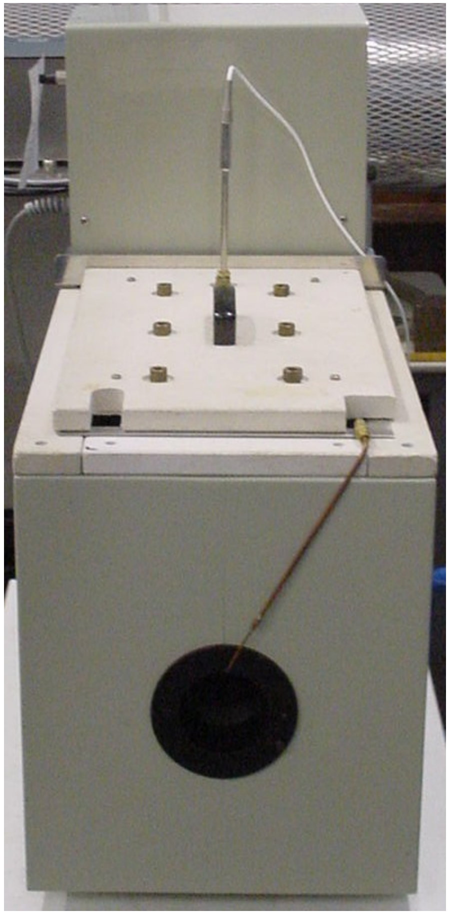
1) Ammonia heatpipe blackbody source (-40 °C to +50 °C)
2) Thermal imaging blackbody (TIBB): 0 °C to 80 °C
3) Water heatpipe blackbody source (50 °C to 250 °C)
4) Caesium heatpipe blackbody source (300 °C to 600 °C)
5) Sodium heatpipe blackbody source (500 °C to 1000 °C)
6) High temperature graphite source (1000 °C to 3000 °C)

NPL

Thermal Imaging Blackbody - TIBB



Thermal Imaging Blackbody - TIBB



Thermal Imaging Blackbody - TIBB

- Temperature range= 0 °C to +80 °C
- 80 mm Ø cavity, 400 mm long
- Rear is grooved to form 5 mm high pyramids
- Coated with high emissivity paint
- Emissivity >0.9998 for apertures of 50 mm or less

NPL

Thermal imaging blackbody (TIBB)

- Cavity immersed in stirred liquid bath
- Dip cooler for low temperature operation
- Temperature measured by ITS-90 calibrated PRT
- Dry gas purge system for below ambient operation

Thermal imaging blackbody (TIBB)

Assessed for:

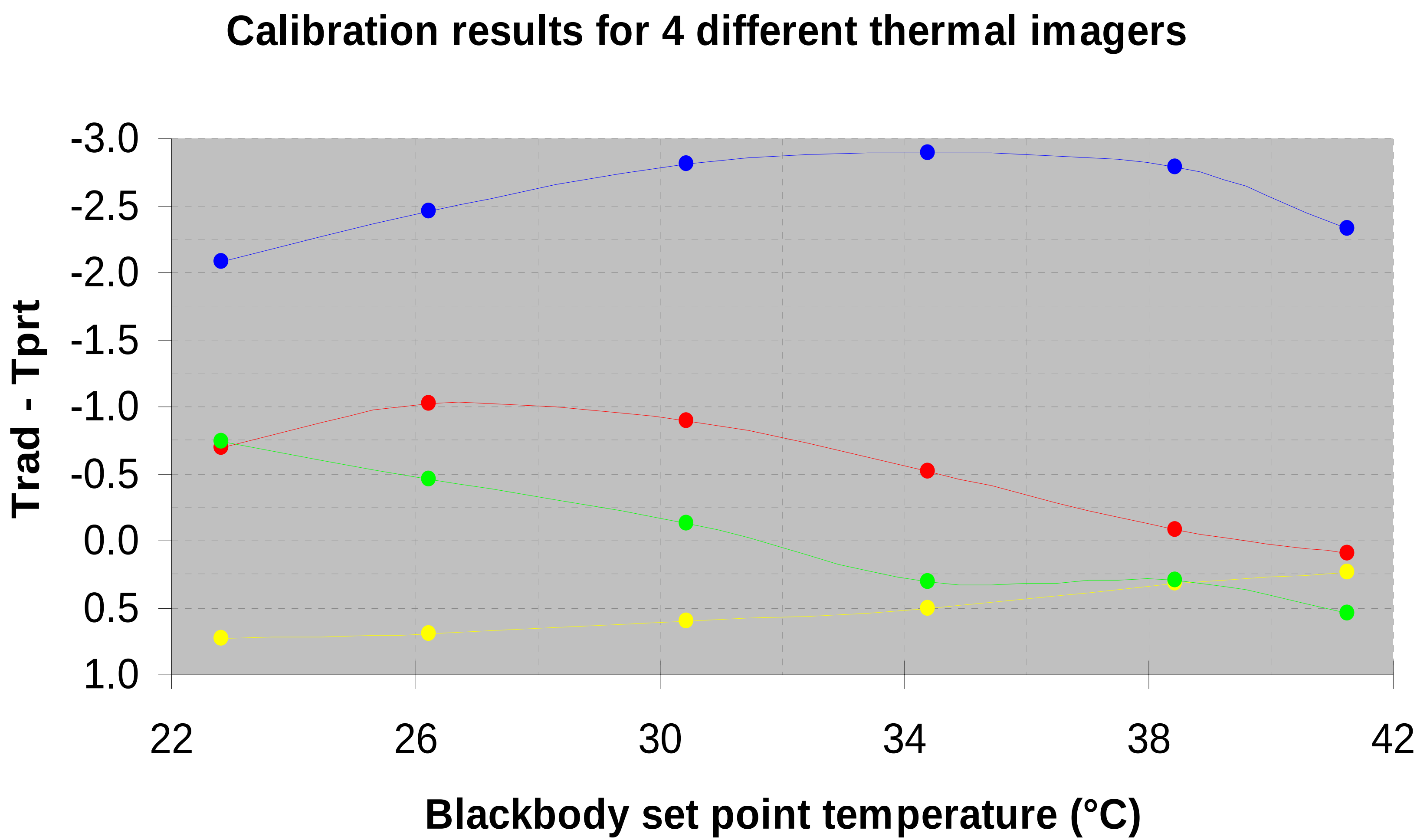
Temperature uniformity: typically within ± 0.02 °C

