Designation: F 2178 – 02

Standard Test Method for Determining The Arc Rating Of Face Protective Products[1]

This standard is issued under the fixed designation F 2178; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is used to measure the arc rating of products intended for use as face protection for workers exposed to electric arcs.

1.2 This test method will measure the arc rating of face protective products. The faceshield or other applicable portions of the complete product must meet ANSI Z87.1. This excludes the textile or non ANSI Z87.1 testable parts of the hood assemblies or other tested products. This standard does not measure optical and impact properties (See ANSI Z87.1).

1.3 The materials used in this method are in the form of faceshields attached to the head by protective helmets (hard hats), headgear, or hood assemblies.

1.3.1 Fabric layers used in hood assemblies or other items tested under this standard meet flammability requirements of Specification F 1506.

1.4 This standard shall be used to measure and describe the properties of materials, products, or assemblies in response to convective and radiant energy generated by an electric arc under controlled laboratory conditions and does not purport to predict damage from light other than the thermal aspects measured.

1.5 *Units*—The values stated in either SI units or in other units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

1.6 This standard shall not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire assessment, which takes into account all of the factors, which are pertinent to an assessment of the fire hazard of a particular end use.

1.7 This standard does not purport to describe or appraise the effect of the electric arc fragmentation explosion and subsequent molten metal splatter, which involves the pressure wave containing molten metals and possible fragments of other materials except to the extent that heat energy transmission due to these arc explosion phenomena is reduced by test specimens.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautions, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus[2]

D 123 Terminology Relating to Textiles[3]

D 4391 Terminology Relating to the Burning Behavior of Textiles[4]

E 457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter[5]

F 1494 Terminology Relating to Protective Clothing[6]

F 1506 Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards[7]

F 1958 Test Method for Determining the Ignitability of Non-Flame-Resistant Materials for Clothing by Electric Arc Exposure Method Using Mannequins[7]

F 1959 Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing[7]

2.2 *ANSI/IEEE Standards:*

IEEE Standard Dictionary of Electrical and Electronics Terms[8]

[1] This test method is under the jurisdiction of ASTM Committee F18 on Electrical Protective Equipment for Workers and is the direct responsibility of Subcommittee F18.65 on Wearing Apparel.

Current edition approved April 10, 2002. Published June 2002.

[2] *Annual Book of ASTM Standards*, Vol 04.06.

[3] *Annual Book of ASTM Standards*, Vol 07.01.

[4] *Annual Book of ASTM Standards*, Vol 07.02.

[5] *Annual Book of ASTM Standards*, Vol 15.03.

[6] *Annual Book of ASTM Standards*, Vol 11.03.

[7] *Annual Book of ASTM Standards*, Vol 10.03.

[8] Available from Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 05584-1331.

ANSI Z87.1-1999 Practice for Occupational and Educational Eye and Face Protection[9]

3. Terminology

3.1 *Definitions*—For definitions of other textile terms used in this method, refer to terminology in Terminology D 123, D 4391 and F 1494.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *afterflame*, *n*—persistent flaming of a material after the ignition source has been removed.

3.2.2 *afterflame time*, *n*—the length of time for which a material continues to flame after the ignition source has been removed.

3.2.3 *arc duration*, *n*—time duration of the arc, s.

3.2.4 *arc energy, vi dt*, *n*—sum of the instantaneous arc voltage values multiplied by the instantaneous arc current values multiplied by the incremental time values during the arc, J.

3.2.5 *arc gap*, *n*—distance between the arc electrodes, in.

3.2.6 *arc rating*, *n*—a value which indicates the arc performance of a material or system of materials; either *ATPV* or E_{BT}.

3.2.6.1 *Discussion*—When the arc rating represents the *ATPV*, it shall be reported as Arc Rating (*ATPV*). When Arc Rating represents the E_{BT}, it shall be designated as Arc Rating (E_{BT}). E_{BT} is determined when the *ATPV* cannot be determined.

3.2.7 *arc thermal performance value (ATPV)*, *n*—in arc testing face protective products, the incident energy on a fabric or material that results in sufficient heat transfer through the fabric or material to cause the 50 % probability of the onset of a second-degree burn based on the Stoll curve.

