



GE Power & Water

Exhaust Thermocouple Installation & Maintenance
GE Part Number 362A1102, 372A2221
Heavy-Duty Gas Turbines

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to General Electric Company. These instructions contain proprietary information of General Electric Company, and are furnished to its customer solely to assist that customer in the installation, testing, operation, and/or maintenance of the equipment described. This document shall not be reproduced in whole or in part nor shall its contents be disclosed to any third party without the written approval of General Electric Company.

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The following notices will be found throughout this publication. It is important that the significance of each is thoroughly understood by those using this document. The definitions are as follows:

NOTE

Highlights an essential element of a procedure to assure correctness.

CAUTION

Indicates a potentially hazardous situation, which, if not avoided, could result in minor or moderate injury or equipment damage.

WARNING

INDICATES A POTENTIALLY HAZARDOUS SITUATION, WHICH, IF NOT AVOIDED, COULD RESULT IN DEATH OR SERIOUS INJURY

*****DANGER*****

INDICATES AN IMMINENTLY HAZARDOUS SITUATION, WHICH, IF NOT AVOIDED WILL RESULT IN DEATH OR SERIOUS INJURY.

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I. GENERAL

Thermocouples are invaluable to the safe and efficient operation of the gas turbine. They can be located in obscure places in the turbine to measure temperature where it would otherwise be impossible by other means. The function of the thermocouple as a temperature sensor is dual:

1. As a SUPERVISOR, and
2. As an ANNUNCIATOR.

The former is indicative of control thermocouples that through the control software may initiate action to change other control parameters or shutdown the turbine. The latter indicates temperature state by annunciating an alarm, without a necessary action for correction when some temperature limit is exceeded. Typical examples are the bearing thermocouples. Several thermocouples in the latter category are used for performance instrumentation purposes.\

II. EQUIPMENT

A. Thermocouples

Exhaust thermocouples are located in the turbine exhaust plenum or diffuser at an insertion depth sufficient to measure an average temperature. The thermocouples are distributed evenly around the circumference of the exhaust plenum. The thermocouples use an ANSI Type K, un-grounded design with a mineral insulated jacket. These thermocouples are inserted directly in the hot gas path to provide fast response to temperature changes.

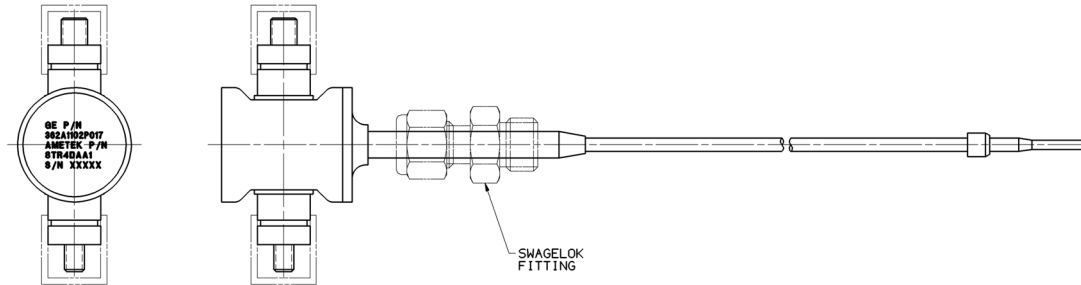


Figure 1. 362A1102 Outline, Thermocouple with Connection Studs

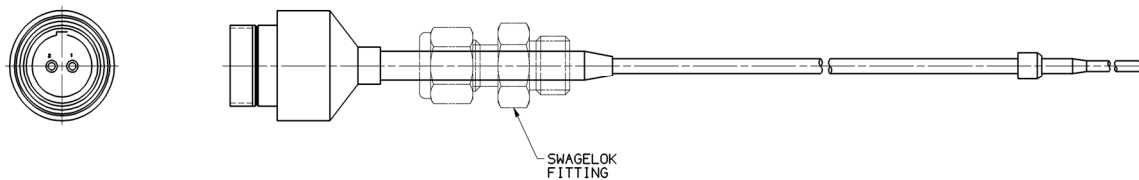


Figure 2. 372A2221 Outline, Thermocouple with Connector

B. Radiation Shields

Exhaust thermocouples are installed into radiation shields, specialized wells that protect the thermocouples from the high velocity flow of exhaust gases. The thermocouple tip protrudes from the radiation shield to be in direct contact with the hot gas. The name “radiation shield” comes from the cross tube at the tip. The intent of the cross tube is to shield the sensing tip from possible radiant heat, when this is a concern.