Stability: within ± 0.02 °C over one hour

Uncertainty = 0.02 °C to 0.03 °C across the range (k = 2)

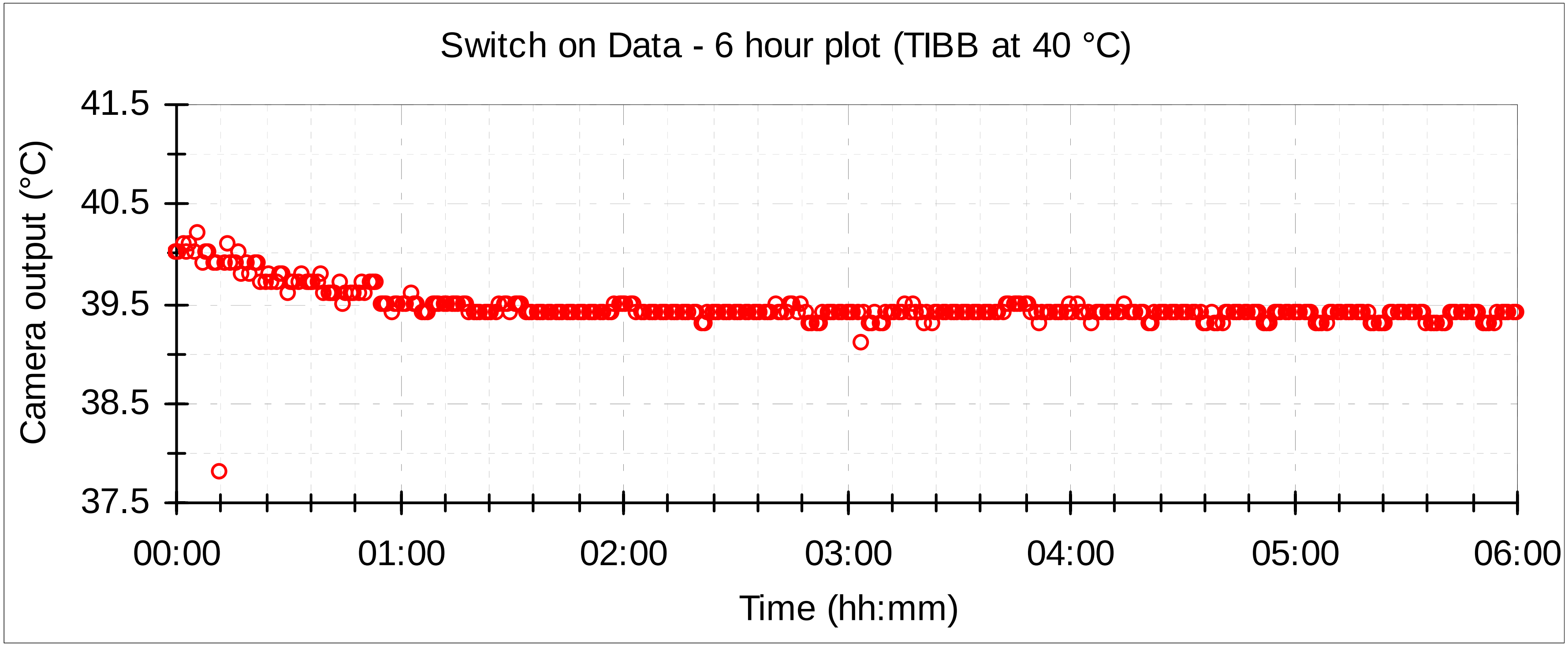
Used to evaluate a number of thermal imaging cameras to assess calibration and drift issues

