THERMAL IMAGING PROCEDURE

ELECTRICITY NORTH WEST CONSTRUCTION AND MAINTENANCE LTD.

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1.0 Scope

This procedure covers the methodologies used for carrying out thermal imaging surveys on LV panels on Electricity North West Construction and Maintenance Ltd. (ENWCML) customer sites with specifications on measurements, equipment, training, processes providing suitable and sufficient guidance for the preparation of Risk Assessments and Method Statements (RAMS) and Safe System of Work (SSoW) relating to these tasks. It applies to all ENWCML employees and subcontractors carrying out work on behalf of ENWCML.

2.0 Purpose

To ensure that health and safety hazards associated with thermal imaging surveys are sufficiently identified and the risks are adequately assessed and controlled in accordance with legal requirements and industry best practice. To provide guidance to persons completing RAMS, SSoW and subsequent works on customer LV equipment.

3.0 Definitions

Hazard	An activity, substance, process, material etc. that has the potential to cause harm to workers, visitors, third party or the general public, e.g. a constant loud noise that has the potential to cause noise induced hearing loss.
Risk	A risk is the likelihood of harm occurring to persons as a result of hazardous activities.
Control	Measures such as processes, guards, personal protection, barriers etc. that can be identified to reduce the risks of certain hazards associated with an activity.
Hierarchy	A system in use for control measures to eliminate or minimise exposure to hazards **as far as reasonably practicable** (afarp).
SSoW	Safe System of Work is a systematic process that identifies hazards and sets out a method to carry out work activities safely, e.g. a Method Statement.
LV	Low Voltage – voltages up to 1000V.

4.0 Reference Documents

The reference documents below are associated with thermal imaging surveys and should be consulted for further guidance:

- Health & Safety at Work etc Act 1974 (HASWA 1974)
- The Electricity at Work Regulations 1989 (EaW 1989)
- Management of Health & Safety at Work 1992
- Construction (Design and Management) Regulations 2015
- Provision and Use of Work Equipment Regulations 1992
- Guidance to the Standard Specification for Thermal Imaging of LV Electrical Installations - FMS 5/98. BSRIA 1999, ISBN 0 86022 516 X.
- BSRIA Application Guide AG 17/97 – Safe Thermal Imaging of Electrical Systems <1000v ac.)
- BSRIA FMS 5/99 – Guidance and the standard specification for thermal imaging of LV electrical installations.
- HSG230 (2nd edition) 2015 – Keeping electrical switchgear safe (HSE publication)

- The Electricity at work regulations 1989. Guidance on Regulations HSR25 HSE 2015
- Electricity at work: Safe working practices HSG85 (Third edition) HSE 2013
- INDG354 (rev 1) HSE 2013 - Safety in electrical testing at work
- BS EN 61111 Live working. Electrical insulating matting British Standards Institution
- BS EN 61557 Electrical safety in low voltage distribution systems up to 1000v ac and 1500v dc.
- BS EN 50110 Operation and maintenance of electrical installations (Ref 7) procedures and safe distances from live parts.
- Provision and Use of Work Equipment Regulations 1992 (PUWER) (Ref 7)

5.0 Methods

The only time live working can be conducted is if it is deemed 'reasonably practicable' (section 40 of the HASWA 1974) and all other avenues to produce the information required have been exhausted. Justification must be made for working adjacent live conductors. The correct PPE for the task MUST be controlled and will adhered to at all times during the process (details and how to assess the PPE requirements are in this document)

All works carried out within or on behalf of ENWCM must be risk assessed and a SSoW must be identified in accordance with the Risk Assessment and Method Statement Procedure (ENWCML-HSE-P001).

