

APPENDIX H—AVIATION HEAT-FLUX CALIBRATION STANDARD, INCLUDING SPECIFICATION, CALIBRATION SETUP, AND PROCEDURE

H.1. SCOPE

H1.1 APPLICABILITY

This document describes a standardized approach for transferring National Institute of Standards and Technology (NIST) primary heat-flux calibrations to total heat flux gauges (HFG) used in flammability testing of aircraft materials. An apparatus consisting of a reference HFG, a radiant heat source capable of producing flux levels up to 5 W/cm^2 , and a precision alignment system are required.

H.2. DEFINITIONS

H.2.1 CALIBRATION FACTOR (SCALE FACTOR)

The calibration factor is a constant multiplier which converts a HFG's millivolt signal to the measured value of heat flux. It is derived from incident flux (W/cm^2 or $\text{BTU/ft}^2\cdot\text{sec}$) / Sensor Output (mV). The responsivity or sensitivity is the reciprocal of the calibration factor.

H.2.2 HEAT FLUX

The rate of thermodynamic energy transfer per unit area that is incident on a material (W/cm^2 or $\text{BTU/ft}^2\cdot\text{sec}$).

H.2.3 HFG

A transducer used in determining heat-flux levels (see Section H.3).

H.2.4 HFG CALIBRATION HIERARCHY

NIST (Primary) → Secondary Standard HFG → Transfer Standard HFG → Working HFG

H.2.5 NIST

NIST (USA) is considered the owner of the Primary Heat Flux Standard.

H.2.6 SECONDARY STANDARD HFG

The Secondary Standard HFG is calibrated by NIST using their heat-flux calibration service. This gauge is used to transfer NIST calibration values to a Transfer Standard HFG.

H.2.7 STANDARDIZED HFG

A Secondary Standard HFG or a Transfer Standard HFG are considered to be Standardized HFGs.

H.2.8 TRANSFER STANDARD HFG

The Transfer Standard HFG is calibrated by a Secondary Standard HFG. This gauge is used to transfer NIST calibration values to a Working HFG.

H.2.9 WORKING HFG

A HFG received from a testing facility to be calibrated. This gauge is used for setting heat-flux levels in day to day laboratory flammability testing.

H.3. HFG SPECIFICATION

H.3.1 TYPE

A Gardon or Schmidt-Boelter HFG

H.3.2 FULL SCALE RANGE (NOMINAL)

0 – 5 W/cm² (0 – 4.4 BTU/ft²*sec)

H.3.3 CONSTRUCTION

The HFG shall be continuously water-cooled and cylindrical in shape having a 1-inch (25.4 mm) diameter body. A mounting flange attached to the body is permissible. Cooling water tubing length and diameter may vary.

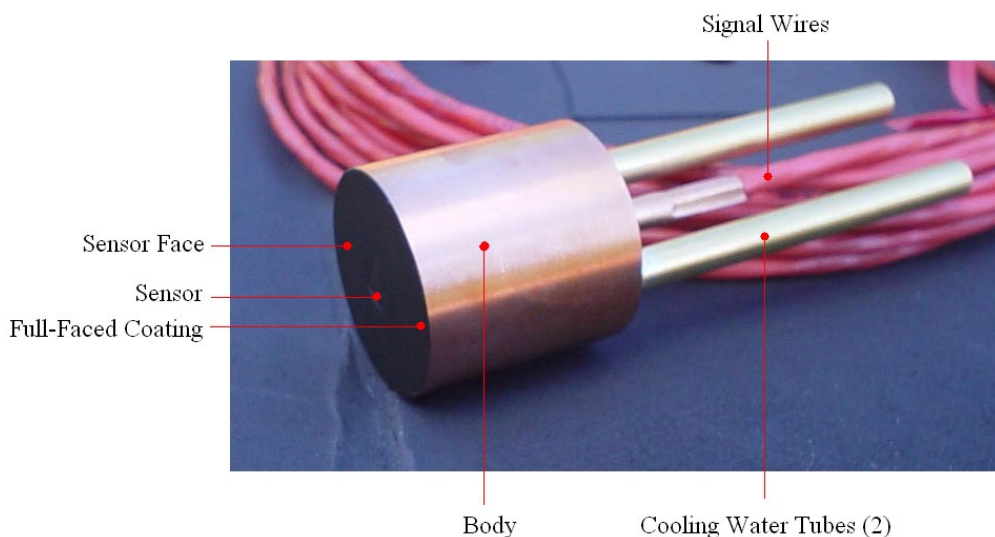


Figure H-1. HFG diagram

H.3.4 COATING

The HFG must have a thin, full-faced, opaque coating of high-quality, high-temperature, ultra-flat black paint having a diffuse surface finish (see figure H-1). To better obtain an ultra-flat finish, several very light coats of paint are sprayed on the sensor face and permitted to dry between coatings. If sprayed until wet, the binder agent may puddle, engulfing suspended particles (typically carbon) and therefore making the surface appear shiny even when dry. Repeat

application until the surface is completely covered. The nominal dry film thickness of the coating on the sensor face must be 5 mils or less with the “orangey” copper face of the sensor not visible.