3.2.8 *arc voltage*, *n*—voltage across the gap caused by the current flowing through the resistance created by the arc gap (V).

3.2.9 *asymmetrical arc current*, *n*—the total arc current produced during closure; it includes a direct component and a symmetrical component, A.

3.2.10 *blowout*, *n*—the extinguishing of the arc caused by a magnetic field.

3.2.11 *breakopen*, *n*—in electric arc testing, a material response evidenced by the formation of one or more holes in the material which may allow thermal energy to pass through material.

3.2.11.1 *Discussion*—The specimen is considered to exhibit breakopen when any hole in the material or fabric is at least one-half square inch in area or at least one inch in any dimension. For textile materials, single threads across the opening or hole does not reduce the size of the hole for the purposes of this standard. In multiple layer specimens of flame resistant material, all the layers must breakopen to meet the definition.

3.2.12 *breakopen threshold energy (E_{BT})*, *n*—in arc testing face protective products, the incident energy on a fabric or material that represents the 50 % probability that a breakopen response will occur.

3.2.13 *calorimeter*, *n*—a device used in which the heat measured causes a change in state.

3.2.13.1 *Discussion*—The determination of heat energy, as a consequence of an electrical arc exposure, is made in this standard by measuring the change in temperature of an exposed copper slug of specific geometry and mass during finite time intervals.

3.2.14 *closure*, *n*—point on supply current wave form where arc is initiated.

3.2.15 *deformation*, *n*—for electric arc testing of face protective products, the sagging of material greater than 3 in. or melting in any manner that the faceshield/window touches any part of the body.

3.2.16 *delta peak temperature*, *n*—difference between the maximum temperature and the initial temperature of the sensor during the test, °C.

3.2.17 *dripping*, *n*—in electric arc testing, a material response evidenced by flowing of the fiber polymer or the faceshield window polymer.

3.2.18 *electric arc ignition*, *n*—in electric arc testing of face protective products, the initiation of combustion as related to electric arc exposure, a response that causes the ignition of textile test specimen material which is accompanied by heat and light, and then subsequent burning for at least 5 s, and consumption of at least 25 % of the test specimen area.

3.2.18.1 *Discussion*—For multilayer specimens, consumption of the innermost FR layer must be at least 25 %.

3.2.19 *faceshield*, *n*—a protective device commonly intended to shield the wearer's face, or portions thereof, in addition to the eyes, from certain hazards.

3.2.20 *heat attenuation factor, HAF*, *n*—in electric arc testing, the average of the percent of the incident energy which is blocked by a material.

3.2.20.1 *Discussion*—In Arc Testing of Face Protective Products, *HAF* (face) is based on the highest sensor reading among the four head sensors for each head exposure.

3.2.21 *heat flux*, *n*—the thermal intensity indicated by the amount of energy transmitted per unit area and time (cal/cm^{2}s).

3.2.22 i^2t, *n*—sum of the instantaneous arc current values squared multiplied by the incremental time values during the arc, A^2/s.

3.2.23 *incident energy monitoring sensors*, *n*—sensors mounted on each side of each head, using calorimeters, not covered by specimens, used to measure incident energy.

3.2.24 *incident exposure energy (E_i)*, *n*—in arc testing, the total incident energy delivered to monitor calorimeter sensors as a result of the arc exposure, cal/cm^2.

3.2.24.1 *Discussion*—In an arc test exposure, incident exposure energy for a specimen is determined from the average of the measured incident energy from the respective two monitor sensors adjacent to the test specimen.

3.2.25 *material response*, *n*—material response to an electric arc is indicated by the following terms: breakopen, melting, dripping, deformation, afterflame time, shrinkage, and electric arc ignition.

3.2.26 *melting*, *n*—in testing face protective products, a material response evidenced by softening of the fiber polymer or the faceshield window polymer.

[9] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

3.2.27 *peak arc current*, *n*—maximum value of the AC arc current, A.

3.2.28 *RMS arc current*, *n*—root mean square of the AC arc current, A.