Calibration results using TIBB



NPL

Switch-on data using TIBB

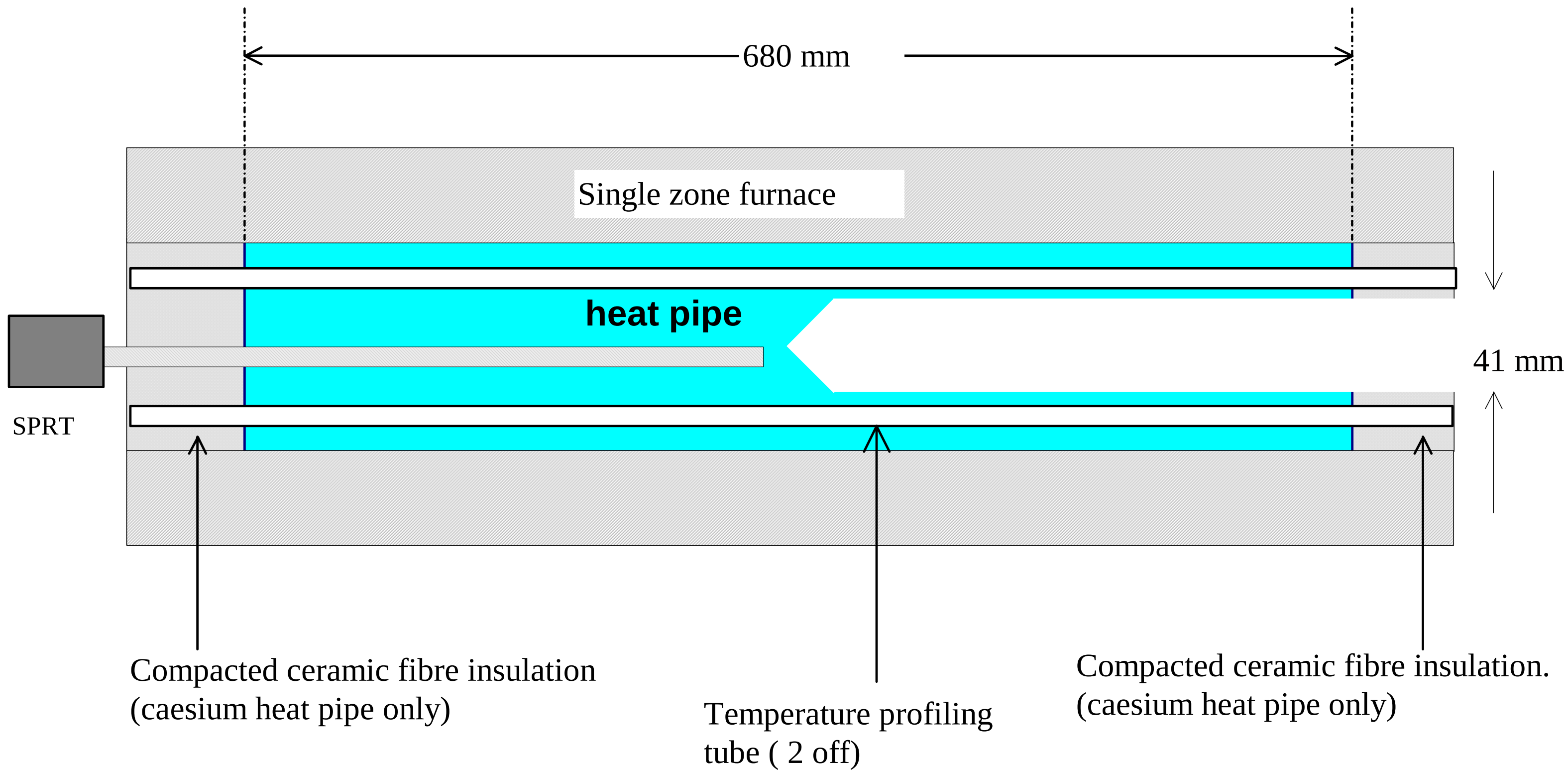


NPL

NH_3 heatpipe source

- Temperature range from – 40 °C to + 50 °C
- 75 mm Ø blackbody cavity inside metal jacket
- Cavity coated with high emissivity paint
- Effective emissivity for the source is ≥ 0.999
- Temperature controlled by circulating fluid within the walls of the jacket
- Temperature measured using ITS-90 calibrated PRT in rear

Water /Cs heatpipe blackbody sources



Water heatpipe source

- Constructed of monel metal coated with high emissivity paint
- 41 mm diameter and 358 mm long with 120° cone in rear
- Effective emissivity estimated to be 0.9997
- Contained within electrically heated furnace
- Temperature measured using ITS-90 calibrated PRT

Summary

- For reliable measurements issues such as calibration and drift have to be understood
- NPL maintain blackbody sources to provide traceable calibrations of infrared thermometers and thermal imagers from - 40°C to 3000 °C
- Trials of a number of different thermal imaging systems have been undertaken using the TIBB source
- Identify need for calibration standards

NPL

TMAN Meeting - February 2005

Thermal Imaging for Building Fabric Insulation Compliance

Evaluating the thermal performance of reflective insulation systems

Ray Williams

Two basic types of reflective insulation

- **Aluminium coated bubble wrap**
  - One layer of bubble wrap
  - Multiple layers of bubble wrap
  - Layers of bubble wrap + sheet(s) of foam insulation

- **Multi-layer quilt**
  - Thin layers of low density fibrous insulation, separated by aluminium coated plastic sheet.
  - Tough outer sheets of aluminium coated plastic or plastic coated aluminium.
  - Sewn along its length – like a duvet

Multi-layer quilts

Aluminium coated bubble wrap

NPL

Some thermal property claims made for these systems are controversial

- There have been claims that some reflective insulation systems - having an average thickness of 50 mm or less - have a thermal resistance of 5 $m^2.K/W$
- equivalent to a traditional insulation 200 mm thick with a thermal conductivity of 0.04 W/m.K
- These claims have caused consternation in the traditional insulation industry.
- If the measured values are not correct then there will be many houses whose energy (and CO_2) consumption, over the next 50 years or so, will be significantly higher than predicted.