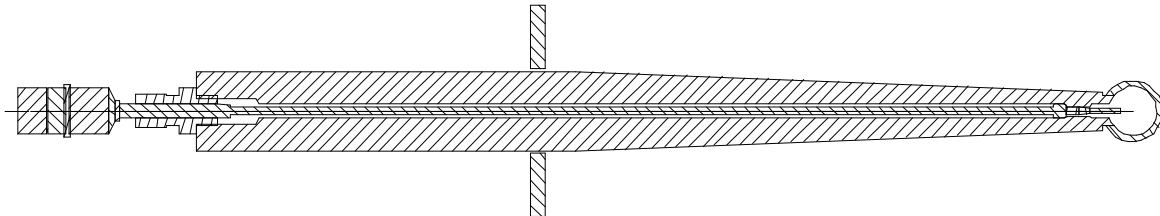


Figure 3. Radiation Shield with Thermocouple Inserted

C. Thermocouple Cables

Thermocouple probes included in this instruction have a hermetically sealed construction with a separate flexible cable back to the thermocouple junction box. The 362A1102 thermocouple has a hermetically sealed junction box with screw terminal studs for attachment of the flexible cable ring lugs. The 372A2221 thermocouple has a hermetic circular connector to interface with the mating flexible cable. From the thermocouple junction box, thermocouple extension cable conveys the signal back to the control system. It is important that thermocouple wire of the proper type (Type K) be used and proper polarity maintained throughout the system.

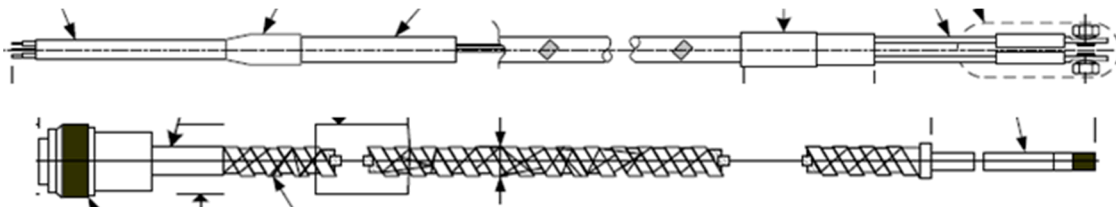


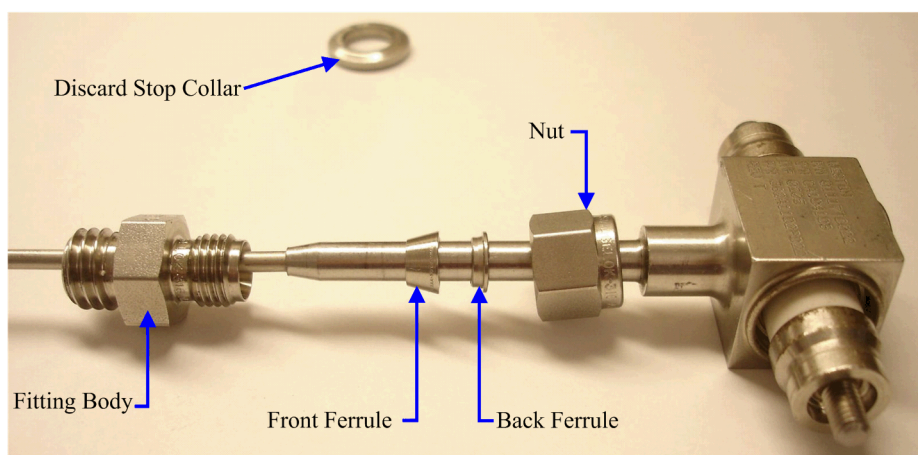
Figure 4. Thermocouple Cables

III. SOFTWARE

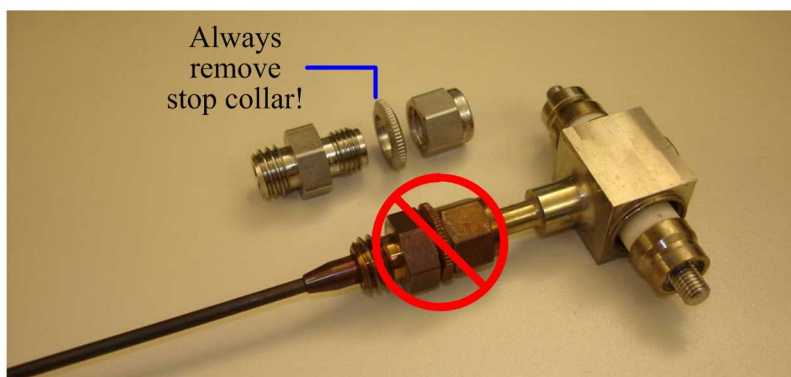
The exhaust gas temperature is used by the Control Panel software as a factor in the control of fuel flow as well as a trip parameter. These functions are covered separately in instructions for exhaust temperature control and combustion monitoring.