5.1 Thermal Windows

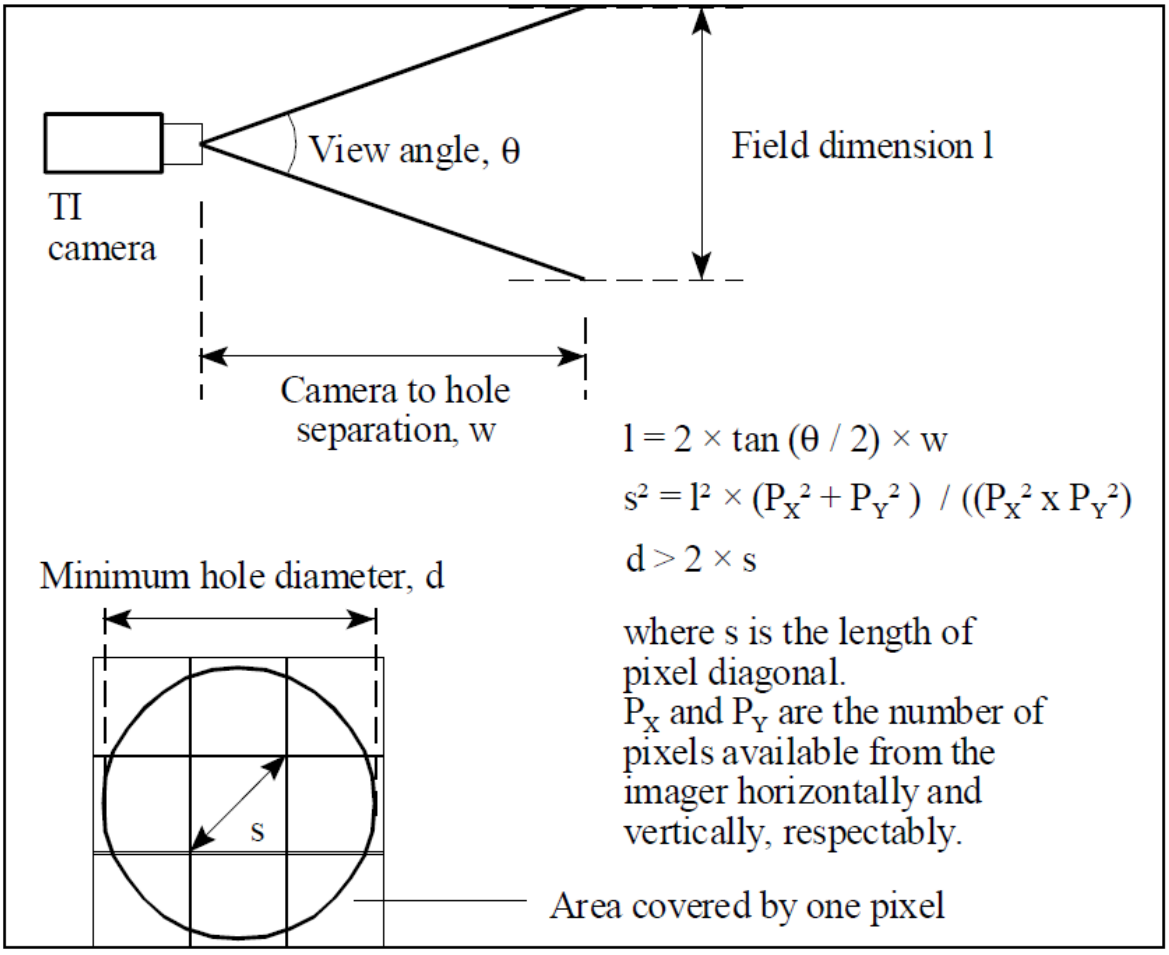
This is the ENWCML preferred method as this is considered to be on the top of the hierarchy of risk control.

Following a thorough internal investigation into the safe working practice of conducting thermal image reports on client LV systems ENWCML's **preferred** method is installation of Infrared image capture windows (Thermal windows), these windows minimise any risk to the engineer conducting the survey as they reduce the access to live conductors by 98%. Images are taken through a small window fitted to the required point on the panel or equipment, the window provides access for the thermal camera lens to capture the internal live components with limited exposure to conductors (PPE must still be worn in case of faults occurring whilst the window is open (if using an open window type system).

The thermal windows provide a duty of care from the employer and client to the engineer carrying out the works under the *Health and Safety at work Management regulations*, minimising the risk to the operative and others in the location and during the process.

Thermal windows will only be fitted when safe to do so. Isolation of the panel will be required for live panels which have unknown factors which can cause risk to the engineer.