3.2.29 *shrinkage*, *n*—in testing face protective products, a material response evidenced by reduction in specimen size of the fabric or the faceshield window.

3.2.30 *Stoll curve*, *n*—curve produced from data on human tissue tolerance to heat and used to predict the onset of second-degree burn injury (See Table 1).

3.2.31 *time to delta peak temperature*, *n*—the time from beginning of the initiation of the arc to the time the delta peak temperature is reached, s.

3.2.32 *X/R ratio*, *n*—the ratio of system inductive reactance to resistance.

3.2.32.1 *Discussion*—It is proportional to the L/R ratio of time constant, and is, therefore, indicative of the rate of decay of any DC offset. A large X/R ratio corresponds to a large time constant and a slow rate of decay.

4. Summary of Test Method

4.1 This test method determines the heat transport response across a material, fabric, or fabric system when exposed to the heat energy from an electric arc. This heat transport response is assessed versus the Stoll curve, an approximate human tissue tolerance predictive model that projects the onset of a second-degree burn injury (found in Table 1).

4.1.1 Products are mounted on the standard mannequin head containing copper slug calorimeters inserted in the eyes, mouth, and chin positions. During this procedure, the amount of heat energy transferred by the specimen face protective products is measured during and after exposure to an electric arc.

TABLE 1 Human Tissue Tolerance To Heat—Second-degree Burn[A]

Exposure Time s	Heat Flux kW/m²	Heat Flux cal/cm²s	Total Heat kW/m²	Total Heat cal/cm²s
1	50	1.2	50	1.20
2	31	0.73	61	1.46
3	23	0.55	69	1.65
4	19	0.45	75	1.80
5	16	0.38	80	1.90
6	14	0.34	85	2.04
7	13	0.30	88	2.10
8	11.5	0.274	92	2.19
9	10.6	0.252	95	2.27
10	9.8	0.233	98	2.33
11	9.2	0.219	101	2.41
12	8.6	0.205	103	2.46
13	8.1	0.194	106	2.52
14	7.7	0.184	108	2.58
15	7.4	0.177	111	2.66
16	7.0	0.168	113	2.69
17	6.7	0.160	114	2.72
18	6.4	0.154	116	2.77
19	6.2	0.148	118	2.81
20	6.0	0.143	120	2.86
25	5.1	0.122	128	3.05
30	4.5	0.107	134	3.21

[A] Derived from: Stoll, A.M. and Chianta, M.A., "Method and Rating System for Evaluations of Thermal Protection," Aerospace Medicine, Vol 40, 1969, pp. 1232-1238 and Stoll, A.M. and Chianta, M.A., Heat Transfer through Fabrics as Related to Thermal Injury, "Transactions-New York Academy of Sciences," Vol 33 (7), Nov. 1971, pp. 649-670.

4.1.2 The thermal energy exposure and heat transport response of the test specimen(s) are measured with copper slug calorimeters. The change in temperature versus time is used, along with the known thermo-physical properties of copper to determine the respective heat energies delivered to and through the specimen(s).

4.2 This procedure incorporates incident energy monitoring sensors.

4.3 Product and material performance for this procedure are determined by comparing the amount of heat energy generated by the arc flash on monitor sensors with the energy transferred by or through the test specimen(s) and measured by sensors on the mannequin head.

4.4 Product and material responses shall be further described by recording the observed effects of the electric arc exposure on the specimens using the terms in the Report section.

5. Significance and Use

5.1 This test method is intended for the determination of the arc rating of a product/design, intended for use as face protection for workers exposed to electric arcs.

5.1.1 Because of the variability of the arc exposure, different heat transmission values may result for individual sensors. The results of each sensor are evaluated in accordance with Section 12.

5.2 This test method maintains the specimen in a static, vertical position and does not involve movement except that resulting from the exposure.

5.3 This test method specifies a standard set of exposure conditions. Different exposure conditions may produce different results.

NOTE 1—In addition to the standard set of exposure conditions, other conditions representative of the expected hazard may be used and shall be reported should this data be cited.

