Standard for Infrared Inspection of Electrical Systems & Rotating Equipment

2008 Edition

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Standard for Infrared Inspection of Electrical Systems & Rotating Equipment

Foreword

This standard outlines the procedures and documentation requirements for conducting infrared inspections of electrical systems and rotating equipment. This standard covers an application which is both art and science. This document assumes that the reader is generally familiar with the science of infrared thermography. It is not intended to be an absolute step-by-step formula for conducting an infrared inspection.

The use of this standard is not intended to qualify an individual using it to conduct an infrared inspection, or to analyze the resulting infrared data without formal training prior to its use. This document is intended to support infrared thermographers who have been professionally trained and certified. It must be acknowledged and understood that the misinterpretation of data that can occur without proper training and experience cannot be avoided simply by using this standard. In no event shall Infraspection Institute be liable to anyone for special, collateral, incidental or consequential damages in conjunction with or arising from use of this standard.

Other Infraspection Institute Standards

Infraspection Institute began publishing guidelines for infrared thermography in 1988. Since their initial publication, Infraspection Institute guidelines have been adopted by hundreds of companies worldwide and incorporated into documents published by other recognized standards organizations such as the American Society for Testing and Materials (ASTM). Beginning in 2007, Infraspection Institute guidelines were renamed as standards to reflect their industry-wide acceptance and the best practices they embody.

Several standards are available from Infraspection Institute. These standards cover equipment operation, temperature measurement, and specific applications. A complete list of current Infraspection Institute standards may be found online at www.infraspection.com.

Infraspection Institute standards represent the work of many practicing infrared thermographers and other experts. We thank them for their valuable contributions.

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1.0 Scope

1.1 This standard covers procedures for conducting infrared inspections of electrical systems and rotating equipment.

1.2 This standard provides a common document for the end user to specify infrared inspections and for the infrared thermographer to perform them.

1.3 This standard lists the joint responsibilities of the end user and the infrared thermographer that, when carried out, will result in the safest and highest quality inspection for both.

1.4 This standard outlines specific content for documenting qualitative and quantitative infrared inspections.

1.5 This standard may involve use of equipment in hazardous or remote locations or in close proximity to energized electrical equipment.

1.6 This standard addresses criteria for infrared imaging equipment, such as spatial resolution and thermal sensitivity.

1.7 This standard addresses meteorological conditions under which infrared inspections should be performed.

1.8 This standard addresses operating procedures and operator qualifications.

1.9 This standard addresses verification of infrared data.

1.10 This standard provides temperature limits for electrical and mechanical components and lubricants.

1.11 This standard provides several means for prioritizing exceptions based on temperature.

1.12 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.0 Referenced Documents

2.1 *Standard for Measuring and Compensating for Emittance Using Infrared Imaging Radiometers.* Infraspection Institute, 425 Ellis Street, Burlington, NJ 08016.

2.2 *Standard for Measuring and Compensating for Reflected Temperature Using Infrared Imaging Radiometers.* Infraspection Institute, 425 Ellis Street, Burlington, NJ 08016.

2.3 *Standard for Measuring and Compensating for Transmittance of an Attenuating Medium Using Infrared Imaging Radiometers.* Infraspection Institute, 425 Ellis Street, Burlington, NJ 08016.

2.4 *NFPA 70B Recommended Practice for Electrical Equipment Maintenance.* National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169.

2.5 *NFPA 70E Standard for Electrical Safety in the Workplace.* National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169.

2.6 *Occupational Safety and Health Standards for General Industry 29 CFR, Part 1910.* US Department of Labor. Occupational Safety & Health Administration, Washington, DC.

2.7 *Occupational Safety and Health Standards for the Construction Industry 29 CFR, Part 1926.* US Department of Labor. Occupational Safety & Health Administration, Washington, DC.

2.8 *Level-I Certified Infrared Thermographer® Reference Manual.* Infraspection Institute, Burlington, NJ.

2.9 *Level-II Certified Infrared Thermographer® Reference Manual.* Infraspection Institute, Burlington, NJ.

3.0 Terminology

For the purpose of this standard,

3.1 **End user -** the person requesting an infrared thermographic inspection.

3.2 **Exception -** an abnormally warm or cool connector, conductor or component that may be a potential problem for the end user.