Thermal window guide for correct image recording



5.2 Thermal Imaging is Working 'NEAR' Not 'ON' Live Conductors

To provide a recommended safe method of conducting thermal imaging on LV panels and distribution equipment.

This process guides engineers working with 'Live' exposed components however site risk-based assessments MUST be carried out in all cases by the competent qualified electrical engineer, at NO point should the engineers take unknown risks which could cause harm to themselves or others.

EAW Regulation 14:

No person shall be engaged in any work activity on or so near any live conductor (other than one suitably covered with insulating material, so as to prevent danger) that danger may arise unless –

a) It is unreasonable in all the circumstances for it to be dead; and
b) It is reasonable in all the circumstances for him to be at work on or near it while it is live; and
c) Suitable precautions (including where necessary the provision of suitable protective equipment) are taken to prevent injury.

Clause (c) is critical and suitable precautions can only be determined by completing a site-specific risk assessment.

THE ABOVE STATEMENT MUST BE SATISFIED

With the statement above (EaW 1989 - Reg 14)

Thermal imaging requires heat generated by electrical load on the system to show faults, the need to work around live conductors will be high.

Isolation of the system would reduce the risk of injury to the engineer however would also jeopardise the thermal readings taken thus causing a risk that faults are not identified. To satisfy both elements of safety to both the engineer conducting the thermal image survey and the site systems the processes in this document will guide the engineer to conduct the live works in the safest, with least risk to client operations and controlled manner.

With this in mind the main scope of the risk assessment must be on how to protect the engineer accessing and operating whilst working around the live systems (care must also be taken to protect others).

To comply with the Management of Health and Safety at Work Regulations 1999 'a full and sufficient risk assessment' must be carried out for every work activity.

This risk assessment will be completed for each site and a bespoke POWRA will be carried out by the site engineer conducting thermal imaging for each panel (there are multiple reasons this method has to be carried out on site), some items listed below;

a) Panel manufactures differ in their construction methods, close examination of the build will identify risks.
b) Risk assessments cannot identify hidden obstacles or dangers behind covers.
c) Panel modifications could have been made which could add to the risks subjected to the engineer carrying out the thermal survey.
d) Site conditions will vary, for example if a cover is removed exposing live parts on a panel that is located on an exit route and a fire alarm activates site staff will add to the risk of injury by rushing past the live works area, barriers and signs could be moved or pushed away during the rush by staff unaware of the present danger (this cannot be foreseen but during the completion of the POWRA the engineer will determine the location of the works and assess the need to speak to site management to control the exit routes in a safe manor during evacuation).
e) Earth tails could be fitted to panel covers (these are fitted to the rear of the cover and cannot be seen from the front when the cover is attached).

5.3 Risks and Ways to Remove Them

All sites are different; an engineer attending site will be faced with multiple variants, for example:

Panel manufacturer (variants in construction and fixing methods)

Form rating of panels (different Form ratings will require additional PPE, Control and RAMS)

Locations of work (areas where public or general site staff are passing by or located on a fire escape route etc)

Site historic information which could highlight dangers (for instance there could have been a leaking roof which the water has pooled in one of the panel compartments, if the cover is removed it could possibly cause a flashover)

Site engineers experience and advice (a client's site maintenance engineer might know about previous modifications to the panel or faulty fixings on the panel covers etc)

Visibility in the work area (poor lighting could cause risk when working)

Trip hazards (the floor could be uneven or other obstacles which could cause the engineer to fall into the live conductors if not assessed correctly prior to conducting the works)

6.0 Hazards Associated with the Works

There are 3 main groups of hazards associated with thermal imaging surveys:

1 - FIRE

Fire hazards can result from extreme temperatures in electrical equipment or sparks igniting materials that have a low flashpoint.

Thermal imaging is conducted to identify any areas in advance to reduce this risk.

2 - EXPLOSION (Flashover)

There are situations in which protective devices or isolators present an explosion hazard;

Operation in explosive atmospheres (this includes carbon dust build up), when breaking a large fault current and under catastrophic failure.

Special switchgear is used where explosive atmospheres may occur and these **MUST** never be open whilst live. *Guidance to be taken from the appropriate regulations.*

A circuit breaker breaking fault current approaching its limit, which may be 50kA, produces a significant discharge of ionised gas. This could cause serious burns to personnel some distance from the vents on the breaker.

