

# Gamma Thermometers

## Gamma sensitive detector for power monitoring in new nuclear plant designs

### Precise, durable, efficient reactor power measurement

Gamma thermometers (GT) are proven sensors that use differential thermocouples to measure local gamma flux up to reactor full power. Although these gamma thermometers have generally been used in local power range monitors (LPRMs), they can be a fundamental component for new plant designs.

Reuter-Stokes has decades of experience manufacturing gamma thermometers which have been used for calibrating LPRM fission chamber detectors in boiling water reactor (BWR) plant designs. Because gamma thermometers require no drive mechanism and remain in place during normal reactor operation, they provide a durable, efficient alternative to gamma traversing in-core probe (TIP) and neutron TIP detectors for LPRM calibration. Unlike neutron TIP detectors, gamma thermometers can provide independent LPRM power readings throughout reactor power operation without sensitivity depletion.

**Reuter-Stokes' gamma thermometers have been tested in four operating reactors in the United States, Japan, and Mexico - including multi-year testing for up to ten years.**

### Benefits

- Fixed in-core assembly
- Compact size, no drive equipment required
- Continuous measurement for in-situ power monitoring and fission chamber calibration
- No fissile material
- Low cobalt construction to minimize neutron activation lowering radiation exposure and reducing disposal costs

### Product configuration and operation

**Gamma thermometers (GT) are stainless steel rods with short sections that are thermally insulated from the reactor coolant by chambers of Argon gas.**

Interactions between the gamma flux and stainless steel sensor generate heat in the gamma thermometer. A thermally isolated thermocouple junction and a reactor water-cooled thermocouple junction create a measurable temperature differential that is proportional to the gamma flux. At steady-state reactor power condition, the gamma flux is then used to calibrate fission chamber sensitivity and measure reactor power.

Each gamma thermometer includes an integrated heater wire, providing calibration of the gamma thermometer against a known heat source, independent of the gamma flux. Gamma thermometer calibration provides a repeatable response curve of thermocouple output from a known given heat input, which is used to correlate sensor response with gamma flux.

## Applications

Gamma thermometers are typically integrated in LPRMs and installed as a single GT LPRM device for nuclear power instrumentation (non-safety) applications.

The U.S. Nuclear Regulatory Commission (NRC) has outlined a gamma thermometer methodology for calibrating in-core instrumentation in reactor monitoring. Some American Society of Mechanical Engineers (ASME) Code assemblies have included Reuter-Stokes gamma thermometers.

## Customizable solutions

Reuter-Stokes can customize gamma thermometers for a variety of lengths with various chamber lengths and positions, up to a maximum of nine chamber locations within a GT detector assembly. We can incorporate the GT into a combined assembly with other types of detectors.

## Specifications

### Mechanical

- Maximum diameter: 0.313 in.
- Maximum overall length: customizable
- Connector: LEMO
- Heater cable power supply: 3 amp 200V

### Materials

- Outer and middle shell: low cobalt SS316L
- Inner shell: SS316L
- Active portion of heater cable: NiCr
- Connector: SS304L
- Thermocouple: Type K
- Thermocouple and heater cable insulation:  $Al_2O_3$



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## Gamma thermometer service environments

### Environment

Coolant temperature	300°C (572°F)
Pressure	1500 psia
Coolant water flow rate (min)	5 ft/sec

### Seismic

Operational Basis Earthquake (OBE)	2.24g vertical
Safe Shutdown Earthquake (SSE)	3.24g vertical

### Radiation

Gamma flux (max)	$2.2 \times 10^9$ R/hr
Thermal neutron flux (max perturbed)	$2.8 \times 10^{14}$ nv

### Lifetime

Exposure weighted average thermal neutron flux (in ABWR at 60 kW/l, perturbed) for 10 years	$8.9 \times 10^{13}$ nv
Exposure weighted average fast (1 MeV) neutron flux (in ABWR at 60 kW/l, perturbed) for 10 years	$7.5 \times 10^{13}$ nv

### Readings

Response rate (hot junction time constant)	~20-30 sec
Output reading units	mV

Gamma thermometer accuracy validation vs gamma TIP