3.3 **Infrared imaging radiometer (imaging radiometer) -** a thermal imager capable of measuring temperature.

3.4 **Infrared inspection -** the use of infrared imaging equipment to provide specific thermal information and related documentation about a structure, system, object or process.

3.5 **Infrared thermal imager (infrared camera) -** a camera-like device that detects, displays and records the apparent thermal patterns across a given surface.

3.6 **Infrared thermographer -** a person who is trained and qualified to use an imaging radiometer.

3.7 **Non-imaging radiometer (infrared thermometer) -** an instrument that measures the average apparent surface temperature of an object based upon the object's radiance.

3.8 **Qualified assistant -** a person provided and authorized by the end user to perform the tasks required to assist the infrared thermographer. He/she is knowledgeable of the operation and history of equipment to be inspected and is trained in all the safety practices and rules of the end user.

3.9 **Qualitative infrared thermography -** the practice of gathering information about a structure, system, object or process by observing images of infrared radiation, and recording and presenting that information.

3.10 **Quantitative infrared thermography -** the practice of measuring temperatures of the observed patterns of infrared radiation.

3.11 **Rotating equipment -** Stationary machinery or electro-mechanical devices that have rotating components.

3.12 **Standard -** a set of specifications that define the purposes, scope and content of a procedure.

3.13 **Thermal imager -** see Infrared thermal imager.

3.14 **Thermogram -** a recorded visual image that maps the apparent temperature pattern of an object or scene into a corresponding contrast or color pattern.

3.15 **Thermographer -** see Infrared thermographer.

4.0 Significance and Use

4.1 The purpose of an infrared inspection is to identify and document exceptions in the end user's electrical system and/or rotating equipment.

4.1.1 In electrical systems, exceptions are usually caused by loose or deteriorated connections, short circuits, overloads, load imbalances or faulty, mismatched or improperly-installed components.

4.1.2 For rotating equipment, exceptions are usually caused by friction due to improper lubrication, misalignment, worn components or mechanical loading anomalies.

4.2 Providing opinions about the causes of exceptions, the integrity of the system, or recommendations for corrective actions requires knowledge and skills beyond those of infrared thermography.

4.2.1 Infrared thermography will be presented as an inspection technique to gather and present information about the system at a specific time.

4.2.2 Infrared thermography will not be promoted as a remedial measure.

4.2.3 An infrared inspection of an electrical system or rotating equipment does not assure proper operation of such equipment. Other tests and proper maintenance are necessary to assure their reliable performance.

5.0 Responsibilities of the Infrared Thermographer

5.1 Infrared inspections will be performed when environmental and physical conditions such as solar gain, wind, surface and atmospheric moisture and heat transfer are favorable to gathering accurate data.

5.2 The infrared thermographer will have sufficient knowledge of the components, construction and theory of electrical systems and/or rotating equipment to understand the observed patterns of radiation.

5.3 The infrared thermographer will use thermal imaging and/or measurement equipment with capabilities sufficient to meet the inspection requirements.

5.4 The infrared thermographer will be accompanied by a qualified assistant who is knowledgeable of the equipment being inspected.

5.5 Unless he/she is a licensed electrician, professional engineer, or has other equivalent qualifications, the infrared thermographer **will not** perform any tasks that are normally done by these personnel. Unless so qualified and authorized by the end user, the infrared thermographer:

5.5.1 **Will not** remove or replace covers or open or close cabinets containing electrical equipment.

5.5.2 **Will not** measure electric loads of the equipment.

5.5.3 **Will not** touch any inspected equipment and will maintain a safe distance from such equipment.

5.5.4 **Will** comply with the safety practices and rules of the end user and applicable safety standards.

5.6 When performing quantitative infrared inspections, the infrared thermographer will assure that all temperature-measuring equipment meets the manufacturers' standard specifications for accuracy.

5.7 After repair, and when requested by the end user, the thermographer will reinspect each exception to assure that the problem has been corrected.

6.0 Responsibilities of the End User

6.1 The end user will provide or help develop an inventory list of the equipment to be inspected in a logical and efficient route through the facility.