The UK and Europe do not have a BS EN standard for the distance from an exposed conductor within which serious burns could occur, the US standard ANSI/NFPA 70E (ref 10) recommends 914mm from the live conductor which we can use as a responsible guide to conduct safe operations. The design of the panel, with access doors closed, will normally vent the gas safely away from any user.

When an engineer is required to conduct operations within the 914mm on a panel with a PFC of 40kA a full 50-Cal ARC suit will be worn (possible fault currents that are above this rating will require bespoke planning which would be picked up at the risk assessment stage prior to site attendance, these are rare and will be dealt with individually).

A catastrophic failure of a circuit breaker or fuse could result in its disintegration which in turn will expel hot parts in all directions (this is extremely rare but possible) The extent of the explosion will depend on the size of the device, the voltage and short circuit current at the panel and the protective enclosure of the device.

Based on the above, 2 engineers will be at risk. (thermal imaging around live parts will always be a 2 person task) Protective arc flash clothing would be essential for anyone in the work area (the CAL rating would increase the higher PFC and proximity to the device (the standard ENWL overalls are 12.5 yellow and blue versions – blue and orange versions are 7.5CAL) ARC ban gloves and face shield are also required, the actual PPE requirements would be assessed in the site specific risk assessment.

3 - SHOCK

The effects and severity of electrical shock on the human body depend upon the magnitude, duration and path of the current through the body, along with the weight, age and physical condition of the individual. It is therefore very difficult to identify the effects of electric shock, other than to accept that

currents in the order of a few milliamps can be fatal, ENWL's view is NO level of electric shock is acceptable.

As the thermal imaging works are NEAR rather than ON live conductors and should be always more than 500mm from the conductors to carry out a detailed image the likelihood of electric shock is remote. Accidental contact is still possible, and this must be assessed in the risk assessment and planning of the work task.

6.1 Identification of Hazards

The action of thermal imaging can affect the camera operator's perception of distance. This will relate directly to the camera operator's experience and familiarity with the camera being used. There are also hazards related to the opening of panel covers:

- Touching live parts
- Shock from contact of opening covers with live parts exposed
- Shock from contact between a tool and live parts
- Burn or damage from tool repelled by explosion following contact with live parts
- Burns from ionised gas discharge
- Burns and other injuries from expelled parts
- Psychological shock from noise and flash or operating circuit protective device.
- Earth bonding tails connected to the panel cover (can cause an unexpected jolt when removed and unaware of the restriction, this can result in the cover pulling back into the panel)

6.2 Control Methods

There are several control measures that can be implemented when thermal imaging.

These can be divided between physical and procedural measures.

Physical Measures

- All door / panel cover fixings to be the captive type, such as they cannot fall into the panel when the door or cover is removed. Ideally doors should be hinged
- One of the hazards to be avoided is items falling from the engineer's pockets onto live conductors (ie phone or spanner). This is best achieved using clothing without pockets or in the case of the ENWL protective overalls have a secure seal pocket (either zip or Velcro). Jewellery including metal bracelets, watches, chains etc must be removed.
- The thermal imaging activity requires that the camera operator be a distance away (500mm minimum for focus but usually greater distance is used to capture larger areas of the panel), from the live conductors, this is a control measure linked to the thermal process.
- The use of protective rubber mats (BS 921) along with insulated tools, barriers, danger warning notices and the signs prohibiting unauthorised persons.
- Correct PPE to be decided during the management risk assessment (Arc ban overalls, Arc ban gloves, Flash hood etc)
- When opening a panel door, the engineer should stand at the hinge side so the door acts as a protective shield as it opens to reduce the risk of a violent release of energy causing harm, care should be made to keep others out of the way whilst the door is opened.
- Only one panel cover, or door should be opened at any one point, the engineer undertaking the thermal survey should have TOTAL control of the section of live conductors he or she is working on.

