

Infrared (IR) Inspection Procedures

SUMMARY

This utility procedure outlines infrared (IR) inspection procedures – a key element of the Preventive Maintenance Program.

Level of Use: Informational Use

TARGET AUDIENCE

Electric transmission employees who perform IR inspections.

SAFETY

The inspection process can pose risks associated with working on or getting close to energized equipment.

BEFORE YOU START

- REFER to the [Electric Transmission Preventive Maintenance Manual](#) (TD-1001M), Section 2, “Inspections.”
- An IR inspection cannot be substituted for an aerial inspection.

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PROCEDURE STEPS

1 General Information

- 1.1 IR inspection procedures are a key element of the preventive maintenance program. The recommended maintenance priorities reduce the potential for component failures and facility damage and facilitate a proactive approach to repairing or replacing identified abnormal components.
- 1.2 PERFORM IR inspections when required by [Utility Procedure TD-1004P-04, “Conductor Rerate Process for Overhead Transmission Circuits,”](#) or as triggered.

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- 1.3 In addition, PERFORM IR inspections on lines that have exceeded their emergency ratings for 30 minutes or more.
 1. Grid Control Center (GCC) personnel must NOTIFY the local electric transmission supervisor that a condition requiring an inspection has occurred.
 2. SCHEDULE this inspection as soon as possible or when conditions allow (line loading, weather, etc.).
- 1.4 Additional IR inspections may be required, as triggered, in accordance with [TD-1001M, Electric Transmission Preventive Maintenance Manual](#), Sections 2.3.2 and 2.5.1.

2 Detailed IR Procedures

2.1 Overview

1. Electric transmission system inspections and preventive maintenance programs use IR imaging and temperature-measuring systems to identify faulty components and initiate repairs or replacements proactively.
2. Connectors experience lower operating temperatures than their respective conductors. This means any time the temperature of a connector is greater than the temperature of its respective conductor, a higher-resistance connection exists, and a failure can be expected but not precisely predicted. It is probable that degradation occurs faster with an increase in load or temperature.
3. Conductor manufacturers usually recommend a maximum operating temperature of 185° Fahrenheit (F) for tensioned, bare conductor.
4. Conductor manufacturers recommend the following maximum operating temperatures for insulated conductors:
 - 167°F for high-molecular-weight polyethylene (HMWPE)
 - 194°F for cross-linked polyethylene (XLPE)
 - 194°F for ethylene-propylene rubber (EPR)
5. With insulated conductor systems, the temperature measured at the surface of an insulated conductor or component can be between 20% and 50% of the actual temperature of the targeted conductor or component (for example, if the actual temperature of the component is 212°F, the measured temperature can be between 68°F and 122°F, respectively).

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2.1 (continued)

6. IR imaging systems detect and record all the heat being radiated in their fields of view.
 - IR cameras use an image-scanning technique to identify heat radiated from a target and its background.
 - IR imaging systems capture and store the heat images pictorially for immediate or future evaluation.
 - Using IR imaging systems, the operator can pinpoint the precise location of the hottest spot on the observed target.
7. The recommended maintenance is based on the following factors and the operational risk associated with each:
 - Measured operating temperature of both the target and its respective connectors or conductors
 - Temperature differentials between the target and its respective, adjacent components
 - Thermal image showing hot component

2.2 Equipment

1. Video imaging equipment used for IR inspections must meet the following minimum specifications:
 - Image storage – Equipment must have the ability to store images for future analysis.
 - Lens interchangeability – The IR camera must have lens interchangeability, or personnel must have access to a camera with lens interchangeability to enable inspections at varying distance to the object to be inspected.
 - Wave length – The IR system must be “long wave,” responding to wave lengths of 8 to 14 microns.
 - Camera lens – A 3× to 10× telescopic lens is required for accurate IR measurements at a safe distance.
 - Palette – The IR system must have a color palette, with unique and easily distinguishable colors for over-temperature conditions, to locate hot spots and verify that the image is not saturated. A gray-scale palette with a color-distinguishing minimum and maximum saturation threshold is also acceptable.

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2.2 (continued)

- Camera mount – For helicopter IR inspections, a gimbal or gyro-stabilized remote-controlled camera mount attached to the exterior of the helicopter is preferred to dampen vibration.
 - Calibration – IR cameras that provide temperature readings must have been factory-calibrated within 1 year before the patrol.
 - IR cameras or systems that do not provide temperature readings do not require calibration within 1 year before the patrol.
 - Hand-held IR cameras used for overhead only must have been factory-calibrated within 2 years (due to the minimal use of cameras).
 - Recording media – The system must be capable of recording IR or color video of the entire inspection scan for special requests, along with color and IR still photos of each anomaly found.
 - Audio input – For helicopter IR inspections, the system must be capable of recording audio input from the helicopter intercommunication system.
2. Systems that contractors use for aerial (helicopter) IR inspections must be used in accordance with the manufacturer's requirements and must meet all requirements listed in Section 2.2.1 above.