6.2 The end user will provide a qualified assistant(s) who is knowledgeable of the operation and history of the equipment to be inspected. This person(s) will accompany the infrared thermographer during the infrared inspection and, unless specified otherwise, will be qualified and authorized by the end user to:

6.2.1 Obtain authorization necessary to gain access to the equipment to be inspected and will notify operations personnel of the inspection activities.

6.2.2 Open and/or remove all necessary covers immediately before inspection by the infrared thermographer.

6.2.3 Close and/or replace these cabinet and enclosure covers immediately after inspection by the infrared thermographer.

6.2.4 Assure that the equipment to be inspected is under adequate load, create satisfactory loads when necessary, and allow sufficient time for recently-energized equipment to produce stable thermal patterns.

6.2.5 Measure electric loads when requested by the infrared thermographer.

6.3 The end user takes full responsibility for consequences resulting from actions taken, or not taken, as a result of information provided by an infrared inspection.

6.4 After repair, the end user will authorize reinspection of each exception to assure that the problem has been corrected.

7.0 Instrument Requirements

7.1 General

7.1.1 Infrared thermal imaging systems shall detect emitted radiation and convert detected radiation to a real-time visual signal on a monitor screen. Imagery shall be monochrome or multi-color.

7.1.2 Spectral Range: the infrared imaging system shall operate within a spectral range from 2 to 14 μm. A spot radiometer or nonimaging line scanner is not sufficient.

7.1.3 The infrared thermal imaging system shall have a Minimum Resolvable Temperature Difference (MRTD) of 0.3°C or less at 20°C.

7.1.4 Infrared equipment may be man portable or vehicle mounted.

7.1.4.1 For vehicle mounted equipment, care should be taken to ensure that equipment is mounted securely, will not interfere with the safe operation of the vehicle, and meets all applicable regulatory requirements.

8.0 Inspection Procedures

8.1 Equipment to be inspected shall be energized and under adequate load; ideally this is normal operating load. For acceptance testing, higher loads may be warranted.

8.2 Subject equipment shall be externally examined before opening or removing any protective covers to determine the possible presence of unsafe conditions. If abnormal heating and/or unsafe conditions are found, the end user or qualified assistant shall take appropriate remedial action prior to commencing the infrared inspection.

8.3 Electrical and mechanical equipment enclosures shall be opened to provide line-of-sight access to components contained therein. In some cases, further disassembly may be required to allow for a complete infrared inspection. Examples include dielectric barriers, clear plastic guards, and other materials that are opaque to infrared energy.

8.4 In some cases, the infrared inspection may be conducted through permanently installed view ports or infrared transparent windows. Care must be taken to ensure that all subject equipment can be adequately and completely imaged. In some cases, special lenses may be required for the thermal imager.

8.5 Infrared inspections may be qualitative or quantitative in nature. Qualitative thermographic inspections may be conducted using a thermal imager or an imaging radiometer. Quantitative inspections may be conducted using an imaging radiometer or a thermal imager in combination with a non-imaging radiometer.

8.5.1 When performing qualitative inspections, the thermographer shall utilize a thermal imager with resolution sufficient to provide clear imagery of the inspected components.

8.5.2 When performing quantitative inspections, the thermographer shall utilize an imaging radiometer with resolution sufficient to provide clear imagery and accurate temperature measurement of the inspected components.

8.5.2.1 When performing a quantitative inspection, the thermographer shall make every effort to ensure the accuracy of non-contact temperature measurements. In particular, consideration should be given to target emittance, reflected temperature, weather conditions, and target size.

8.6 Using inventory lists provided by the end user, the thermographer shall inspect electrical components and/or rotating equipment utilizing a thermal imager or imaging radiometer. Inspection shall be conducted in a manner so as to ensure complete coverage of all components.

8.7 Whenever possible, similar components under similar load shall be compared to each other. Components exhibiting unusual thermal patterns or operating temperatures shall be deemed as exceptions and documented with a thermogram and visible light image.

8.7.1 Thermal images shall be stored on electronic media or videotape. Every effort shall be made to ensure the thermal image is in sharp focus.

8.7.2 Visible light images may be recorded with a daylight camera integral to the infrared imager or with a separate daylight or video camera.

8.7.2.1 Visible light images shall be properly exposed to ensure adequate detail. Particular attention should be given to perspective, focus, contrast, resolution, and lighting. Visible light images should align with the thermal image as closely as possible.