6. Apparatus

6.1 *General Arrangement for Determining Rating Using Sensor Heads and Monitor Sensors*—The test apparatus shall consist of supply bus, arc controller, recorder, arc electrodes, two (or optionally three) four-sensor heads, and four (or optionally six) incident energy monitoring sensors. The arc exposure shall be monitored with two incident energy-monitoring sensors for each head.

6.1.1 *Arrangement of the Four-Sensor Heads*—The standard test set up is three four-sensor heads spaced at 120° around the arc (Fig. 1). If you only use one video camera to view the tests, place it so that the front of two of the heads can be viewed, and you may remove one of the heads to facilitate viewing. Locate each head vertically to the arc electrodes as shown in Fig. 2. You may use only calorimetry data from heads that are viewed from the front (must view minimum 50 % of the facial area) to record subjective data during the test. Each four-sensor head shall have two incident energy monitoring sensors. One monitoring sensor shall be positioned on each side of each four-sensor head as shown in Fig. 3.

6.1.2 *Head Construction*—Each four-sensor head and each monitor sensor holder shall be constructed from non-conductive heat resistant material as shown in Fig. 4. Use a

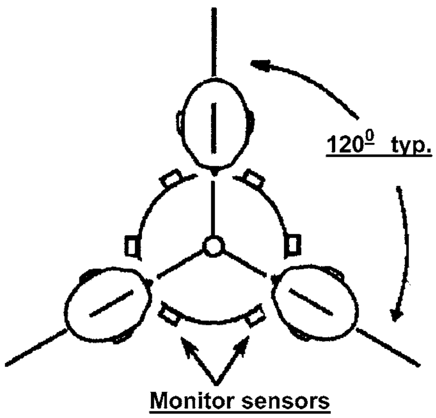

FIG. 1 Location of Mannequin Heads

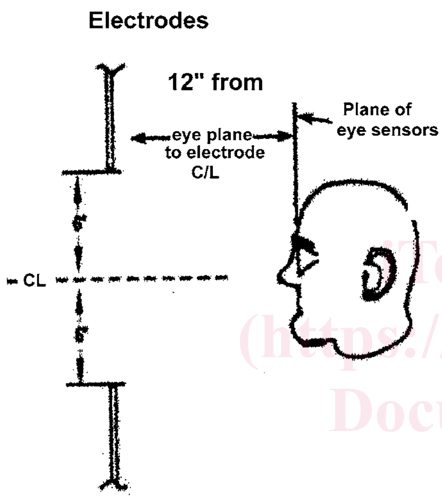

FIG. 2 Vertical Location of Heads to Arc Electrodes

mannequin head, size large, made from a non-conductive high temperature resin/fiberglass construction. (A mannequin head, such as Model 7001 D-H, Morgese Soriano or equivalent is acceptable.) It is recommended that the high-temperature resin used in the construction of the head be non-melting and flame resistant. Each four-sensor head and monitoring sensors shall be placed 12 in. (305 mm) from the centerline of the arc electrodes as shown in Fig. 2. Four-sensors shall be mounted in the head as shown in Fig. 4. The mouth sensor shall be forward of the eye sensor plane by ¼ in. (6 mm). The chin sensor shall be in the horizontal plane (perpendicular to the plane of the eye and mouth) under the chin as shown in Fig. 4. The chin sensor shall protrude below the lowest point of the chin by ⅛ in. (3 mm).

6.1.3 Each four-sensor head may be mounted on the mannequin body specified in Test Method F 1958 and the mannequin to simulate a human body. Any clothing on the mannequin (if used) shall be reported.