2.3 Setting Up the IR Camera

1. Establishing the proper IR imaging system setup parameters for emissivity and background temperature is critical for obtaining accurate measurements with IR cameras. The other system setup parameters are used primarily to record and assist initial or future evaluations of heat radiated from a target and its background.
2. Setting the emissivity value at 1.0 eliminates the need to set the background temperature. The target, in this case, is considered a blackbody – totally reflective and non-transmissive. With highly emissive targets, the actual reflected energy is so small with respect to the emitted energy, that the temperature measurement is well within reason for predictive maintenance applications.
3. As the emissivity value of the target decreases, the influence of background radiation increases, and consequently so does the potential for errors based on background temperature settings.
 - a. IF the emissivity value is set at **less than 1.0**, AND the background temperature setting is adjusted inaccurately,

THEN the resulting temperature measurement of the target could have more error than it would if the emissivity value were set at 1.0.

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2.3 (continued)

Example:

With an emissivity setting **less than 1.0**, if the background temperature setting is **higher** than the actual background temperature, the target's temperature measurement will be less than it should be.

If the background temperature setting is **lower** than the actual background temperature, then the target's temperature measurement will be higher than it should be.

The measurement deviation compounds as the emissivity setting decreases from 1.0.

4. Setting the emissivity value at 1.0 eliminates the need to determine exact emissivity and background temperature values, simplifies the system operation, and results in reasonably accurate measurements.

Example:

When IR measurements are taken on overhead systems where the ceiling (sky) is unlimited, an accurate background temperature is nearly impossible to determine. Furthermore, most targets have dark surfaces and, therefore, have emittance values very close to 1.0.

2.4 Infrared (IR) Scanning Technique

1. Overhead

- a. CENTER the targeted component in the viewer or sight of the IR scanning device, AND OBSERVE the temperature(s) measured.
- b. SCAN 1 to 2 feet of the conductor or cable entering and/or leaving the targeted image, AND OBSERVE the temperature(s) measured.
- c. CENTER the respective, adjacent components in the viewer or sight of the IR scanning device, AND OBSERVE the temperature(s) measured.
- d. REPEAT Steps a, b, and c above for each respective, adjacent component.

IF the temperature of the targeted component is greater than those listed in [Table 1, "Determining Maintenance Priorities,"](#) on Page 7, OR shows **hot** with an IR system that does not provide temperature readings,

THEN PERFORM the following steps:

- (1) RECORD the information requested in [Section 3.4, "IR Inspection Documentation,"](#) on Page 9, using [Form TD-1001M-F15, "Transmission Line Infrared Data Sheet."](#)
- (2) ATTACH [Form TD-1001M-F15](#) to the notification created for abnormal findings.

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2.4 (continued)

2. Underground

- a. CENTER the targeted component (terminal-composite or porcelain) in the viewer or sight of the IR scanning device, AND OBSERVE the temperature(s) measured. SEE [Figure 1](#) below.