IV. INSTALLATION OF THERMOCOUPLE INTO RADIATION SHIELD

1. Use .500-13 UNC-2B straight thread tap to chase the threads on each radiation shield prior to installation of new fitting part 287A1399P023. Perform this operation on radiation shields which have .500-13 UNC tapped holes at end of radiation shield on units which have already had first fire.
2. Apply anti-seize compound 287A1397P001 to threads on each compression fitting 287A1399P023 prior to installation into radiation shield. Install fitting into radiation shield and tighten with 5/8 inch box wrench to just snug, approximately ¼ turn past finger tight.
3. Install temporary label on each thermocouple and record serial numbers of each thermocouple for each location. This allows tracking any failures by serial number and thermocouple location.
4. In some cases the probe may need to bend slightly to facilitate installation. Care should be used to avoid bending past a radius of 30" to avoid damage to the probe and to prevent improper seating of the probe.

**Figure 5. Tube Fitting Assembly**

5. Install thermocouple into compression fitting. Verify both ferrules are in each compression fitting. If a stop collar is included, remove it from the fitting. Before thermocouple is pushed into fitting and radiation shield, align the path down the diffuser. The terminals shall be aligned with downstream flow path for part 362A1102 with terminal studs. Push thermocouple into radiation shield through fitting until it makes contact with mechanical stop in radiation shield. (Refer to Figure 13 in Appendix A). While holding thermocouple in place with light pressure, tighten cap on compression fitting 1 full turn beyond hand tight with 9/16 inch wrench. Do not over-tighten; stop collar shall have been removed.

**Figure 6. Compression Stop Collar Removal**

6. Install cables per applicable section below in V, Installation of Cable Assembly.
7. Verify polarity by performing heat check; refer to VII.F, Thermocouple Polarity.
8. Reinstall sheet metal rain covers when originally provided and verify cables leaving terminal head are not chafing against any sharp edges of sheet metal cover. Install cushioned loop clamp on cable. One clamp should be provided close to the thermocouple head to keep cable from chafing on the sharp edge of the cover over the thermocouple. Cable clamp shall be cushioned loop clamp per 361A2538P003 and shall be installed no more than 18 inches (46 cm) from the connection head.
9. On some installations minor bending of the thermocouple is allowed to clear physical interferences. Avoid bending if at all possible. This can lead to fretting of the tip and sheath.

Refer to Appendix A, Thermocouple Images, for images relating to installation problems.

If the radiation shield is much hotter than the probe, damage could occur. Do not complete the compression fitting tightening until the probe and shield are at temperatures within approximately 200°F (80°C) of each other.

V. INSTALLATION OF CABLE ASSEMBLY

A. Terminal Stud Thermocouple (362A1102)

NOTE

Each Type K positive and negative terminal has a unique thread size to prevent accidental polarity errors.

1. When installing braided thermocouple cable 361A2327 to thermocouple probe 362A1102, torque captive nuts to 25 in-lb. (2.8 N·m) maximum for 10-32 UNF stud and .250-28 UNF stud. Use preset torque wrench provided GE part 361A2994P007 with head P002 and wrench 361A2994P007 with drive head P003 to avoid cracking ceramic insulator and stripping threads on studs of the thermocouple probe. The insulator is found beneath the terminal stud. Captive nuts should first be installed finger tight and final tighten with torque wrench. Do not cross thread. Use of hand tools other than torque wrench on terminal nuts may over-tighten nuts resulting in cracking of ceramic insulator and/or snapping off of terminal stud. Care must be used when tightening cable 361A2327 captive lock nuts.
- 2.

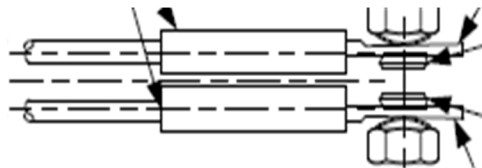


Figure 7. 361A2327 Captive Lock Nuts

3. Route braided cable 361A2327 to junction box in conduit, referencing conduit installation drawing if available. Remove all metal loop clamps. Support cable with cushioned loop clamps 361A2538P003 provided and support through conduit. Do not use metal clamps. Cables shall be supported within 18 inches (46 cm) of thermocouple. It is recommended all cables be run in conduit versus exposed.

4. Install cord grip body 361A2558P002 into conduit fittings. Install high temp bushing 361A2558P014 (rust colored). Discard black neoprene bushing that is supplied with fitting.
5. Terminate red and yellow leads of cable 361A2327 to same location on terminal strips as removed cables.
6. At no point along the length of the cable shall it be buried under exhaust diffuser insulation on F-class turbines. It is essential to keep the braided stainless steel cables which run up to the thermocouple terminal studs exposed to air for cooling, and away from all hot surfaces. After final installation the thermocouple connection head and braided cable shall be exposed to air for cooling and not beneath insulation. On F-class machines rain covers should be provided.