8.7.3 Thermograms and visible light images shall be included in a written report along with the information required in section 9.

8.8 In certain cases, one may elect to capture thermograms and visible light images for all inspected components. This practice may be useful for providing quality assurance information or baseline data; however, it can be time and labor intensive for large inventories.

8.8.1 When capturing imagery for all inspected components, thermal and visible light images shall be included in a written report along with the information required in section 9.

8.9 As an option, the criteria listed in sections 10 and 11 may be used to help prioritize repair actions; however, use of these criteria is not an exact science and involves risking an unplanned failure. For best results, it is recommended that each exception be inspected for cause and appropriate corrective action taken as soon as possible.

8.10 In some cases, imaging from a motor vehicle or aircraft can provide greater mobility, a superior vantage point, and allow for rapid inspection of large or remote areas.

8.10.1 When imaging from a motor vehicle or aircraft, precautions should be taken to ensure safe operation of the vehicle and imaging equipment, as well as the safety of all occupants.

9.0 Documentation

9.1 The thermographer will provide documentation for all infrared inspections. The following information will be included in a written report to the end user:

9.1.1 The name and any valid certification level(s) and number(s) of the infrared thermographer.

9.1.2 The name and address of the end user.

9.1.3 The name(s) of the assistant(s) accompanying the infrared thermographer during the inspection.

9.1.4 The manufacturer, model and serial number of the infrared equipment used.

9.1.5 A list of all the equipment inspected and notations of the equipment not inspected on the inventory list.

9.1.6 The date(s) of the inspection and when the report was prepared.

9.2 When performing a qualitative infrared inspection, the infrared thermographer will provide the following information for each exception identified:

9.2.1 The exact location of the exception.

9.2.2 A description of the exception such as its significant nameplate data, phase or circuit number, rated voltage, amperage rating and/or rotation speed.

9.2.3 When significant, the environmental conditions surrounding the exception including the air temperature, wind speed and direction, and the sky conditions.

9.2.4 Hardcopies of a thermal image (thermogram) and corresponding visible-light image of the exception.

9.2.5 The field-of-view of the infrared imager lens.

9.2.6 Notation of any windows, filters or external optics used.

9.2.7 If desired, a subjective evaluation rating provided by the qualified assistant and/or end user representative, of the importance of the exception to the safe and continuous operation of the system.

9.2.8 Any other information or special conditions that may affect the results, repeatability or interpretation of the exception.

9.3 When performing a quantitative infrared inspection, the infrared thermographer will provide the following additional information for each exception documented:

9.3.1 The distance from the infrared imager to the exception.

9.3.2 Whenever possible, the maximum rated load of the exception and its measured load at the time of the inspection.

9.3.2.1 The percentage load on the exception, calculated by dividing its measured load by the rated load.

9.3.3 The emittance, reflected temperature and transmittance values used to calculate the temperature of the exception.

9.3.4 When using Delta T criteria, the surface temperature of the exception and of a defined reference and their temperature difference.

9.3.5 When using absolute temperature criteria, the surface temperature of the exception and the standard temperature(s) referenced.

9.3.6 If desired, an evaluation of the temperature severity of the exception.

9.3.7 If desired, a repair priority rating for the exception based on its subjective rating, temperature severity rating or an average of both.

10.0 Delta T Criteria for Electrical Systems

10.1 The infrared thermographer may use the following Delta T (temperature difference) criteria to evaluate the temperature severity of an exception. These Delta T criteria are reported as the temperature rise of the exception above the temperature of a defined reference, which is typically the ambient air temperature, a similar component under the same conditions or the maximum allowable temperature of the component:

NETA Maintenance Testing Specifications,[1] for electrical equipment

Priority	Delta T between similar components under similar load	Delta T over ambient air temperature	Recommended Action
4	1 to 3C°	1C° to 10C°	Possible deficiency; warrants investigation
3	4 to 15C°	11C° to 20C°	Indicates probable deficiency; repair as time permits
2	– – –	21C° to 40C°	Monitor until corrective measures can be accomplished
1	>15C°	>40C°	Major discrepancy; repair immediately