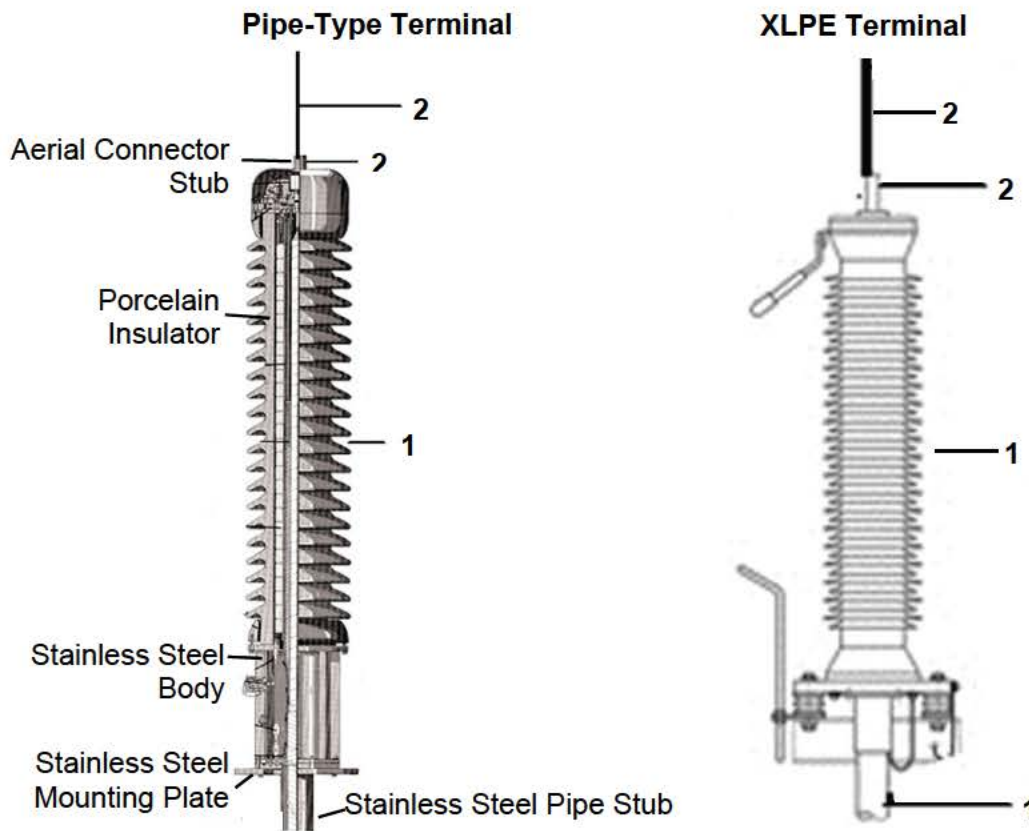


Figure 1. Pipe-Type and XLPE Terminals

- b. CENTER the respective, adjacent components (terminal ferrule or aerial connector stub) in the viewer or sight of the IR scanning device AND OBSERVE the temperature(s) measured.
- c. SCAN 1 to 2 feet of the conductor connected to the terminal ferrule or aerial connector stub, AND OBSERVE the temperature(s) measured.
- d. REPEAT Steps a, b, and c above for each respective, adjacent component.

IF the temperature of the targeted component is greater than those listed in [Table 1, "Determining Maintenance Priorities,"](#) on Page 7, OR shows **hot** with the IR system that does not provide temperature readings,

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2.4.2 (continued)

THEN PERFORM the following steps:

- (1) RECORD the information requested in [Section 3.4, "IR Inspection Documentation,"](#) on Page 9, using [Form TD-1001M-F15, "Transmission Line Infrared Data Sheet."](#)
- (2) ATTACH [Form TD-1001M-F15](#) to the notification created for abnormal findings.

2.5 Determining Maintenance Priorities

1. To assess and prioritize the relative severity of the conditions found during an IR inspection, as based on the measured temperatures and/or temperature rise, REFER to [Table 1, "Determining Maintenance Priorities,"](#) below.
 - a. IF the IR system does not provide temperature readings AND there are no obvious visual signs of deterioration,

THEN CREATE a three-month priority E tag (level 2) AND COMPLETE as soon as possible.

Table 1. Determining Maintenance Priorities

| Transmission Facilities | Temperature Differential (ΔT) | Priority/Remarks |
|---|--|---|
| Overhead and Underground Direct heat (See Notes) | $\geq 100^{\circ}\text{F}$ | Priority A: Notify supervisor and repair, replace, or make component safe immediately. |
| | 25°F to 99°F | Priority E: Repair or replace component within 3 months. |
| | $\leq 24^{\circ}\text{F}$ | Priority E 1: Repair or replace component within 3 months. |
| Underground Indirect heat ^{2,3} (See Notes) | 20°F and over | Notify supervisor. Contact underground engineering personnel to determine mitigation. |

Notes:

- ¹ All IR findings with a differential delta of less than 24°F may be prioritized as a "E" tag at the discretion of the inspector/CIRT reviewer, when additional evidence supports the rating (e.g., limited load, additional wind speed, photos of addition mechanical damage).
- ² Underground – Upon completion of repair or replacement, perform another IR inspection to verify that the abnormal condition was corrected, and component is operating under normal condition.
- ³ Temperature taken at underground cable terminals is illustrated in [Figure 1, "Pipe-Type and XLPE Terminals"](#) on Page 6: Location 1 is an indirect reading; Location 2 is a direct reading.

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3 IR Inspection Requirements

The intent of the IR inspection program is to capture the conductor at its highest loaded condition. It is preferable for lines to be loaded to 40% or greater of the operating ratings during the IR inspection. IR inspections are less likely to yield results if the lines are not heavily loaded.

However, in some scenarios (for example, single-source generation lines and some tap line configurations), loads cannot be switched to achieve this 40% target load, or doing so may put system reliability at risk. Additionally, some line sections may lack the ability to accurately track loading. Lines with zero amp loading for the remainder of the year may be omitted from IR inspection plans – these lines should be documented in the IR work plan.