Procedural Measures

- A comprehensive method statement should be written that details all of the stages of the thermal image activity, including the opening and closing (or removal) of panel doors and/or the removal of panel covers. This may require a shut-down so that a thorough

understanding can be gained of the electrical equipment located behind the panel cover or door prior to any thermal image being taken. ENWCML aim to do these surveys during the LV maintenance, where possible, prior to conducting the thermal imaging survey (where we identify reasons of lack of information or knowledge of the panel construction methods). Photographic evidence and information will be recorded and uploaded to the customers file for future reference.

- Personnel involved in the thermal survey will be competent and qualified electrical engineers.
- Some hazards may be time dependent, it may therefore be possible to select a time of the day when the risk of hazard is lowered. This approach may be suitable for noise hazards in factories etc.
- On detection of a 'hot spot' no remedial action should be undertaken until the electrical supply has been 'isolated and proven dead' (using ENW approved procedures). This will require separate RAMS for the remedial task (if the item is classed as immediately dangerous the engineer will ask the site representative to isolate the LV supply (if the contract is a COMA which includes 'Control' then the site will be informed and ENW engineer will isolate and control via a LV IC as per the ENWCML LV policy)).
- The RAMS process should be written down, signed, dated and agreed by all parties before any work commences (the thermal imaging engineer conducting the works should be involved in the completion of the RAMS for each site). The RAMS will require ENWCML review process prior to work commencing.

CONCERNS TO NOTE

(a) Whilst removing a cover from a live panel it might slip and touch live conductors

(b) A metallic object could fall into the panel

(c) A fault could occur whilst the panel cover is removed

(d) Accidental contact of conductors if the operative is not far enough away.

Proper knowledge of how the panel cover is secured is imperative before it is removed (on a live panel), most modern panel covers have a lip formed to which the cover hooks over, this prevents the cover slipping down when loosening or re-fixing.

Form separation ratings of panels are designed to add protection for the engineer working on or inside the panel. Various Form separation ratings are available and provide varied protection. (higher the Form rating the more enclosed the internal live parts are) These internal barriers can also cause issues when conducting a standard 'Direct' method thermal image survey due to be a further internal barrier which restricts a thermal image being taken directly from the conductor. Under NO circumstance should these internal separation enclosures / covers be removed when the panel is live.

The process for thermal image capture will change from the 'Direct' method to 'Reflective heat' method.

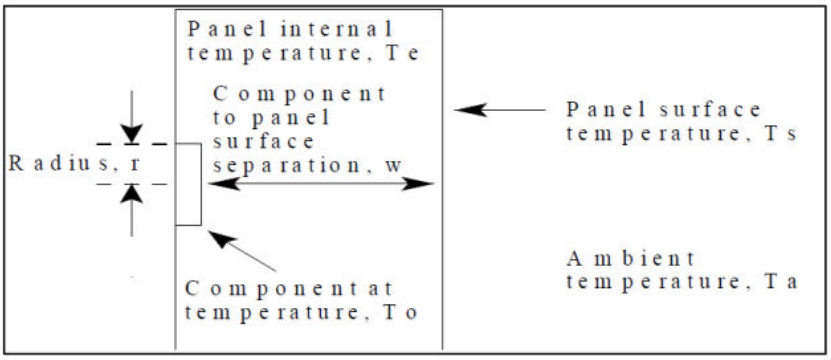
1/ 'Direct – Live opening' is the method normally employed by ENWCML engineers to gain the most detailed results.

2/ 'Direct – Isolated opening' method is not normally employed. Used on higher risk panels where removal of panels is deemed more dangerous and isolation of supplies is recommended prior to removal of covers. The supply is reinstated following removal of covers and method No1 is then employed.

3/ 'Residual heat' – method is not normally employed. Used on higher risk panels where removal of panels is deemed more dangerous and isolation of supplies is recommended prior to removal of covers. This method does not produce the best results due to some of the heat being dissipated.

4/ ‘Reflective heat’ method is imaging conducted ‘through’ a panel barrier or internal enclosure. This is reliant on a detectable level of heat being transferred from faulty equipment or connections to the cover that is surrounding the faulty area, the heat transfer will be minimal compared to the internal ‘hot spot’ however it will show as a comparable base as the other areas of the internal enclosure will also be at a lower temperature so the heat will be identified. Any area identified by the engineer as a potential ‘hot spot’ would be recorded and reported to the client for further investigation (this would require isolation).