B. Circular Connector Thermocouple (372A2221)

1. Cable plug shall be threaded onto thermocouple receptacle hand tight using no tools. Plug shall be tightened $\frac{1}{4}$ turn beyond hand tight with soft pliers. Over tightening of connector will damage self-locking feature and may result in connector backing off causing open circuit.



Figure 8. Soft Jaw Connector Pliers

2. Route braided cable 362A3345 to junction box in conduit, referencing conduit installation drawing if available. Remove all metal loop clamps. Support cable with cushioned loop clamps 361A2538P003 provided and support through conduit. Do not use metal clamps. Cables shall be supported within 18 inches (46 cm) of thermocouple. It is recommended all cables be run in conduit versus exposed.
3. Install cord grip body 361A2558P002 into conduit fittings. Install high temp bushing 361A2558P014 (rust colored). Discard black neoprene bushing that is supplied with fitting.
4. Terminate red and yellow leads of cable 362A3345 to same location on terminal strips as removed cables.
5. At no point along the length of the cable shall it be buried under exhaust diffuser insulation on F-class turbines. It is essential to keep the braided stainless steel cables which run up to the thermocouple connector exposed to air for cooling, and away from all hot surfaces. After final installation the thermocouple connection head and braided cable shall be exposed to air for cooling and not beneath insulation.

Also note that rain covers shall not be used with connector-type thermocouples 372A2221. The mating connector pair used per this design provides a weather-tight seal. Rain covers are not necessary and may cause elevated connector temperatures and connector deterioration.

VI. THERMOCOUPLE MAINTENANCE

Thermocouples, in general, are very simple and robust devices, but consideration must be given to the harsh environment of the gas turbine. The best protection against shutdowns due to failed thermocouples is good thermocouple maintenance. Replace failed thermocouples promptly during normal downtime so that the likelihood of operation with more than one failed thermocouple is low.

A. Recommended Replacement

Thermocouples should be checked at the hot gas path inspections. If readings appear to be in error, check condition of the sensor per this GEK. Radiation shields should be inspected for wear or cracks at each hot gas path inspection. Either part should be replaced if inspection uncovers wear. Repeated probe tip wear indicates that the bore of the radiation shield may be damaged (see Appendix A).

B. Failure Modes

At the electrical level, two conditions may cause inaccurate or lost thermocouple signal:

a. Open circuit

There is a loss of continuity somewhere in the circuit loop: the control panel board termination, cabling, junction box, connector, or internal to the probe. May be intermittent, as in the case of a loose connection.

b. Short circuit:

There is low electrical resistance between the two thermocouple conductors at any point besides the measuring junction. Also, low electrical resistance between either conductor and the thermocouple sheath, or any other metal object.

An open circuit thermocouple is reported as -0°F (-18°C) by the control system, and an intermittent open circuit could result in a measurement that moves erratically or cyclically.

A thermocouple with a short circuit (low resistance) between the two thermocouple conductors will act as two thermocouple junctions in parallel, which has the effect of averaging the temperatures present at the two junctions. Typically this will result in a lower temperature reported at the control panel. A short circuit of one thermocouple conductor to another metal object may cause either a low or high reading depending on the circumstance.

1. Causes of Open circuit conditions

- a. Break in a conductor, internal to the probe
- b. Break in a conductor in the cable
- c. Loose connection at the thermocouple probe
- d. Loose termination at a junction box or control panel
- e. Severe mechanical wear to the probe or cable causing conductor breakage

2. Causes of Short circuit conditions

- a. Poor insulation resistance internal to the probe (moisture or contaminant)
- b. Foreign material creating a circuit path between connector/termination points
- c. Insulation failure or tear on the thermocouple cable allowing short circuit or ground
- d. Excessive mechanical deformation of probe

C. Thermocouple Checking

The combustion monitor display and the printer, if available, can be used to check thermocouple readings at any time. The combustion monitor will continue to protect the gas turbine while the thermocouple readings are being displayed and printed.

