

MIL-STD-2194(SH)  
12 February 1988

MILITARY STANDARD .  
INFRARED THERMAL IMAGING SURVEY PROCEDURE  
FOR  
ELECTRICAL EQUIPMENT



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12 February 1988

DEPARTMENT OF DEFENSE  
NAVAL SEA SYSTEMS COMMAND

Washington, DC 20362-5101

Infrared Thermal Imaging Survey Procedure for Electrical Equipment

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1. SCOPE

1.1 Scope. This standard provides detailed procedures for conducting an infrared thermal imaging (IRTI) survey on electrical equipment aboard ship. An IRTI survey is recommended for new construction ships, pre-overhaul test and inspection, post repair and overhaul checks, and whenever major changes to the ship's electrical system occur.

2. REFERENCED DOCUMENTS

2.1 Government publication. The following Government publication forms a part of this standard to the extent specified herein.

OFFICE OF THE CHIEF OF NAVAL OPERATIONS (OPNAV)  
OPNAVINST 5100.19A - Navy Safety Precautions for Forces Afloat.

(Copies of the Government publication required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

3. DEFINITIONS

3.1 Electrical equipment. Electrical equipment is equipment, other than electronic, which is designed to generate, convert, distribute, control, or utilize electrical energy. Examples of electrical equipment are generators, switchboards, power panels, motor controllers, motor generators, and bus transfer switches.

3.2 Electronic equipment. Electronic equipment is equipment designed to generate, transmit, convey, store, process, or otherwise use electronic signals. Examples of electronic equipment are oscillators, transmitters (sonar, radar, and radio), amplifiers, sensing devices, receivers, computers, underwater detection equipment, fire control equipment, drone control, and associated test equipment.

3.3 Phase I survey. The phase I survey is that part of the IRTI survey, specified herein, that is conducted at dockside for the purpose of keeping the phase II survey (underway) time to a minimum. The phase I survey temperature measurements are performed on all electrical equipment which can be operated dockside under normal operating conditions.

3.4 Phase II survey. The phase II survey is that part of the IRTI survey, specified herein, that is conducted while the ship is underway. The phase II survey temperature measurements are performed on all electrical equipment which can only be operated at sea under normal operating conditions, and the balance of the electrical equipment not available during the phase I survey.

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3.5 Normal loading. Normal loading is the level of current which would be drawn by equipment, or through conductors, under normal operating conditions.

3.6 Thermogram. A thermogram is an instant hard copy photograph of the infrared image.

3.7 Gray scale. The gray scale is a reference scale on the monitor containing bars of different shades from dark to light.

3.8 Reference temperature. Reference temperature is the enclosure temperature of a piece of electrical equipment or component operating under normal loading conditions.

3.9 Hot spot. A hot spot is any area of the equipment which is surveyed 10 degrees Celsius ( $^{\circ}\text{C}$ ) or more above the equipment reference temperature.

3.10 Cold spot. A cold spot is any area of the equipment where the surveyed temperature is less than the reference temperature and where there is an indication of an open connection or component or some other similar type problem.

#### 4. GENERAL REQUIREMENTS

4.1 Phase I and II survey. The phase I and II surveys shall consist of the following:

- (a) The IRTI survey shall be planned and coordinated with all participating personnel to ensure optimum utilization of dockside and underway time. The Electronic Equipment Guide List (EEGL) (if available) shall be used to identify and locate the equipment to be surveyed. At the conclusion of the IRTI survey, a report shall be prepared detailing the survey results (see 5.5).
- (b) Measuring the temperature of the EEGL equipment while in normal operating mode.
- (c) Determining cause for hot or cold spots on EEGL equipment or identifying potential problem areas for future analyses as appropriate.

#### 5. DETAILED REQUIREMENTS

5.1 Electrical equipment to be surveyed during phase I. During phase I (dockside), as much of the electrical equipment as possible shall be surveyed to reduce the phase II (underway) workload. Equipment to be surveyed during phase I includes shore power switchboards, shore power connections, shore power receptacles, cables, and motor controllers (except as specified in 5.3).

5.2 Electrical equipment to be surveyed during phase II. During phase II survey, any equipment (except as specified in 5.3) which is on the EEGL and could not be operated while dockside, shall be surveyed. This equipment shall include the following:

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- (a) Electrical equipment associated with the anchor windlass motor, whale boat, catapult, and underway replenishment system.
- (b) Power panels, transformers, and load centers providing power service to electronic equipment and motors.
- (c) Steering gear motors, direct current (dc) propulsion motors and bow thrusters.