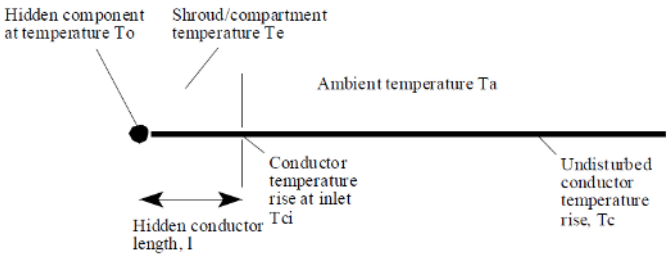
Reflective measurement approach



7.0 Measurement of Hidden Components

The figures below can be used to estimate the temperature of hidden equipment from the temperature measurement on observable connecting cables/busbars. Examples are shrouded terminals and components located in adjacent compartments which cannot be opened (Form sectional rated compartments are included in this). A heat dissipation/conduction parameter ‘m’ is used as the basis of the estimate. Typical values of ‘m’ are given in Figure 6.2. Figure 6.3 can be used to calculate the product ‘m*1’ for different conductor lengths. Figure 6.4 then enables an initial estimate of the object temperature To’ to be made on the basis that the shroud/compartment temperature Te is at ambient temperature Ta. Correction for shroud/compartment temperatures above ambient (Te > Ta) can subsequently be made using Figure 6.5 to estimate the actual object temperature To. The temperature rise inside the shroud/compartment can be measured by one of the methods noted.

Figure 6. 2
Heat dissipation/conduction for hidden components



Heat dissipation/conduction parameter m defined such that:

$m = \sqrt{[(h.P)/(k.A)]}$

where:

h is the surface heat transfer coefficient of the cable (W/m^2K)
P is the cross-sectional perimeter of the conductor (m)
k is the conductivity of the conductor (W/mK)
A is the cross-sectional area of the conductor (m^2)

Typical values of m

	Cables								Busbars	
Cross-sectional area (mm^2)	0.5	1.0	1.5	2.5	4.0	6.0	10	25	144	306
Parameter m	14	11	10	8.8	7.6	6.6	5.7	4.1	4.0	3.6

Figure 6. 3
Calculation of product m*l for various values of m

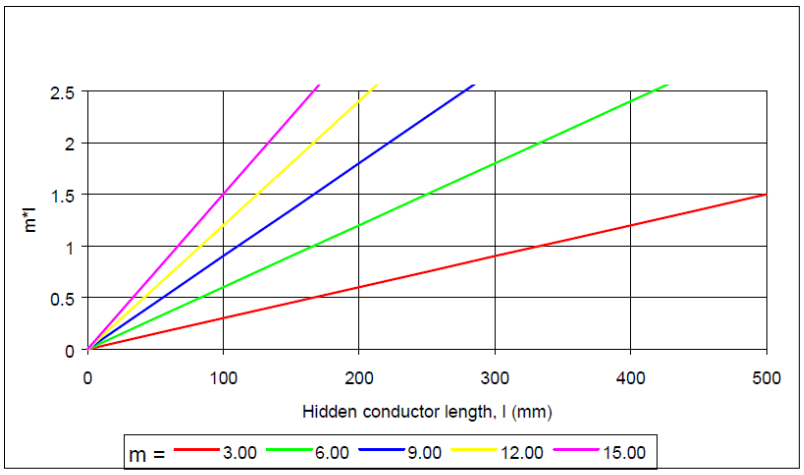


Figure 6. 4
Initial estimate of component temperature for Te = ta and various values of m*l