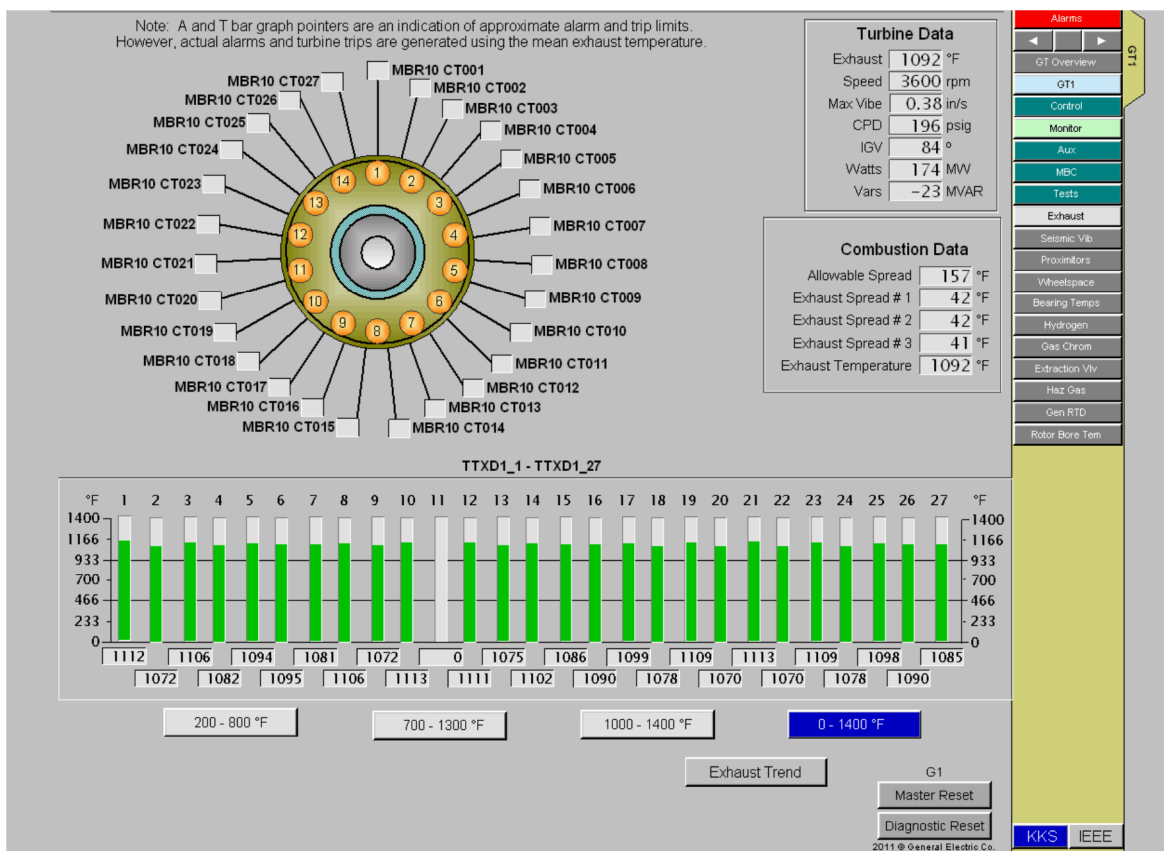


Figure 9. HMI Screen

D. Thermocouple Circuit Resistance Check

With the turbine not running, disconnect each thermocouple in turn at the termination board and measure the thermocouple resistance using a good quality ohmmeter. Measure each thermocouple in each polarity and average the two results to avoid errors from the thermoelectric action. Record all readings and determine the average, and the deviation of each reading from the average. Any thermocouple circuit with a deviation of more than 15 ohms from the average reading should be considered defective and replaced after assuring there are not cable or connector problems.

When circuit resistance is high or when there are indications of an open circuit condition, disconnect the cable from the affected thermocouple. Inspect for obvious damage or wear; replace if necessary. Reconnect the cable per installation procedure. Re-check circuit resistance. If resistance is still high, connect cable from selected position to a known-good thermocouple and re-check circuit resistance. If resistance with a good thermocouple is high, replace the cable. Also, if resistance drops when the cable is reinstalled but the problem repeats, suspect damage to the cable plug and replace the cable.

VII. THERMOCOUPLE TESTING

A. Test Equipment

- 1) Megohmmeter: The megohmmeter must be capable of determining values of resistance from 500,000 ohms to 1000 megohms minimum within $\pm 10\%$. The applied voltage for the resistance measurement is 50 v dc.
- 2) High quality digital multimeter

B. Visual Inspection

- 1) Verify that thermocouple has no obvious damage and there are no inconsistencies in appearance.
- 2) Inspect to verify that surface finish, straightness, and cleanliness are acceptable.

C. Insulation Resistance Test

The minimum electrical insulation resistance (IR) between the thermocouple and the sheath shall be 100 megohms or greater at room temperature at 50 v dc. Original part specification calls for 1000 megohms (1 gigaohm) or greater.

NOTE

Insulation resistance measurements are changed by variations in temperature of the insulation material. Typically when the temperature goes up the IR drops, and inversely when the temperature drops the IR goes up. To obtain an accurate resistance reading from the meter, you must take environmental conditions into consideration. You must test in an area where the humidity is less than 50%. The ideal temperature is 68°F (20°C). If you must test at a temperature other than 68°F (20°C), multiply the resistance read from the meter by the following multiplication factor:

° F	° C	Multiplication Factor	° F	° C	Multiplication Factor
32	0	0.25	77	25	1.40
41	5	0.36	86	30	1.98
50	10	0.50	95	35	2.80
59	15	0.75	104	40	3.95
68	20	1.00	113	45	5.60

Table 1. Insulation Resistance Ambient Temperature Correction Factors

Adjust the megohmmeter through the selector switch for an output voltage of 50 v dc and simultaneously select the range which will read gigaohms (1000 megohms = 1 gigaohm). Perform the preliminary check as outlined below: Verify selector switch is not between positions. Selector switch should click into position. Verify pointer is on black triangle on selector scale.