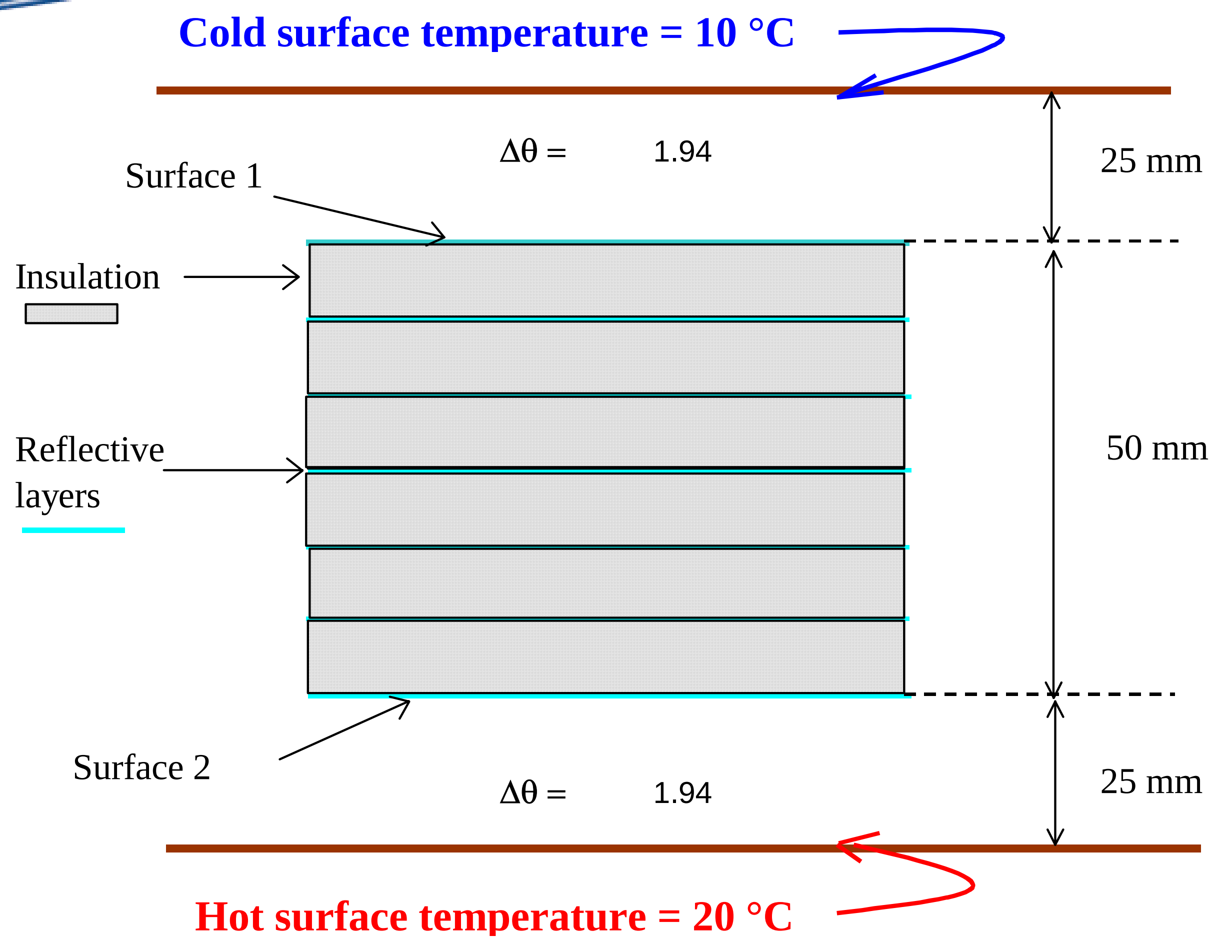
NPL

Factors Contributing to Doubts About Some Quoted Values

- No CEN product standards for these insulation systems
- Consumers & specifiers often have a poor understanding of the heat transfer principles involved, leaving them unable to make their own judgement.
- Most of the values obtained are “commercially in confidence”.
- Some organisations have developed “ad-hoc” measurement procedures that are not well documented nor properly validated

NPL

“Perfect” insulation (1)
With unventilated air cavities each side of the reflective insulation



NPL

“Perfect” Insulation (1)
With unventilated air cavity each side of the reflective insulation

OPTION 1 - An enclosed & unventilated air cavity each side of the reflactive insulation

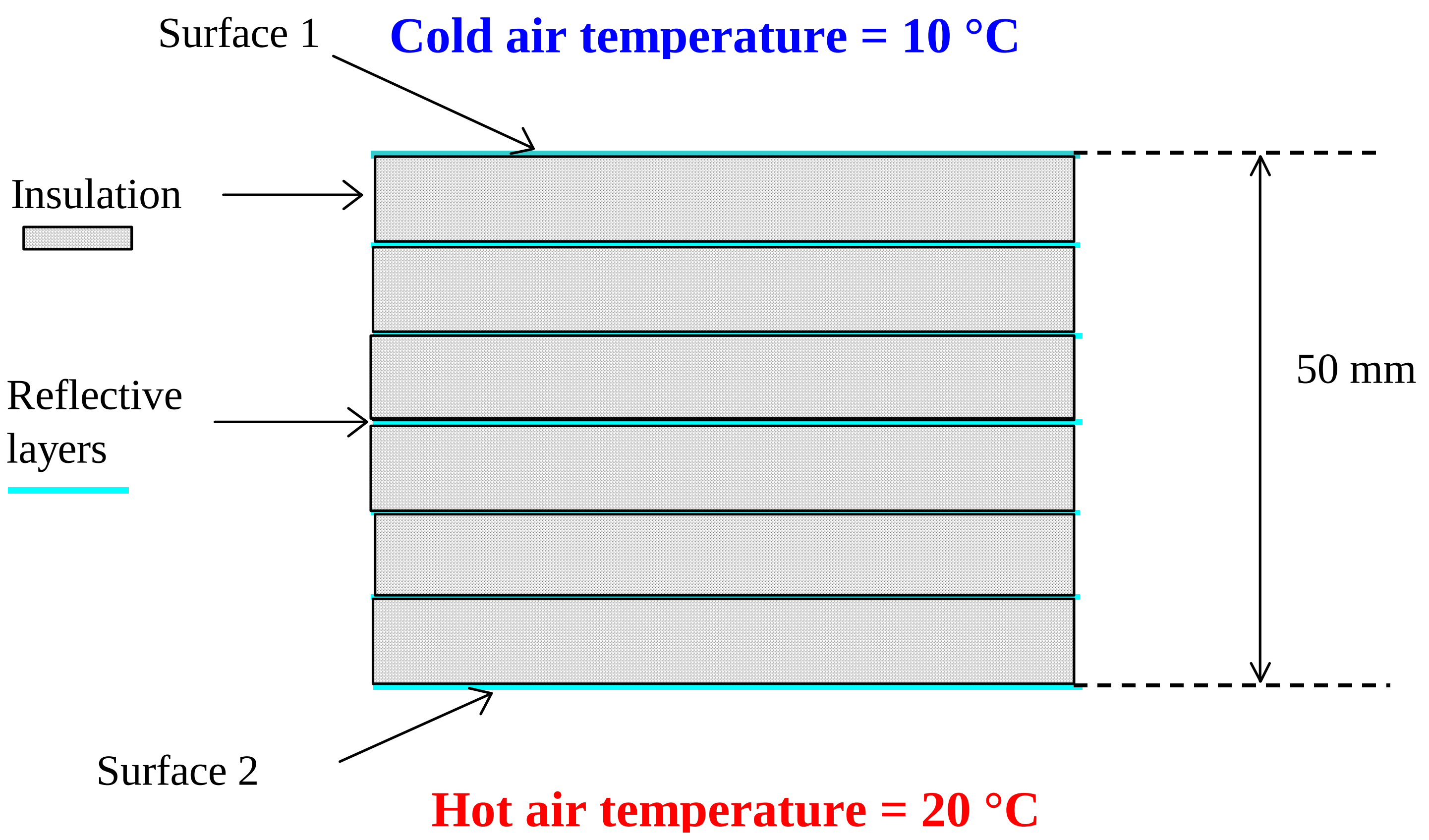
Assume surfaces 1 and 2 have a near normal emissivity of		0.05	
Assume radiant heat exchange across the insulation **is totally eliminated**	**- NO RADIATION**	0	Watts
Assume thermal conductivity of insulation **is same as still air**	**- NO CONVECTION**	0.025	W/m.K
Thickness of the insulation layer (uniform thickness)	**- NO QUILTING**	0.05	m
Thermal resistance of insulation **(NB: No radiant exchange at all)**		2	m^2.K/W
Temperature difference across the 25 mm deep air cavities		1.94	°C
Thermal resistance of each of the 25 mm deep air cavities (EN 673 @ E=0.05 @ 45 degrees)		0.636	m^2.K/W

Total thermal resistance of 50 mm thick reflective insulation plus an unventilated air cavity each side **3.3 m^2.K/W**