6.2 *Sensor Response*:

6.2.1 The copper slug calorimeter monitor sensor response is converted to incident energy of units cal/cm^2 by using the relationship:

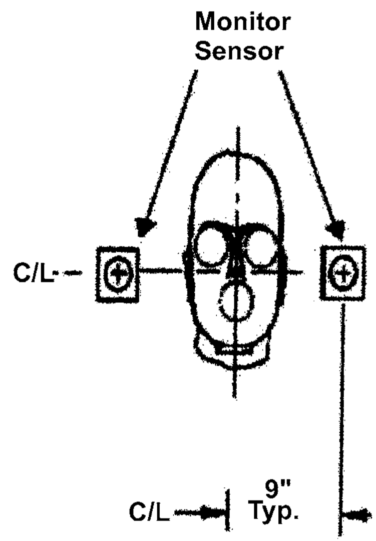

FIG. 3 Mannequin Head with Monitor Sensors

$$\text{Total Heat Energy, } Q = \frac{\text{mass} \times \bar{C}_p \times (Temp_{final} - Temp_{initial})}{\text{area}} \quad (1)$$

where:

Q = heat energy, cal/cm^2,
mass = mass of the copper disk/slug, g,
$\bar{C}_p$ = average heat capacity of copper during the temperature rise, cal/g°C,
$temp_{final}$ = final temperature of copper disk/slug at $time_{final}$, °C,
$temp_{initial}$ = initial temperature of copper disk/slug at $time_{initial}$, °C, and
area = area of the exposed copper disk/slug, cm^2.

The heat capacity of copper in cal/g°C at any temperature between 289 and 1358 K is determined via (Shomate Equation coefficients from NIST):

$$C_p = \frac{(A + B \times t + C \times t^2 + D \times t^3 + E/t^2}{63.546 \text{ g/mol}} \quad (2)$$

where:

t = (measured temperature °C + 273.15) / 1000,
A = 4.237312,
B = 6.715751,
C = -7.46962,
D = 3.339491, and
E = 0.016398.

The average heat capacity of copper during the temperature rise is then determined by calculating the C_p at $Temp_{initial}$ and C_p at $Temp_{final}$ and averaging the two results:

$$\bar{C}_p = \frac{C_p \text{ @ } Temp_{initial} + C_p \text{ @ } Temp_{final}}{2} \quad (3)$$

For a copper disk/slug that has a mass of 18.0 g and exposed area of 12.57 cm^2, the determination of heat flux reduces to:

$$\text{Total Heat Energy, } Q = 1.432 \times \bar{C}_p \times (Temp_{final} - Temp_{initial}) \quad (4)$$

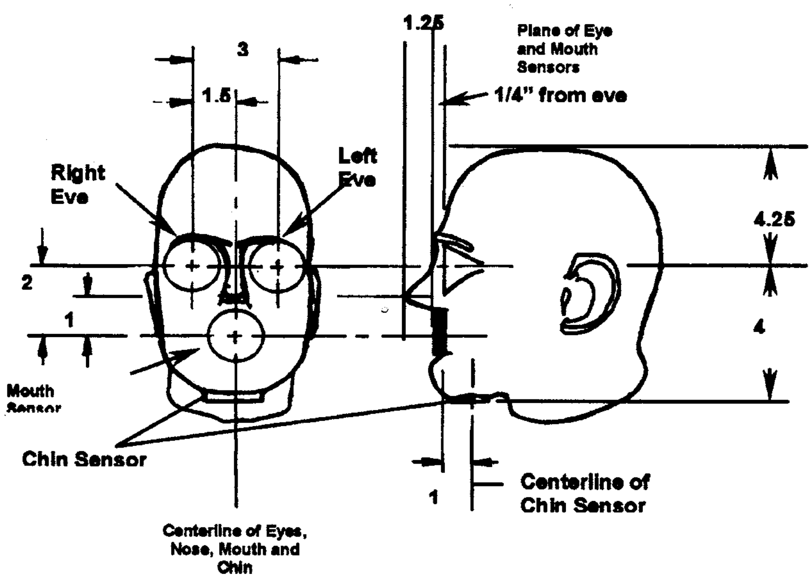

FIG. 4 Mannequin Head and Sensor Locations

If a copper disk/slug with a different mass or exposed area, or both, is used, the constant factor should be adjusted correspondingly.

6.2.2 Each head sensor response shall be converted to total heat energy using Eq 4 in 6.2.1 and compared with the Stoll Curve information in Table 1.