D. Preliminary Check**NOTE**

Ensure the batteries are suitable charged before continuing. Verify that no voltage is present on the circuit to be tested.

Verify the thermocouple to be tested is clean, dry, and at room temperature.

When testing the IR of 362A1102P022, 372A2221P012 or 372A2221P022, you will need to attach clips to the wires of the megohmmeter.

With the 3 electrical leads connected to the input terminals of the megohmmeter (line, earth, and guard terminals).

1. To test the 351A3488 or earlier model

(See Figure 10)

- a. Attach the first electrical lead from the line terminal to the thermocouple bare wire conductors twisted together
- b. Attach the second lead from earth to the middle of the metal sheath
- c. Attach the third lead from the guard terminal to the insulation over the wires
- d. Ground the thermocouple

2. To test the 362A1102 series

(See Figure 11)

- a. Attach the first electrical lead from the line terminal to either stud.
- b. Attach the second lead from earth to the middle of the metal sheath
- c. Attach the third lead from the guard terminal to the metal sheath
- d. Ground the thermocouple

3. To test the 372A2221series

(See Figure 12)

- a. Attach the first electrical lead to the line terminal and carefully clip the other end to either pin of the t/c connector
- b. Attach the second lead from earth to the middle of the metal sheath
- c. Attach the third lead from the guard terminal to the metal sheath
- d. Ground the thermocouple

After 30 seconds, record the reading indicated by the megohmmeter. The reading should not be less than 100 megohms at 50 v dc. After applying test voltage, allow one minute for discharge before handling any connections to avoid electrical shock.

Actual typical megohm reading for any good quality thermocouple should exceed 1000 megohms (1 gigaohm) at 50 v dc. Any thermocouple reading which is marginally acceptable should be rejected.