*** Insulation equivelent to 50 mm of still air**
*** No radient heat transfer across quilt**
*** Quilt a uniform 50 mm thick - no seams**
*** On each side of the quilt is an enclosed air cavity with a 25 mm air gap**

NPL

“Perfect” Insulation (2)
Low emissivity surfaces facing large, internal air spaces



"Perfect" Insulation (2)
Low emissivity surfaces facing large, internal air spaces

OPTION 2 - Low emissivity surfaces facing large, internal air spaces

Assume surfaces 1 and 2 have a near normal emissivity of		0.05	
Assume radiant heat exchange across the insulation **is totally eliminated**	**- NO RADIATION**	0	Watts
Assume thermal conductivity of insulation **is same as still air**	**- NO CONVECTION**	0.025	W/m.K
Thickness of the insulation layer (uniform thickness)	**- NO QUILTING**	0.05	m
Thermal resistance of insulation **(NB: No radiant exchange at all)**		2	m^2.K/W
Surface resistance of warm side - (EN 6946 Annex A - heat flow upwards)		0.189	m^2.K/W
Surface resistance of cold side - (EN 6946 Annex A - heat flow upwards)		0.190	m^2.K/W

Total thermal resistance of 50 mm thick reflective insulation with each reflective surface facing a large internal air space **2.4 m^2.K/W**

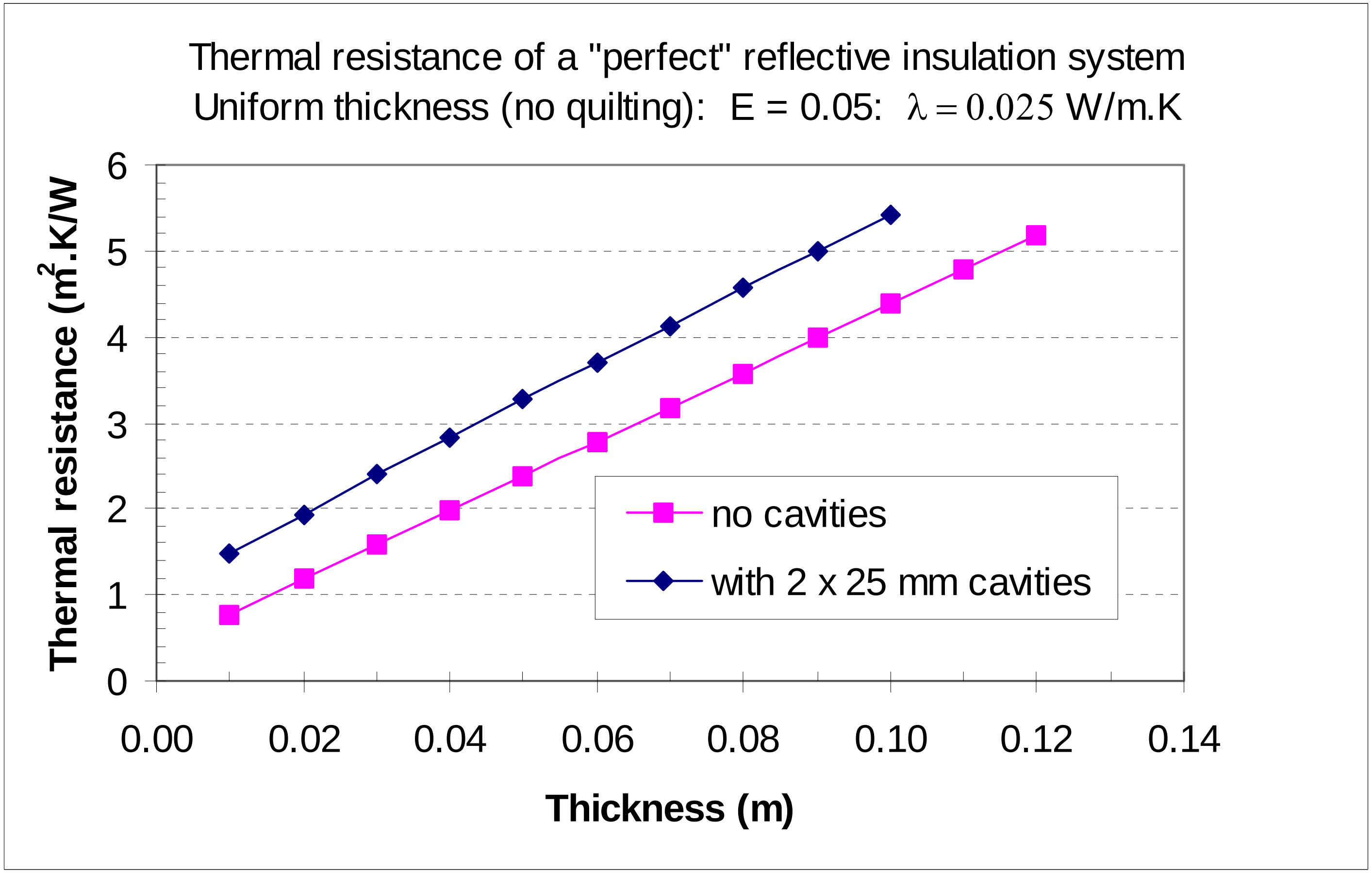
*** No radient heat transfer across quilt**

*** Quilt a uniform 50 mm thick - no seams**

*** Insulation equivelent to 50 mm of still air**

NPL

Thermal Resistance of "Perfect" Reflective Insulation Systems vs Thickness



NPL

Determining the Thermal Performance of Reflective Insulation Systems.
1) Calculation

- Measure the appropriate properties of the individual components and calculate the overall heat transfer through the system.
  - Thermal resistance of the fibrous insulation measured between surfaces with the same emissivity as the aluminium coated sheets it will be used with.
  - Total hemispherical emissivity of the different types of aluminium coated surfaces involved.
  - Thickness – with a quilt this brings in other issues.
  - Calculate overall heat transfer using appropriate boundary conditions (from BS EN ISO 6946) to the exact application.