Military Standard,[2] for electrical equipment

Priority	Delta T	Recommended Action
4	10 to 25C°	Component failure unlikely but corrective measure required at next scheduled routine maintenance period or as scheduling permits
3	25 to 40C°	Component failure probable unless corrected
2	40 to 70C°	Component failure almost certain unless corrected
1	70C° and above	Component failure imminent. Stop survey. Inform cognizant officers

Experience-Based,[3] for electrical and/or mechanical equipment. Any Delta T classification system based on experience, such as the following[3]

Priority	Delta T	Recommended Action
4	1 to 10C°	Corrective measures should be taken at the next maintenance period
3	>10 to 20C°	Corrective measures required as scheduling permits
2	>20 to 40C°	Corrective measures required ASAP
1	>40C°	Corrective measures required immediately

Motor Cores,[4] (on test bench, not in service)

Priority	Delta T	Recommended Action
3	1 to 10C°	No exception likely
2	>10 to 20C°	Possible exception, consult motor core test data
1	>20C°	Exception likely

11.0 Absolute Temperature Criteria for Electrical Systems

11.1 The infrared thermographer may use absolute temperature criteria based on the following ANSI, IEEE and NEMA or other standards to identify electrical system exceptions.

11.2 All temperatures of the following standards are specified in Celsius as follows:

Ambient / Rated Rise / Maximum Allowable

Note: Ambient = rated ambient temperature
Rated Ambient + Rated Rise = Maximum Allowable Temperature

11.3 When the exception is heating several adjacent components, the lowest temperature component specification should be used.

Example: You are inspecting a heating terminal that connects an insulated conductor to a circuit breaker. The component with the lowest temperature specification should be used.

11.4 When several different temperatures for similar equipment are given in the referenced standards, the **lowest temperatures** (most conservative) are listed. If an exception temperature exceeds the listed maximum allowable temperature limit, it could be operating at a temperature lower than a higher (less conservative) specification. Consult the referenced standard(s).

11.5 When the infrared thermographer is unable to determine the class of insulation or equipment being inspected, he/she should use the **lowest temperature** (most conservative) specification within the component grouping.

Example: You are inspecting an insulated wire that has no visible markings. Use the lowest temperature specification for any conductor insulation.

11.6 Unless noted otherwise, these absolute temperature criteria are based on equipment operating at the stated ambient temperature and at 100% of their rated load. The following formula[5] can be applied to these absolute temperature criteria to give a corrected maximum allowable temperature ($Tmax_{corr}$) for the reduced operating load and actual ambient temperature of the exception:

$$Tmax_{corr} = \left\{(A_{meas} \div A_{rated})^2 (T_{rated\ rise})\right\} + Tamb_{meas}$$

$Tmax_{corr}$ = corrected maximum allowable temperature

A_{meas} = measured load, in amperes

A_{rated} = rated load, in amperes

$T_{rated\ rise}$ = rated temperature rise (from standard)

$Tamb_{meas}$ = measured ambient temperature

Example: A fuse is found to be operating at a temperature of 68°C. The measured ambient temperature ($Tamb_{meas}$) = 35°C. The fuse is rated at 100 amps (A_{rated}) but its actual load is measured at only 50 amps (A_{meas}).

1. What is the $Tmax_{corr}$ for the fuse?
2. Is the temperature of the fuse an exception?

$$Tmax_{corr} = \left\{(A_{meas} \div A_{rated})^2 (T_{rated\ rise})\right\} + Tamb_{meas}$$

$$\begin{aligned} Tmax_{corr} &= \left\{(50 \div 100)^2 (30)\right\} + 35 \\ &= \left\{(.5)^2 (30)\right\} + 35 \\ &= \left\{(.25)(30)\right\} + 35 \\ &= 7.5 + 35 \\ Tmax_{corr} &= 42.5°C \end{aligned}$$

The actual operating temperature of the fuse (68°C) is greater than the $Tmax_{corr}$ of 42.5°C. This is an exception!