- 3.1 When feasible, PERFORM IR inspections when line loading is at 40% or more of the line operating rating. It is generally agreed that IR testing will produce better results when line loading exceeds this 40% threshold; however, results can still be found when performing IR inspections on lines loaded less than 40%.

IF 40% line loading is not achievable,

THEN CONSIDER the following additional criteria in planning the optimal conditions to perform the IR test:

1. Seasonal peak loading (for example, winter/summer peaking)
 2. Historic loading (for example, targeting 90th percentile of daylight historic load)
 3. Other environmental factors such as rainfall, wind speeds, seasonal ambient temperatures, cloud cover, etc.
- 3.2 IR inspections for line re-rate requests **SHOULD NOT BE PERFORMED** at less than 40% loading of their normal ratings prior to re-rate.
- 3.3 Weather conditions can have an adverse effect on IR inspection results. **DO NOT PERFORM** IR inspections under the following conditions:
1. Winds exceeding 25 miles per hour (mph)
 2. Steady rain in progress

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3.4 IR Inspection Documentation

1. The qualified company representative (QCR) or thermographer TAKES the following steps:
 - a. DOCUMENTS abnormal findings.
 - b. RECORDS the information listed below on [Form TD-1001M-F15, "Transmission Line Infrared Data Sheet."](#)
 - (1) Name of the employee performing the inspection (thermographer)
 - (2) Time and date of the inspection
 - (3) Circuit SAP number
 - (4) Identification of the "hot item" type and phase location (for example, connector, jumper)
 - (5) Weather conditions
 - (6) Disk (or file name) and photo numbers
 - (7) Load amperes
 - c. ATTACH [Form TD-1001M-F15](#) to the IR finding notification. This form is generated by SAP.
2. QCRs, using IR cameras with the capacity to provide temperature readings, must RECORD the following information:
 - a. Background (or ambient) temperature setting
 - b. Emissivity setting
 - c. Fault temperature
 - d. Reference temperature (like piece of equipment)
 - e. Temperature rise
 - f. Temperature-differential grade

3.5 IR Inspector Qualifications

1. The QCR or contracted thermographer must possess a Level II or higher certification that meets or exceeds ASNT SNT-TC-1A guidelines or international equivalent.

End of Instructions

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DEFINITIONS

NA

IMPLEMENTATION RESPONSIBILITIES

The transmission line maintenance superintendent implements scheduled inspections of underground facilities.

The transmission line supervisor implements underground inspections.

The senior manager of inspection operations implements overhead facility inspections.

GOVERNING DOCUMENT

[Utility Standard TD-1001S, "Electric Transmission Line Inspection and Preventive Maintenance Program"](#)

COMPLIANCE REQUIREMENT / REGULATORY COMMITMENT

Records and Information Management:

Information or records generated by this procedure must be managed in accordance with the Enterprise Records and Information Management (ERIM) program policy, standards, and Enterprise Records Retention Schedule (ERRS). Refer to [GOV-7101S, "Enterprise Records and Information Management Standard,"](#) and related standards. Management of records includes, but is not limited to:

- Integrity
- Storage
- Retention and Disposition
- Classification and Protection

REFERENCE DOCUMENTS

Developmental References:

NA

Supplemental References:

[Form TD-1001M-F15, "Transmission Line Infrared Data Sheet"](#)

[TD-1001M, *Electric Transmission Preventive Maintenance Manual*](#)

[Utility Procedure TD-1004P-04, "Conductor Rerate Process for Overhead Transmission Circuits"](#)

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APPENDICES

NA

ATTACHMENTS

NA

DOCUMENT REVISION

This utility procedure cancels and supersedes Utility Procedure TD-1001P-14, "Infrared (IR) Inspection Procedures, Rev. 2, dated 12/21/2021.

DOCUMENT APPROVER

██████████ Manager

DOCUMENT OWNER

██████████ Manager

DOCUMENT CONTACT

██████████ Senior Engineer, Transmission Line Standards and Work Methods

██████████ Principal Specialist, Transmission Line Standards and Work Methods

██████████ Supervisor, Inspection Programs – Aerial Field Operations

██████████ Senior Advising Engineer, Transmission Line Asset Strategy

REVISION NOTES

| Where? | What Changed? |
|---------------------------|---|
| Section 2.5, Table 1 | Relabel "B" tags to three month "E" tags per GO 95 level 1/2/3 conversion project |
| Section 3 | Clarified guidelines around target loading. |
| Section 3.5 | Add inspector qualification requirements. |
| Document Contact sections | Updated document contact information. |