NPL

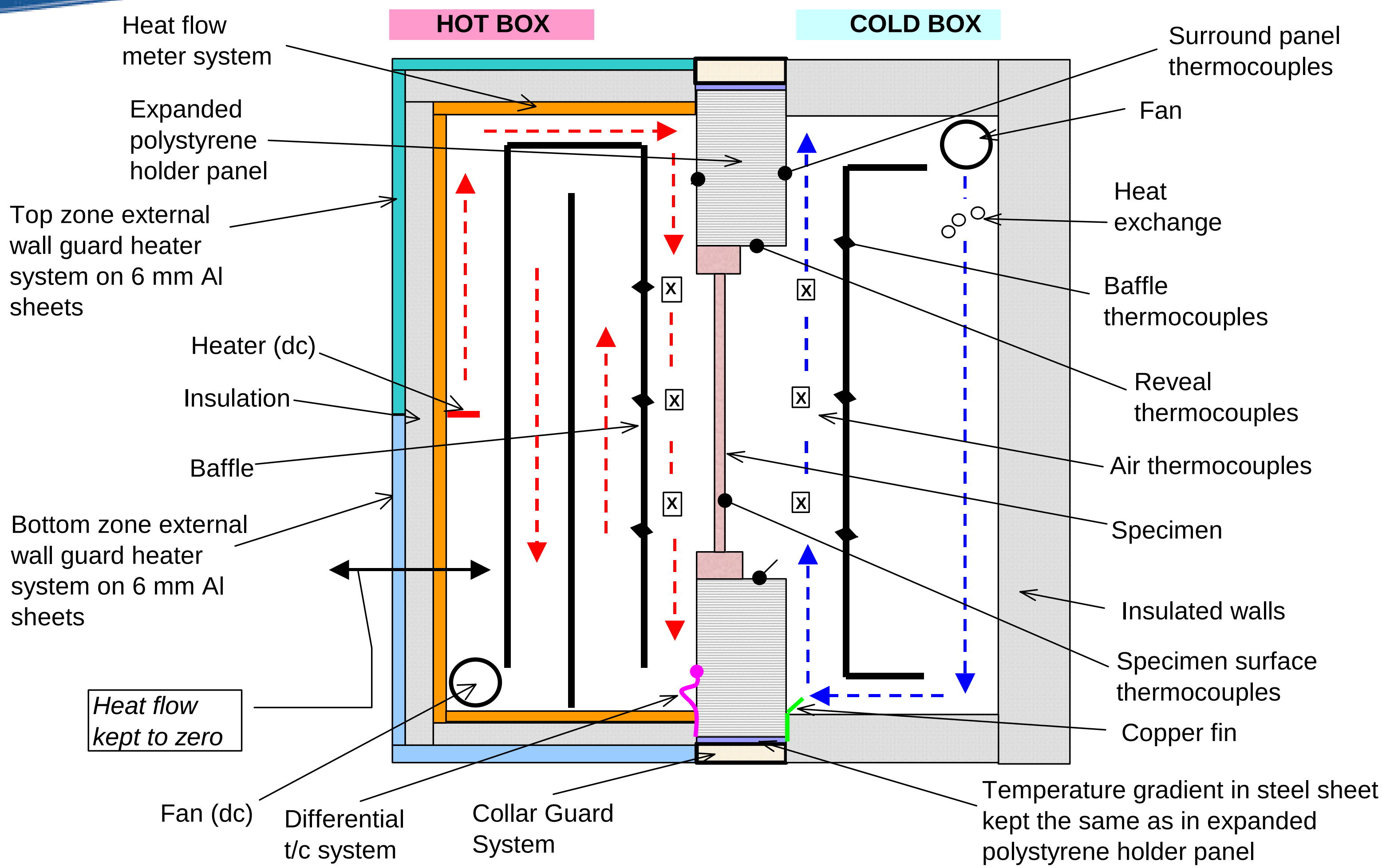
Determining the Thermal Performance of Reflective Insulation.
2) Direct Measurement

Measurement of U-value (thermal transmittance) or thermal resistance using a hot box apparatus.

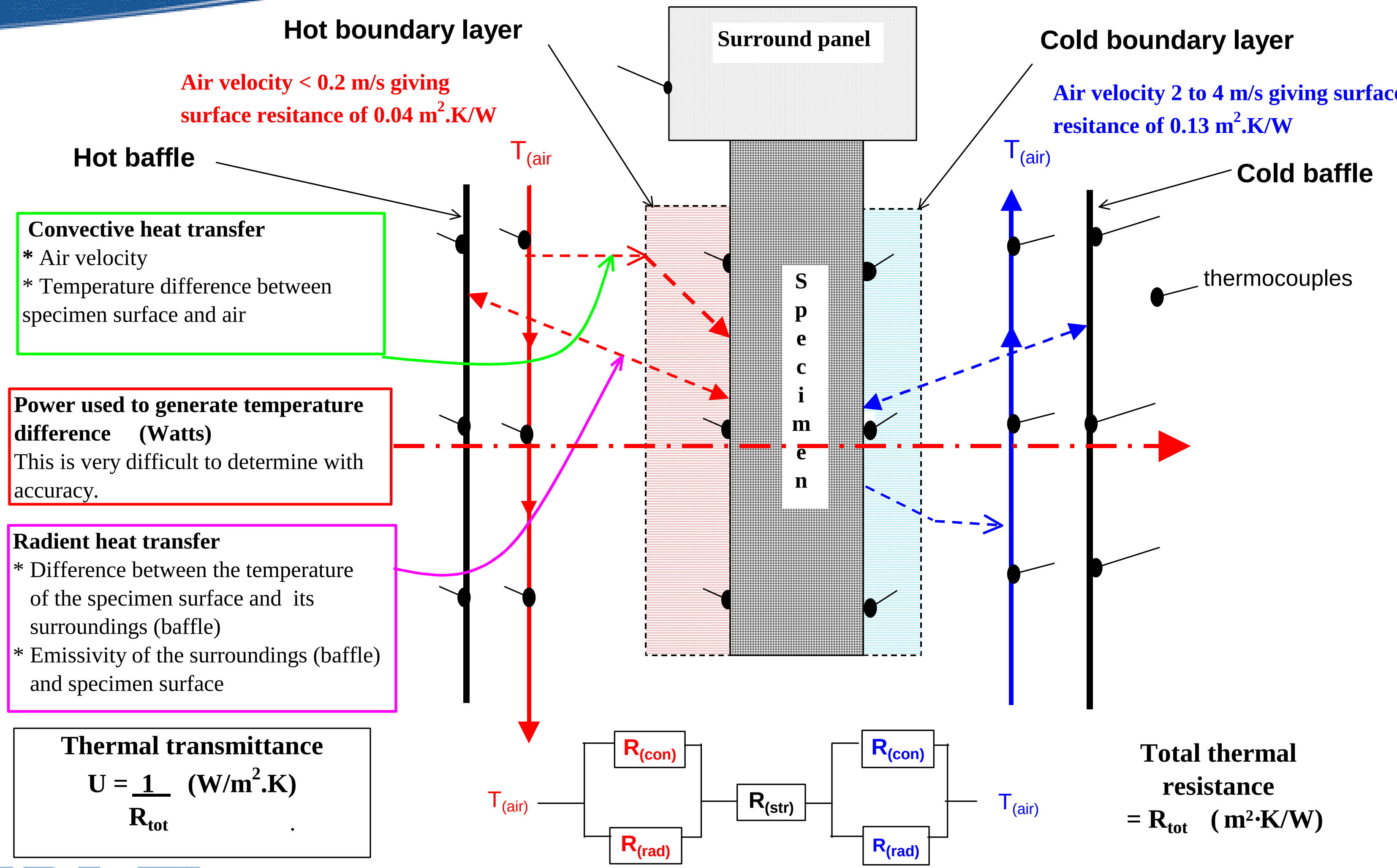
- Designed to measure the overall heat transfer through large, non-homogeneous structures – in the steady state.
- The apparatus is the subject of two International standards BS EN ISO 8990 and BS EN 1946-4.
- Absolute measurement uncertainty of ± 5.5%
- Repeatable to about 1%.
- The NPL Rotatable hot box can be used to measure thermal properties at all orientations.
- Hot box measurements are used as the reference values when validating calculations of structures.