5.3 Electrical equipment which does not have to be surveyed. Electrical equipment which does not have to be surveyed includes portable electrical equipment, office equipment, hand dryers, shop equipment (drill presses, milling machines, lathes, induction furnaces, and so forth), ventilation duct heating elements, and other types of electrical heating elements.

5.4 Survey procedures. Survey procedures shall be as specified in 5.4.1 through 5.4.5.

5.4.1 Preliminary. Procedures preliminary to the survey shall be as specified in 5.4.1.1 through 5.4.1.4.

5.4.1.1 Safety. Ship electrical safety procedures shall be followed at all times. Forces afloat shall be in accordance with OPNAVINST 5100.19A. Unauthorized personnel shall be kept away from equipment being surveyed by the use of barricades and warning signs. The IRTI test equipment operator shall not extend the scanner across the plane of open electrical panels or coverings.

5.4.1.2 Ship's force assistance. The survey team leader shall contact the ship's electrical officer and request the assistance of ship's personnel to gain access to all equipment to be surveyed.

5.4.1.3 Equipment loading. Electrical equipment to be surveyed shall be under normal loading conditions and in service for at least 1/2 hour prior to being surveyed.

5.4.1.4 Sequence of equipment to be surveyed. The ship's EEGI, if available, shall be utilized to plan sequence of testing since equipment is listed by location (compartment level, frame, and athwartship position).

5.4.2 Test equipment calibration and operational checks. Only calibrated test equipment will be used for the survey. IRTI test equipment shall be adjusted each time equipment is energized. Initially and when the IRTI test equipment is operated continuously for long periods of time, a gray scale check shall be made. Procedures for the gray scale check shall be as follows:

- (a) Turn the IRTI test equipment on.
- (b) Set the system to gray scale and adjust brightness and contrast for optimal viewing.
- (c) Switch back to normal operation; do not adjust brightness or contrast while in normal operational mode.

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5.4.3 Procedures for checking hot or cold spots on electrical equipment.  
Procedures for checking for hot or cold spots on electrical equipment shall be as follows:

- (a) Scan electrical equipment being surveyed while observing the monitor for hot or cold spots using the ship's EEGL (if available).

Note - Most problems are due to loose electrical connections such as fuse connections, switch connections, breaker connections, and terminal lugs, corrosion, and improper screw or lug material or size. Another common problem is the breakdown of wire insulation and open components or connections.

- (b) When a potential hot or cold spot is found, the IRTI test equipment operator shall determine the temperature difference between the hot spot and background by adjusting the necessary IRTI test equipment controls (refer to specific IRTI system operating manual).
- (c) If the EEGL equipment is found to have a hot or cold spot, the following procedure shall be completed:
- (1) Two thermograms shall be taken showing the faulty component with isotherm level shown.
  - (2) Two color, instant photographs shall be taken showing the faulty component.
  - (3) A severity code shall be assigned to the equipment as specified in table I.
  - (4) Data shall be taken listing all necessary IRTI test equipment settings to verify the actual temperature difference between the hot spot and background.
  - (5) Data shall be listed on sheet 1 of the IRTI survey data sheet as shown on figure 1.
  - (6) An arrow shall be affixed to the thermograms and color photographs to identify the faulty component.
  - (7) A numbering system shall be devised by the survey team leader to match the color photographs with the appropriate thermogram.

TABLE I. Severity code.<sup>1 3</sup>

Severity code	Temperature above or below reference temperature (°C)	Remarks
****	70 and above	Component (electrical) failure imminent. <sup>2</sup> Stop survey. Inform cognizant officers.
***	40 and above to less than 70	Component (electrical) failure almost certain unless corrected.

See footnotes at end of table.

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TABLE I. Severity code.<sup>1 3</sup> - Continued

Severity code	Temperature above or below reference temperature (°C)	Remarks
**	25 and above to less than 40	Component (electrical) failure probable unless corrected.
	Above 0	Component (electronic) failure probable unless corrected.
*	10 and above 0 to less than 25	Component (electrical) failure unlikely but corrective measure required at next scheduled routine maintenance period or as scheduling permits.
-*	Below 0 to ambient	Component has probably failed or degraded or been affected by an upstream component or equipment.