The coating on the HFG to be calibrated must be removed and replaced prior to calibration.

NOTE: Mankiewicz Black Suede, Krylon Flat Black, Pyromark 1200 Flat Black paints or products of similar specification or function have been found suitable.

H.3.5 COOLING WATER

The HFG cooling water temperature, pressure, and flow is maintained within the manufacturer’s recommendations. It is not recommended to connect cooling water circuits in series.

H.4. DATA-ACQUISITION SYSTEM SPECIFICATION

The data-acquisition system must have a minimum scan rate frequency of 4 Hz, a measurement uncertainty less than ± 0.01 mV (at 95% confidence, $k=2$), and be able to collect the two HFG signals within 0.1 seconds of each other. The data-acquisition system must be calibrated annually to NIST traceability.

The calibration software must convert millivolt data of a Working HFG (gauge to be calibrated) to that of a Standardized gauge (having a known slope) to generate a calibration factor. Calibration data between the range of 1 W/cm² (0.88 BTU/ft²*sec) and 4 W/cm² (3.52 BTU/ft²*sec) is used to linearize the slope. Zero offset data are not to be considered and data beyond these two ranges must be omitted.

H.5. CALIBRATION INTERIM

H.5.1 SECONDARY STANDARD HFG

The Secondary Standard HFG must be calibrated at NIST using their heat-flux calibration service at least once every 5 years. This HFG should not be used for anything else but calibrating transfer standard sensors.

H.5.2 TRANSFER STANDARD HFG

The Transfer Standard HFG must be calibrated by a Secondary Standard HFG at least once every year.

H.5.3 WORKING HFG

The Working HFG must be calibrated by a Standardized HFG at least once every year.

H.5.4 DATA-ACQUISITION SYSTEM

The data-acquisition system must be calibrated to NIST traceable voltage sources at least once every year.

H.6. LABORATORY ENVIRONMENT

The air circulating around the apparatus must be draft-free (stagnant). The ambient laboratory dew point must be lower than 5° below the cooling water temperature (for example, at 73°F [23°C], the ambient relative humidity shall be less than 80% to achieve this). This is to prevent condensation from forming on the sensor face.

H.7. CALIBRATION SETUP

H.7.1 METHOD

The HFG is calibrated for incident heat flux in the vertical orientation as show in figure H-1. Radiant heat is applied to both sensors simultaneously to achieve a near full-scale output. Both HFGs must be monitored to ensure units are not driven over the full-scale range resulting in potential damage or loss of calibration. Data used in determining the calibration factor is recorded during the cool down period of calibration.

H.7.2 GAUGE TYPE

When transferring a calibration from a standardized gauge to a non-standardized gauge, both gauges do not have to be of the same type (see Section H.3.1).

H.7.3 MOUNTING HFGS FOR CALIBRATION

When securing the cylindrical 1-inch body of the instruments into position for calibration, avoid obstructing the sensors' 180-degree field of view of the radiant heat source.

H.7.4 MOUNTING FIXTURE

If more than one HFG mounting fixture is used they must be identical in construction.

H.7.5 HFG POSITIONING

Mount a Standardized HFG and the unit to be calibrated in the vertical orientation (see figure H-1). Each gauge must be located a minimum of 0.375 inches (10 mm) to the radiant heat source. They must be equidistant or within 0.002 inches (0.05 mm) of each other with the sensor faces parallel to the heating elements. Use extreme care when setting the distance from the radiant heat source by avoiding contact with sensor face.

H.7.6 COOLING WATER

Ensure there is proper water flow to each sensor before initiating the HFG exposure to radiant heat (see Section H.3.5).

H.7.7 CONDENSATION

Ensure that there is no condensation that occurs on either sensor face prior to or during the calibration procedure (see Section H.6).

H.7.8 ELECTRICAL

Connect the signal wires of each HFG to the data-acquisition system ensuring that the polarity of each HFG is set correctly with an increase in heat flux corresponding to an increase in millivolt signal.