NPL

Principle of Hot Box Measurements

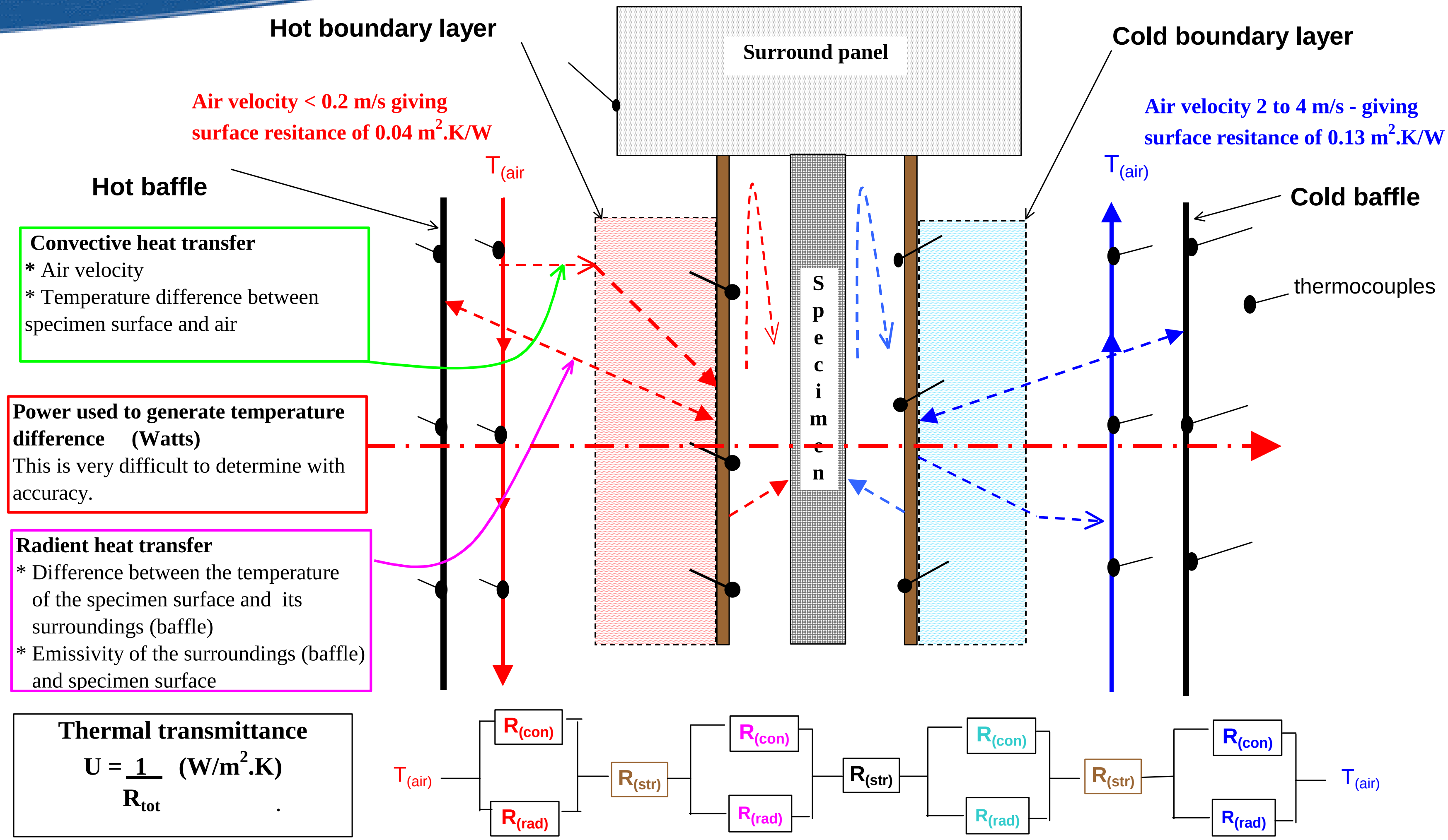


Heat Transfer Processes – No External Cavities



NPL

Heat Transfer Processes - Insulation Inside a Cavity



NPL

What Is Not Measured in a Hot Box

- Effects of solar radiation
- Effect due to installation procedures encountered in practice.
- Air infiltration through the insulation.
- Dynamic effects
- Effects of aging of aluminium surfaces
- Effects of degradation due to dust settling on surface of low emissivity surfaces.