6.2.3 Monitor sensor response shall be converted to total heat energy observed using Eq 4 in 6.2.1.

6.3 *Sensor Construction*—The sensor mount used to hold the calorimeter shall be constructed from a thermally stable heat resistant material with a minimum thermal conductivity value as indicated in Table 2 (such as Fire-Resistant Structural Insulation or equivalent) and shown in Fig. 5 to prevent unwanted heat conduction. The calorimeter shall be constructed from electrical grade copper as shown in Fig. 4 of Test Method F 1959 with four thermocouple wires installed in the arrangement as shown in Fig. 5 of Test Method F 1959. The thermocouple wire shall be installed in the calorimeter as shown in Fig. 6 of Test Method F 1959. For test exposures above 40 cal/cm^2 only, existing monitoring sensors may be moved away from the arc center line, perpendicular to the arc, provided they are not blocked. A multiplier shall be determined to give an equivalent exposure value at 12 in. (for example, at 18 in., the multiplier is 2.25). Alternate calorimeters for the monitor sensors may be used provided they are calibrated and have a similar response at all levels.

TABLE 2 Thermal Conductivity per Test Method C 177 at Various Mean Temperatures

Temperature	Thermal Conductivity Btu-in./ft^2, h, °F(W/m °K)
75°F (24°C)	1.15 (0.17)
400°F (205°C)	1.13 (0.16)
600°F (316°C)	1.15 (0.17)
800°F (425°C)	1.16 (0.17)
1000°F (538°C)	1.17 (0.17)

6.3.1 The calorimeter shall be constructed from electrical grade copper with a single thermocouple wire installed in the position identified in Fig. 5. The thermocouple wire shall be installed in the calorimeter as shown in Fig. 5 of Test Method F 1959.

6.3.2 For test exposures which create a sensor temperature in excess of 300°C, alternate calorimeters for the monitor sensors shall be used. The alternate sensors shall be calibrated and shall have a similar response. An alternate approach for test exposures which create a sensor temperature in excess of 300°C is to increase the distance between the arc centerline and the monitor sensors from the standard distance of 12 to 18 in., and to apply a conversion factor to the incident energy measured at a distance of 18 in. in order to approximate the energy at a distance of 12 in. In this procedure, the specimen remains at a distance of 12 in. from the arc centerline. Copper calorimeter sensor data above 300°C shall be not be valid.

NOTE 2—At an ambient temperature of 25°C, the calorimeter temperature would reach 300°C (ΔT of 275°C) at approximately 36 cal/cm^2.

6.3.3 The exposed surface of the copper slug calorimeter shall be painted with a thin coating of flat black high temperature spray paint. An external heat source, for example, an external heat lamp, may be required to completely drive off any remaining organic carriers in the painted surface.

6.4 *Supply Bus and Electrodes*—A typical arrangement of the supply bus and arc electrodes is shown in Fig. 2. The arc shall be in a vertical position as shown.

6.4.1 *Electrodes*—Make the electrodes from stainless steel (Alloy Type 303 or Type 304) rod of a nominal ¾ in. (19 mm) diameter. Lengths of 18 in. (450 mm) long initially have been found to be adequate.

6.4.2 *Fuse Wire*—A fuse wire, connecting the ends of opposing electrodes tips, is used to initiate the arc. This wire is consumed during the test; therefore, its mass shall be very

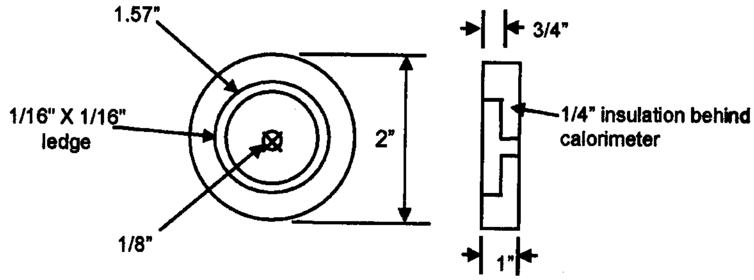

FIG. 5 Sensor Mount

small to reduce any effects on the testing. The fuse wire shall be a copper wire with a diameter not greater than 0.02 in. (0.05 mm).