11.7 Absolute Temperature Criteria:

	Ambient / Rated Rise / Maximum
Conductors (lowest temperature criteria)	
Bare conductors[6], in free air	55/25/80
Bare conductors, in enclosure	40/30/70
Bare conductors, enclosure surface	40/20/60
Insulated conductors[7], in free air	30/30/60
Insulated conductors, in enclosure	30/30/60
Insulated conductors, enclosure surface	30/20/50
Insulated conductors, in sun	50/10/60
Conductor Insulations[7]	
T, TW, R, RW, RU	30/30/60
THW, Polyethylene, XHHW, RH-RW	30/45/75
Varnished Cambric	30/47/77
Paper Lead	30/50/80
Varnished Polyester	30/55/85
THH, Cross Linked Polyethylene, Ethylene-Propylene	30/60/90
Silicone Rubber	30/95/125
Connectors and Terminations (lowest temperature criteria)	
Metals[10], silver or silver alloy	40/40/80
Metals, copper, copper alloy or aluminum	40/50/90
Metals, aluminum alloy	52/53/105
Overcurrent Devices[8,9] (lowest temperature criteria)	
Circuit breakers, molded case	40/20/60
Circuit breakers, all others	40/30/70
Fuses	40/30/70
Disconnects and Switches Including Insulators and Supports[10] (lowest temperature criteria)	40/30/70
Bushings[11] (lowest temperature criteria)	
Transformer, lower end	40/55/95
Circuit breaker, lower end	40/40/80
External terminal	40/30/70
Coils and Relays[8,12]	
Class 90	40/50/90
Class 105	40/65/105
Class 130	40/90/130
Class 155	40/115/155
Class 180	40/140/180
Class 220	40/180/220
AC Motors, Field Windings[13]	
1.00 SF, class A	40/60/100
1.00 SF, class B	40/80/120
1.00 SF, class F	40/105/145
1.00 SF, class H	40/125/165
1.15 SF, class B	40/90/130
1.15 SF, class F	40/115/155

Note: Casing temperatures may be lower than these specified windings temperatures.

DC Motors and Generators, Windings[13]

1.00 SF, class A	40/70/110
1.00 SF, class B	40/100/140
1.00 SF, class F	40/130/170
1.00 SF, class H	40/155/195
1.25 SF, (2hr), class B	40/80/120
1.25 SF, (2hr), class F	40/110/150

Note: Casing temperatures may be lower than these specified windings temperatures.

Cylindrical Rotor Synchronous Generators, Air Cooled, Casing[13]

Class B	40/70/110
Class F	40/90/130
Class H	40/110/150

Transformers, Distribution and Power[14,15,16]

Dry type, class 105, windings	30/55/85
Dry type, class 150, windings	30/80/110
Dry type, class 185, windings	30/115/145
Dry type, class 220, windings	30/150/180
Oil cooled, 55°C rise, casing	30/55/85
Oil cooled, 65°C rise, casing	30/65/95

Note:
1. Oil-cooled casing temperatures measured near top of liquid in main tank.
2. Most 55C° rise transformers built before 1962.
3. For specialty transformers (other than power and distribution) or other liquid-cooled equipment, such as specified on the nameplate.

12.0 Delta T Criteria for Mechanical Systems

12.1 The infrared Thermographer may use Delta T (temperature difference) criteria to rate the temperature severity of mechanical system exceptions. These Delta T criteria are usually reported as the temperature rise of the exception above the temperature of a defined reference. Use the Delta T criteria listed in section 10.1.

12.2 By taking multiple measurements over time of similar components under similar operating and environmental conditions, statistical analysis can be used to set operational limits for trending and predicting the temperature performance of these components.

13.0 Absolute Temperature Criteria for Mechanical Systems

13.1 The infrared thermographer may use absolute maximum allowable temperature criteria based on published standards to identify mechanical system exceptions.

13.2 When an exception is heating several adjacent system components, the component having the lowest temperature specification should be referenced.

Example: You are inspecting a bearing of a motor. The applicable adjacent system components are the seals and the lubricant. The component (bearing, seals or lubricant) having the lowest temperature specification should be referenced.

Note: In most cases, the lubricant will have the lowest temperature specification.

13.3 When unable to determine the type of bearing, lubricant or seal, the infrared thermographer should use the lowest component temperature specification within the applicable group.

Example: You are inspecting a bearing. You identify the bearing and lubricant types and temperature limits, but you do not know the type of seal. From the list, select the lowest applicable temperature specification for any seal. Compare your measured bearing temperature to the lowest of the three component temperatures (the bearing, lubricant and seal).