<sup>1</sup> Applies to electrical, electronic, or I.C. equipment.

<sup>2</sup> Some components such as coils, resistors and thermal overload heaters may have high temperature readings which are normal.

<sup>3</sup> The above general criteria have been determined by past field experience for maintenance scheduling. Final decision as to priorities and order of maintenance shall be determined by the temperature above or below the reference temperature, the type of component and the critical nature of the equipment or system involved.

5.4.4 Potential hot or cold spot locations. When scanning the following equipment, the accessible components listed shall be specifically observed for temperature differences above or below their normal operating temperatures.

(a) Switchboards:

- (1) Bus bar connections.
- (2) Bus disconnect connection.
- (3) Circuit breaker connections.
- (4) Control wire terminal board connections.
- (5) Relay connections.
- (6) Fuse holder connections.

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- (b) Power lighting panels and fuse distribution panels:
  - (1) Line connections.
  - (2) Individual load connections.
  - (3) AQB circuit breaker contacts via molded case signature, fuse and fuse clip connectors.
  
- (c) Automatic bus transfer (ABT) switches:
  - (1) Normal source connections.
  - (2) Alternate source connections (when ABT is placed in manual, and alternate source is selected).
  - (3) Load connections.
  - (4) Control relay connections.
  - (5) Control wire connections.
  - (6) Relay or contactor contacts and electronic components.
  
- (d) Motor controllers:
  - (1) Main contactor connections.
  - (2) Overload connections.
  - (3) Control relay and fuse connections.
  - (4) Control wire terminal board connections.
  - (5) Control wire connections.
  - (6) Overload heaters and contacts, resistors, and contact or relay contacts.
  
- (e) Motor generator sets:
  - (1) Motor and generator line connections.
  - (2) Slip ring connections.
  - (3) Starter/regulator/static exciter components, connections and terminal board connections, internal heater wiring, field and brush pigtail (if applicable) connections.
  
- (f) Static converters:
  - (1) Semiconductor heat transfer devices (heat sinks).
  - (2) Line and load connections.
  - (3) Control relay and control wire connections.
  - (4) Electronic components, bus connections, transformers, terminal boards.

5.4.5 Equipment not available for survey. If an electrical system is not surveyed because it is not operational, the reason for the non-operating condition shall be written on sheet 2 of the IRTI survey data sheet as shown on figure 2.

5.5 Infrared thermal imaging EEGI survey report. The IRTI electrical survey report shall be as specified in 5.5.1 and 5.5.2.

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5.5.1 Preliminary report. At the conclusion of the infrared thermal imaging survey, a report, as shown on figures 3 through 8, shall be provided to the ship's commanding officer, engineering officer and electrical officer. The report shall contain one complete set of photographs and thermograms. (Another set of photographs and thermograms shall be retained by the surveying activity for future reference.) The preliminary report shall contain the following information:

- (a) Cover page (see figure 3).
- (b) Abstract (see figure 4).
- (c) Summary of problems and repair priorities (see figure 5).
- (d) Equipment guide list marked to indicate all electrical equipment surveyed (see figure 6).
- (e) List of electrical equipment not available for survey (see figure 7).
- (f) Description of individual equipment problems (see figure 8).

5.5.2 Final report. A final report, as shown on figures 9 through 13, shall be provided to NAVSEA, the appropriate type Command, the appropriate Planning and Engineering for Repairs and Alterations, and the ship which was surveyed. This report shall contain the following information:

- (a) Cover page (see figure 9).
- (b) Abstract (see figure 10).
- (c) Summary of problems and repair priorities (see figure 11).
- (d) List of electrical equipment not available for survey (see figure 12) and status.
- (e) Summary matrix of electrical equipment problems (see figure 13).

## 6. NOTES

### 6.1 Subject term (key word) listing.

Background  
Equipment, electronic  
Gray scale  
Hot spot  
Thermograph

Preparing activity:  
Navy - SH  
(Project 5855-N282)

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Inspection date: \_\_\_\_\_  
Ship class/name: \_\_\_\_\_  
Inspector name: \_\_\_\_\_  
Activity: \_\_\_\_\_

Problem no.: \_\_\_\_\_

Thermograph no.: \_\_\_\_\_

Equipment under survey: \_\_\_\_\_

Specific component experiencing  
high temperature: \_\_\_\_\_

Temperature above ambient: \_\_\_\_\_

IRTI test equipment nomenclature and settings: \_\_\_\_\_

Probable cause: \_\_\_\_\_

Recommendations: \_\_\_\_\_

Remarks: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

FIGURE 1. IRTI survey data sheet: description of individual equipment problems.