6.5 *Electric Supply*—The electric supply should be sufficient to allow for the discharge of an electric arc with a gap of up to 12 in. (305 mm), with alternating arc current from 4000 up to 25 000 amperes, and with arc duration from 3 cycles (0.05 s) up to 200.0 cycles (3.3 s) (from a 60 Hz supply).

6.6 *Test Circuit Control*—Repeat exposures of the arc currents shall not deviate more than 2 % per test from the selected test level. The make switch shall be capable of point on wave closing within 0.2 cycles from test to test such that the closing angle will produce a symmetrical current wave repeatable from test to test. The arc current, duration, and voltage shall be measured. The arc current, duration, voltage, and energy shall be displayed in graph form and stored in digital format.

6.7 *Data Acquisition System*—The system shall be capable of recording voltage, current, and sufficient calorimeter outputs as required by the test. The data acquisition system shall be capable of reporting the voltage and current to within 1 % and the calorimetry measurements to within 1°C.

6.7.1 The temperature data (calorimeter outputs) shall be acquired at a minimum sampling rate of 20 samples per second per calorimeter. The acquisition system shall be able to record temperatures to 400°C. The temperature acquisition system shall have at least a resolution of 0.1°C and an accuracy of ±1°C.

6.7.2 The system current and voltage data shall be acquired at a minimum rate of 2000 samples per second. The current and voltage acquisition system shall be able to report voltage and amperage to within 1 %.

6.8 *Data Acquisition System Protection*—Due to the nature of this type of testing, the use of isolating devices on the calorimeter outputs to protect the acquisition system is recommended.

7. Precautions

7.1 The test apparatus discharges large amounts of energy. In addition, the electric arc produces very intense light. Care should be taken to protect personnel working in the area. Workers should be behind protective barriers or at a safe distance to prevent electrocution and contact with molten metal. Workers wishing to directly view the test should use very heavy tinted glasses such as ANSI/ASC Filter Shade 12 welding glasses. If the test is conducted indoors, there should be a method to ventilate the area to carry away combustion products, smoke, and fumes. Air currents can disturb the arc reducing the heat flux at the surface of any of the calorimeters. The test apparatus should be shielded by non-combustible materials suitable for the test area. Outdoor tests shall be conducted in a manner appropriate to prevent exposure of the test specimen to moisture and wind (the elements). The leads to the test apparatus should be positioned to prevent blowout of the electric arc. The test apparatus should be insulated from ground for the appropriate test voltage.

7.2 The test apparatus, electrodes, and calorimeter assemblies become hot during testing. Use protective gloves when handling these hot objects.

7.3 Use care when the specimen ignites or releases combustible gases. An appropriate fire extinguisher should be readily available. Ensure the materials are fully extinguished.

7.4 Immediately after each test, the electric supply shall be shut off from the test apparatus and all other laboratory equipment used to generate the arc, and the apparatus and other laboratory equipment shall be isolated and grounded. After data acquisition has been completed, appropriate methods shall be used to ventilate the test area before it is entered by personnel. No one should enter the test area prior to exhausting all smoke and fumes.

8. Sampling and Specimen Preparation

8.1 Test specimens for four-sensor head test shall be representative of the product, as it will be sold.

8.2 Test specimens shall be mounted as they are normally intended to be worn.

9. Calibration and Standardization

9.1 *Data Collection System Precalibration*—The data collection system shall be calibrated by using a thermocouple calibrator/simulator. This will allow calibrations to be made at multiple points and at levels above 100°C. The data collection system shall be calibrated. Due to the nature of the tests, frequent calibration checks are recommended.

9.2 *Calorimeter Calibration Check*—Calorimeters shall be checked to verify their operation. Measure and graph the temperature rise of each calorimeter and system response. At 30 s, no one calorimeter response shall vary by more than 4°C from the average of all calorimeters. Any calorimeter not meeting this requirement shall be suspected of faulty connections and shall be replaced.

NOTE 3—One accepted method follows: After final placement within the test cell of all test head sensors and monitor sensors, expose each