NPL

Potential Problems With Ad-hoc Thermal Measurement Procedures

- They are often comparative methods where it is difficult to ensure that the “reference” and the “unknown” experience the same conditions.
- Difficult or expensive to validate a “one off” test.
- Only one person or one group of people have examined the methodology.
- If carried out in practical conditions (eg outdoors) – problems of direct sun, wind, rain and cycling boundary conditions are very, very difficult to account for.
- **Measuring thermal properties is very difficult.**

NPL

Next steps

- NPL will apply for some additional funding from the DTI under a scheme know as "Studio Projects"
- This will require us to have input from industrial / commercial partners – but this can be mainly in the form of "in-kind" contributions.

Possible contributors

- Universities and/or Research Associations
- Traditional insulation manufacturers
- Reflective insulation manufacturers
- Suppliers of insulation products
- Trade association(s)
- Accreditation bodies
- Building Control officer representative
- Organisations who have carried out measurements on these systems

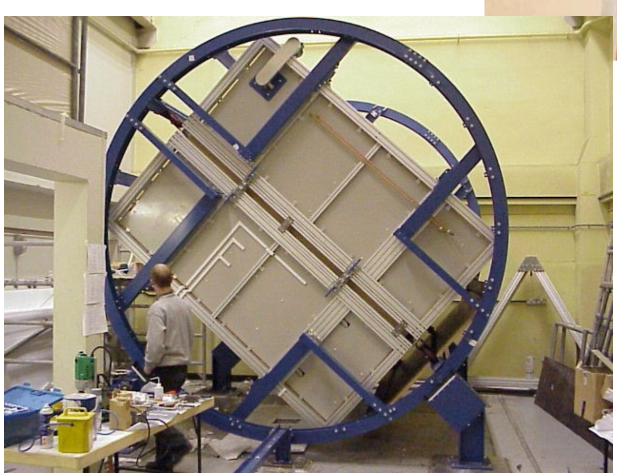
NPL

Outline Project Plan
1st thoughts.

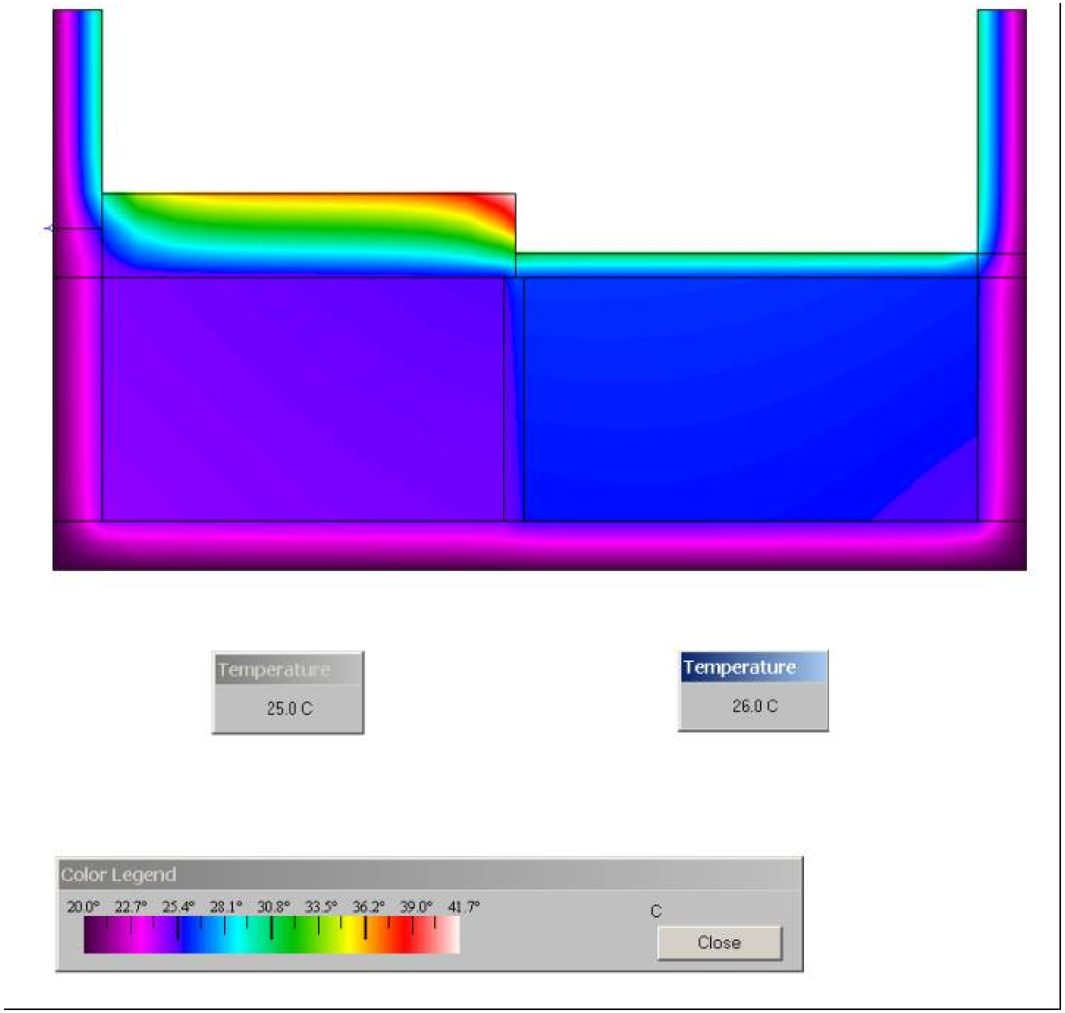
- Review the issues
- Identify any work already carried that is or could be in the public domain.
- Carry out some calculations
- Carry out conventional thermal measurements
- Use a selected alternative measurement technique – perhaps one designed to measure thermal properties in near “actual” situations.
- **Report must be understandable to all and available to all**

NPL

The End



NPL


Temperature
25.0 C
Temperature
26.0 C
Color Legend
20.0° 22.7° 25.4° 28.1° 30.8° 33.5° 36.2° 39.0° 41.7°
C
Close

Calc of environmental temp

$$T_e = \frac{T_a \, \Phi/A + E h_r (T_a - T_r') \, T_s}{\Phi/A + E h_r (T_a - T_r')}$$

where

Φ/A	is the heat flux density (in W/m^2);
T_r'	is the mean radiant temperature of surfaces "seen" by test element (in °C or K);
T_a	is the air temperature adjacent to test element (in °C);
T_s	is the mean surface temperature of test element (in °C);
E	is the emissivity factor;
h_r	is the radiation coefficient [in W/(m^2 K)];

NPL