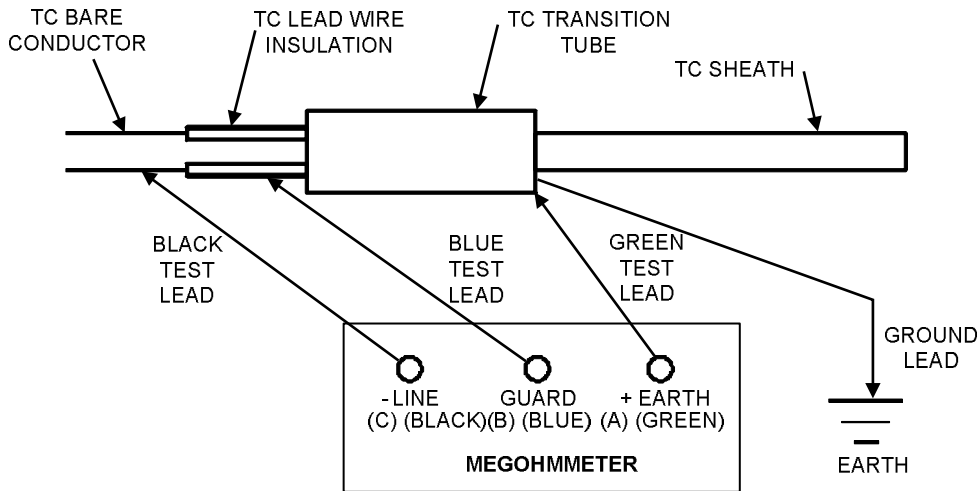


Figure 10. IR Test Layout for 351A3488 or Earlier

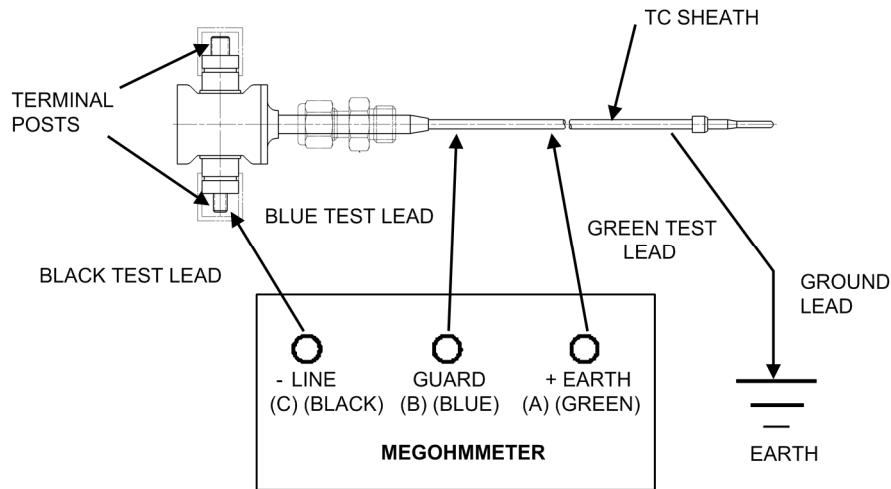


Figure 11. IR Test Layout for 362A1102P022

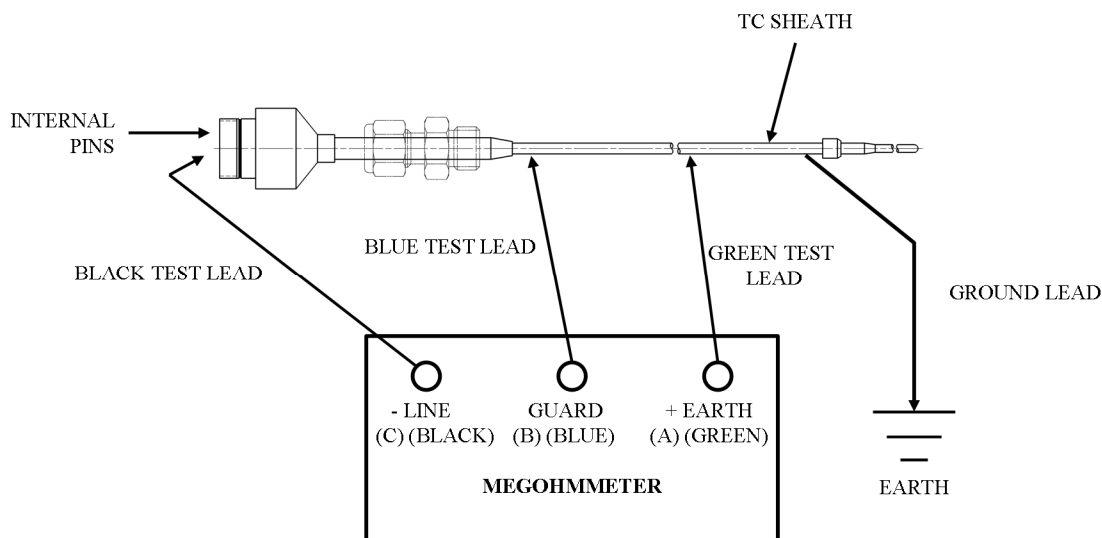


Figure 12. IR Test Layout for 372A2221P012, P022

E. Non-Conforming Material

Thermocouples tested which have IR values below the required 100 megohms at 50 v dc should be dispositioned per following procedure:

1. Record serial number, GE part number, manufacturer's name, manufacturer's model number, and IR value recorded.
2. Place thermocouple into an oven at 392°F (200°C) for 15-30 minutes.
3. Remove thermocouple and let cool to room temp. Repeat IR test. If thermocouple does not pass 100 megohms at 50 v dc requirement, then replace it.

Thermocouples which pass this test indicate the low IR is directly related to moisture contamination and is not caused by other reasons.

IR tests should be performed on thermocouples prior to initial installation on turbine. **IR tests are not required to be performed after operation on turbine on properly functioning thermocouples.** IR tests should only be repeated after installation as part of a failure investigation of the thermocouple or reading. This will minimize potential failures of good thermocouples due to operator error by accidentally performing megohmmeter checks at higher voltage levels which are destructive to thermocouples with small diameters (lessons learned).

F. Electrical Continuity

Check each thermocouple element (positive to negative) with an ohmmeter for a continuous wire to wire electrical circuit. No quantitative measurements are required.

Check either thermocouple conductor to sheath; there should be no connection.

G. Thermocouple Polarity

Check each thermocouple assembly that has a connection head, connector, transition piece, lead wires, or any type of termination device of any kind for proper polarity by heating the measurement junction and noting the polarity of the electromotive force at the termination.

When possible, post an operator in the diffuser with radio and heat gun and operator in control room with radio to read out thermocouples. Perform heat check on each thermocouple from inside the diffuser with a heat gun and read out on Control Panel that each thermocouple responds toward increasing temperature when heat is applied.

For ANSI Type K chromel-alumel thermocouple – red is negative and yellow is positive.

H. Item Identification

Verify that each thermocouple is identified with manufacturer's name, manufacturer's model number, serial number or material traceability number, and GE part number.

I. Report

1. Results of all above tests should be recorded with the following: Date and time of test
2. Identification: GE part number, manufacturer name, and serial number or date code
3. Applied voltage
4. IR values recorded

J. Safety Precautions

The megohmmeters are sources of high voltage. These tests should only be performed with the stand alone thermocouple disconnected from any termination points.

1. Replace defective leads when worn.
2. Do not operate the megohmmeter in an explosive environment.
3. Read the megohmmeter instruction manual prior to using meter.
4. When performing megohmmeter checks, allow twice as much time to discharge the test piece as is used for energizing.