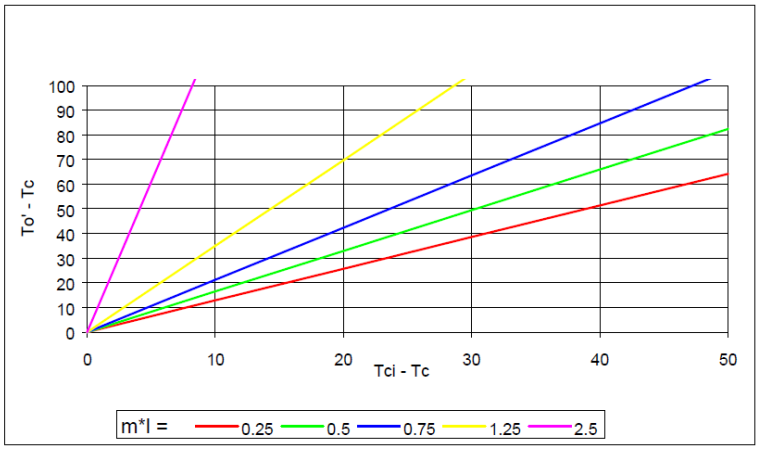
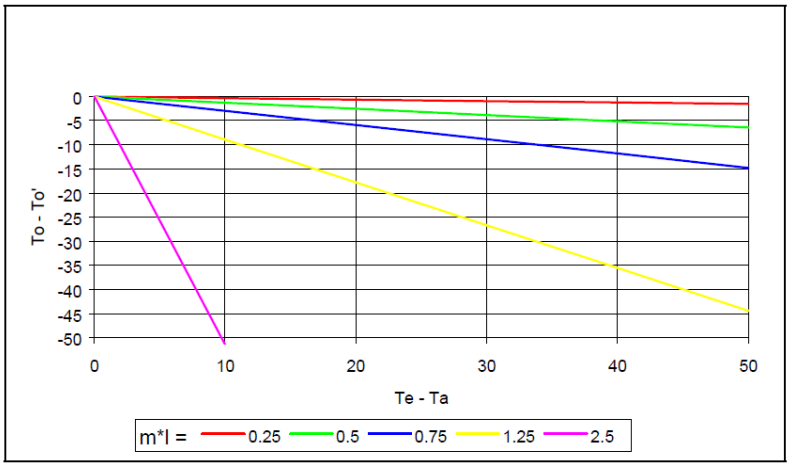


Figure 6. 5
Correction of component temperature for Te > Ta and various values of m*l



8.0 Training and Competence

Training in the HASWA 1974 and procedures arising from it.

Completion of a recognised training course covering First Aid including treatment for electric shock

Aged 18 years and above.

Possession of technical knowledge and sufficient experience so as to avoid danger that may be presented by the work to be undertaken.

The ability to recognise, at all times, whether the task is safe to continue.

Previous experience of work of a similar nature and familiarity with the type of plant on which work is to be undertaken, including sufficient knowledge of the components, construction and theory of electrical and/or mechanical systems to understand the observed patterns of radiation.

Examples of previous work and/or references.

Knowledge of manufacturer's guidance and recommendations for equipment which he/she will use to undertake the work (including completion of induction courses where appropriate)

Possession of technical knowledge and sufficient experience of the thermal imaging, measurement and photographic equipment and techniques employed to meet the inspection responsibilities.

9.0 Client's Scope and Responsibility

Each client has a responsibility (listed below taken from the reference documents) which will assist the safe working practice and also the method the inspection is conducted (prior).

The Client will normally require involvement of competent persons employed on their behalf to assist in the thermal imaging activity. This will usually be the in-house electrician or equivalent contractor personnel.

The Client is responsible in ensuring the presence of the relevant personnel at the agreed time of the survey.

The Client shall detail any additional work elements (or any that are omitted from the standard list).

The Client shall define the scope of plant to be surveyed and produce a supporting detailed schedule.

The Client shall list associated drawings/information in the specification and provide copies to the Contractor.

The Client should assess competency of Contractor.

The Client should confirm details of a Contractor's insurance cover.

The Client should decide whether to commission a consultant to undertake the risk assessment and finalise the method statement or whether to deal with them in-house.

The Client should undertake an assessment to identify business risks for work on critical installations.

The Client shall demonstrate management control over premises.

Conventional inspection and testing tasks should be complete prior to work commencing on new installations. Work should only be undertaken on existing installations that have been routinely maintained to a safe level.

The Client shall arrange for an electrically competent site operative to accompany the Contractor on site.

The Client should decide if independent witnessing of the work is required when the Contractor is engaged as a sub-contractor to the building contractor for acceptance testing.

The Client should detail any specific equipment requirements.

The Client should identify specific requirements.