H.8. CALIBRATION PROCEDURE

STEP 1

Measure the zero flux voltage and resistance of the HFGs.

STEP 2

Apply radiant heat to both sensors until the Standardized HFG reading reaches 5 W/cm^2 ($4.4 \text{ BTU/ft}^2\text{*sec}$). A gradual heat radiance increase from 0 to 5 W/cm^2 (0 to $4.4 \text{ BTU/ft}^2\text{*sec}$) must occur within 45 ± 5 seconds.

STEP 3

Immediately begin decreasing the radiant heat. A gradual cool down rate from 5 W/cm^2 ($4.4 \text{ BTU/ft}^2\text{*sec}$) to less than 1 W/cm^2 ($0.88 \text{ BTU/ft}^2\text{*sec}$) must occur over a minimum time period of 90 seconds.

STEP 4

At the upper threshold of 4 W/cm^2 ($3.52 \text{ BTU/ft}^2\text{*sec}$) begin recording signal data continuously for both HFGs (See Section H.4).

STEP 5

At the lower threshold of 1 W/cm^2 ($0.88 \text{ BTU/ft}^2\text{*sec}$) stop recording signal data.

STEP 6

Repeat STEP 1 verifying the HFGs return to previous conditions and document results.

H.9. ANALYSIS

Multiply the Standardized HFG millivolt values by the known slope and calculate the heat-flux level for each data point. A least squares fit procedure is performed using the calculated heat flux and the Working HFG millivolt values. The linearized slope is determined by:

$$\Delta Y (\text{Units}) / \Delta X (\text{mV}) \quad (\text{H-1})$$

Where:

Y = Standardized HFG (W/cm^2 or $\text{BTU's/ft}^2\text{*sec}$)

X = Working HFG (millivolts)

Note:

*To convert BTU's/ft²*sec to W/cm², multiply slope by 1.135654.*

*To convert W/cm² to BTU's/ft²*sec, multiply slope by 0.88.*

H.10. REQUIREMENTS

H.10.1 REPRODUCIBILITY

It must be shown that if the locations of the two HFGs are interchanged and the calibration is repeated, the difference in the successive calibration factor must not be greater than $\pm 3.0\%$. If the calibration results are within range use the average as the calibration factor.

H.11. REPORTING

Record the required parameters as shown in Table H-1.

Table H-1. Required reporting parameters

TOPIC	SUBTOPIC	DETAILS	
General	Calibration Facility	Facility conducting calibration	
	Customer	Lab performing future tests with the Working HFG	
	Calibration Date	Year / Month / Day	
	Calibration Expiration Date	Year / Month / Day	
Working HFG Information	Manufacturer		
	Part number		
	Serial number		
	Gauge type	Gardon or Schmidt-Boelter	
	Coating	Paint Information	
		Last date painted	
	Calibration Factor	BTU/ft ² *sec or W/cm ²	
	Voltage / Resistance (Zero Flux)	Pre Calibration	Voltage
			Ohm
		Post Calibration	Voltage
			Ohm
	Prior Calibration Data (If available)	Date	
		Calibration Factor	BTU/ft ² *sec/mV or W/cm ² /mV
		Facility where calibration was conducted	

		Percent change in calibration factor	
		Traceability records to a Standardized HFG	
Standardized HFG Information	Manufacturer		
	Part number		
	Serial number		
	Gauge type	Gardon or Schmidt-Boelter	
	Gauge coating material and nominal thickness	Paint information	
		Nominal thickness (mils)	
	Calibration factor	BTU/ft ² *sec/mV or W/cm ² /mV	
	Gauge voltage and ohm reading between signal leads at zero flux	Pre Calibration	Voltage
			Ohm
		Post Calibration	Voltage
			Ohm
	Calibration date of Standardized HFG	Year / Month / Day	
	Traceability records to NIST Primary Standard HFG		
Results	HFG cooling water	F or °C	
	XY plot or raw data table		
	Flux Type	Incident	
	Gauge Type	Gardon or Schmidt-Boelter	
	Linearity of HFG mV signals during calibration	Confidence level	
	Calibration traceability		
	Calibration certificates of devices used		
	Calibration Factor (Initial)	BTU/ft ² *sec/mV or W/cm ² /mV	
	Calibration Factor (Reproducibility)	BTU/ft ² *sec/mV or W/cm ² /mV	
	% Error (< 3)	%	
	Calibration Factor (Average)	BTU/ft ² *sec/mV or W/cm ² /mV	