VIII. APPENDIX A – THERMOCOUPLE IMAGES

A. Properly Seated

The bushing near thermocouple tip sits tightly in the seat at the end of the radiation shield. This seating force centers the thermocouple, ensures adequate protrusion into the gas flow, and limits vibration.

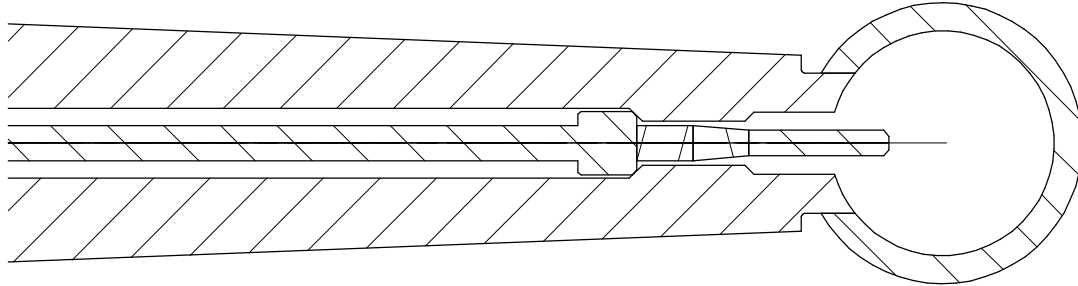


Figure 13. Thermocouple – properly seated

B. Loosely Seated

The bushing is not seated, allowing vibration and fretting or mechanical wear.

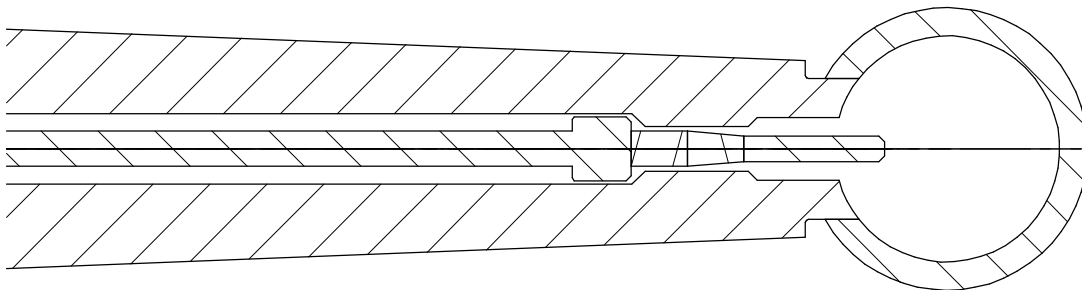


Figure 14. Thermocouple – loosely seated

C. Retracted

The bushing is not seated and the thermocouple tip does not protrude into the gas flow. Vibration and fretting may occur as well as a “lagging” response to changing gas temperatures compared with properly seated thermocouples.

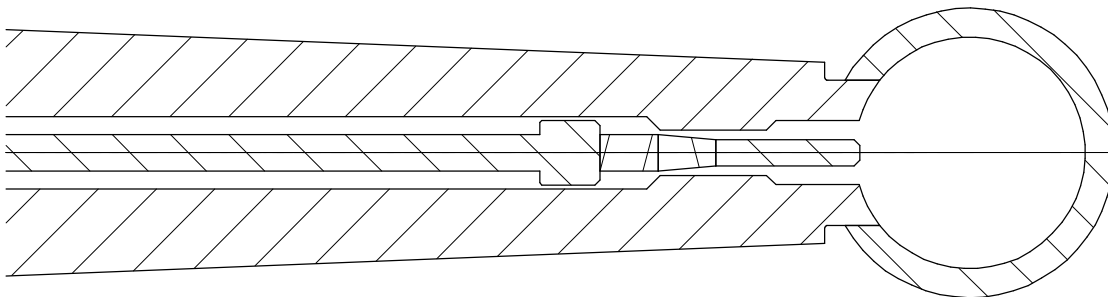


Figure 15. Thermocouple – tip retracted

D. Bent Thermocouple

This thermocouple was installed bent, pressing the tip into contact with the radiation shield seat on one side and the high point of the bend into contact with inner diameter of the radiation shield bore on the other side.



Figure 16. Damaged Thermocouple - Bent

E. Improperly Installed Thermocouple

This thermocouple was not installed fully, allowing vibration. Vibration led to fretting, or mechanical wear, of the bushing and the tip.



Figure 17. Damaged Thermocouple - Improperly Installed

F. Damaged Radiation Shields

Damaged radiation shields: with time, vibration of thermocouples will also wear the inside of the radiation shield. When this occurs, proper seating of the thermocouple is not possible, even when the instructions are properly followed. Shown here are borescope images of the seat area. These radiation shields required replacement.



Figure 18. Damaged Radiation Shield Borescope



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