13.4 The infrared thermographer often cannot directly measure the surfaces of the components in these specification lists. Care and good judgment must be used when applying these specifications to actual field temperature measurements.

13.5 Unless noted, temperature specifications are based on equipment operating at 100% of their rated load/speed. All temperatures are in Celsius.

13.6 Maximum Allowable Temperature Criteria:

Bearings, Rolling Element Types[17]

Races (for metallurgical stability)	125
Rolling elements	125
Plastic retainer (cage)	120
Steel retainer (cage)	300
Brass retainer (cage)	300
Steel shield (closure)	300
Nitrile rubber lip seal	100
Acrylic lip seal	130
Silicone lip seal	180
Fluoric lip seal	180
PTFE lip seal	220
Felt seal	100
Aluminum labyrinth seal	300

Bearings, Plain Types Material[18]

Tin base babbitt	149
Lead base babbitt	149
Cadmium base	260
Copper lead	177
Tin bronze	260
Lead bronze	232
Aluminum	121

Bearings, Plain Types, Factory Produced[19]

Rulon, filled PTFE	204
Graphite bronze	204
DU	288
PTFE lined fiberglass	177
Nylon	149
Polyurethane	82
Polyacetyl	104
Wood	71
Metalized graphite	593
Pure carbon	399
Polyolefin, UHMPW	82

Delrin	149
Zytel	107
Teflon	288
Rubber	49

Lubricants[20] (when used with polyamide plastic bearing retainer)

Mineral oils without EP additives, i.e., machine oils, hydraulic fluid	120
EP oils, i.e., industrial, automotive, gearbox oils	110
EP oils, i.e., rear axle, differential, hypoid gear oils	100

Synthetic oils

Polyglycols, poly-olefins	120
Diesters, silicones	110
Phosphate diesters	100
Greases (mineral oil lubricant), lithium, polyurea, bentonite, calcium complex	120

Lubricants, Greases (mineral oil), when used with steel or brass bearing retainer

Lithium base	110
Lithium complex	140
Sodium base	80
Sodium complex	140
Calcium (lime) base	60
Calcium complex	130
Barium complex	130
Aluminum complex	110
Inorganic thickeners	130
Polyurea	140

Lubricants, Solid lubricant materials

Graphite	427
Molybdenum disulfide	450
Tungsten disulfide	510
Polytetrafluoroethylene	300

Seals and Gaskets, elastomers[21,22]

O-rings and gaskets

Butyl rubber	107
Hypalon	121
Epichlorohydrin rubber	135
Ethylene acrylic	177
EPDM	149
Fluorocarbon (viton, kalrez)	204
Fluorosilicone	177
Neoprene	149
Nitrile	135
Polyacrylate rubber	177
Polysulfide rubber	107
Polyurethane	93
Silicone rubber	232

Lip Seals

Nitrile	121
Polyacrylate rubber	149
Silicone rubber	163
Fluorocarbon (viton, kalrez)	204
Leather	93

Mechanical Seal Material[23], (see above for elastomers)

Stellite	177
Tungsten carbide	232
Stainless steel	316
Ni-resist	177
Bronze, leaded	177
Ceramic	177
Carbon	275
Silicon carbide	1,650
Glass-filled teflon	177

Power Transmission Components[24]

V-belts	60

Chain drives: limited by maximum lube temperature.
Gear drives: limited by maximum lube temperature.

14.0 Documents Referenced by Footnotes

1. *Maintenance Testing Specifications for Electric Power Distribution Equipment and Systems.* International Electric Testing Association, 2700 W. Centre Ave., Suite A, Portage, Michigan 49024

2. *Infrared Thermal Imaging Survey Procedure for Electrical Equipment ML-STD-2194 (SH).* Naval Publications and Printing Service, 700 Robbins Ave., Bldg. 4D, Philadelphia, Pennsylvania 19111

3. *Level-II Certified Infrared Thermographer Reference Manual.* Infraspection Institute, 425 Ellis Street, Burlington, New Jersey 08016

4. *Infrared Inspection of Motor Cores,* by Michael Dreher, 1992. Available from Infraspection Institute

5. *ANSI/IEEE C37.010-4.4.3. IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

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