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IRTI SURVEY - PRELIMINARY REPORT

Ship name and hull no. \_\_\_\_\_

Start date:

Completion date:

Performed by:

FIGURE 3. IRTI survey-preliminary report.

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The purpose of the infrared thermal imaging (IRTI) electrical survey is to scan electrical equipment in order to find hot or cold spots. For each hot or cold spot, the probable cause and recommended corrective actions are determined by the survey team and provided to the ship's electrical officer in this report.

1. Survey dates \_\_\_\_\_
2. Name and hull no. of ship \_\_\_\_\_
3. Ship location \_\_\_\_\_
4. Activity conducting survey \_\_\_\_\_
5. Total number of electrical problems found \_\_\_\_\_
6. Number of problems corrected during survey \_\_\_\_\_
7. Number of remaining problems \_\_\_\_\_

FIGURE 4. Abstract.



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NOTE: The equipment guide list should be marked up to indicate all electrical equipment surveyed.

FIGURE 6. Electrical equipment guide list.



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Inspection date: \_\_\_\_\_  
Ship class/name: \_\_\_\_\_  
Inspector name: \_\_\_\_\_  
Activity: \_\_\_\_\_

Problem no.: \_\_\_\_\_  
Thermogram no.: \_\_\_\_\_  
Equipment nomenclature: \_\_\_\_\_  
Equipment location: \_\_\_\_\_  
Specific component experiencing  
high temperature: \_\_\_\_\_  
Equipment temperature above normal  
operating temperature: \_\_\_\_\_  
IRTI test equipment settings: \_\_\_\_\_  
Probable cause: \_\_\_\_\_  
Recommendations: \_\_\_\_\_  
Remarks: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

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(Attach applicable thermogram and photograph)

FIGURE 8. Description of individual equipment problems.

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IRTI SURVEY - FINAL REPORT

Ship name and hull no. \_\_\_\_\_

Start date:

Completion date:

Performed by:

FIGURE 9. IRTI survey-final report.

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The purpose of the infrared thermal imaging (IRTI) electrical survey is to scan electrical equipment in order to find hot or cold spots. For each hot or cold spot, the probable cause and recommended corrective actions are determined by the survey team and provided to the appropriate Naval activity in this report.

1. Survey dates \_\_\_\_\_
2. Name and hull no. of ship \_\_\_\_\_
3. Ship location \_\_\_\_\_
4. Activity conducting survey \_\_\_\_\_
5. Total number of electrical problems \_\_\_\_\_
6. Number of problems corrected during survey \_\_\_\_\_
7. Number of remaining problems \_\_\_\_\_

FIGURE 10. Abstract.



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No.	Equipment nomenclature	Equipment location	Reason for non-availability
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			

FIGURE 12. List of electrical equipment not available for survey.

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Electrical equipment	Results of this survey by priority code						
	Qty abroad ship	Qty surveyed	Immed.	Mand.	Import.	Desir.	Total
Generators (60 hertz (Hz))							
Switchboards (60 Hz)							
Load centers							
Automatic/manual bus transfer switches							
Motor controllers							
Power panels (fuses/breakers)							
400 Hz systems							
I.C. systems							
Motors							
Miscellaneous & shore power							
Totals							

FIGURE 13. Summary matrix of electrical equipment problems.

**STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL***(See Instructions - Reverse Side)*

1. DOCUMENT NUMBER MIL-STD-2194(SH)	2. DOCUMENT TITLE INFRARED THERMAL IMAGING SURVEY PROCEDURE FOR ELECTRICAL EQUIPMENT
--	--

3a. NAME OF SUBMITTING ORGANIZATION

4. TYPE OF ORGANIZATION (Mark one)

 VENDOR USER MANUFACTURER OTHER (Specify): \_\_\_\_\_

b. ADDRESS (Street, City, State, ZIP Code)

**5. PROBLEM AREAS**

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

**6. REMARKS**

7a. NAME OF SUBMITTER (Last, First, MI) - Optional

b. WORK TELEPHONE NUMBER (Include Area Code) - Optional

c. MAILING ADDRESS (Street, City, State, ZIP Code) - Optional

8. DATE OF SUBMISSION (YYMMDD)

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