The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARD

SAE J2495

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Submitted for recognition as an American National Standard

Thermal Containment Efficiency of Sleeve Materials

1. ***Scope***—This SAE Standard measures the percent thermal efficiency of materials in sleeve form used to contain heat or insulate around a hot component. The percent thermal efficiency (%TE) is determined by measuring the power difference expended by the heat source (cartridge heater) with and without the test sleeve at the specified temperature. See SAE J2302 to measure radiant heat flow of sleeves.

1.1 **Safety**—This method may involve hazardous materials, operations and equipment. This document does not address the safety concerns associated with its use. It is the responsibility of the user of this document to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.2 **Limitations**—The temperature measurement range of this procedure is 260 °C to 700 °C. Sleeve size is limited to 19 mm ± 2 mm ID and 280 to 300 mm long. This procedure is performed under static (passive) air flow with no vibration. Do not adapt the temperature sequencing as a thermal cycle.

1.3 This test method is based on SI units per IEEE/ASTM SI 10.

1.4 Note to Users—Use the appropriate alpha-numeric codes to specify temperature condition (Table 1), sequence (Table 2), smoke generation option (see 6.3.2) and auxiliary thermocouple location(s) (position and distance) when referencing this document. For example, a line code of B(2)P(12)D(10,23) after the SAE document number means: Heating to a step sequence (B2), first at 260 °C, then 427 °C measuring power. The auxiliary thermocouple position (P) is at 12 o'clock, on the sleeve surface in two locations, 100 mm and 230 mm from the cartridge heater flange to the end. Bracket all numbers in parenthesis.

2. ***References***

2.1 **Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J2302—Thermal Effectiveness of Sleeve Insulation

2.1.2 IEEE/ASTM—Available from American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

IEEE/ASTM SI 10-1997—Standard for Use of the International System of Units (SI): The Modern Metric System

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2.1.3 NBS PUBLICATION—National Institute of Standards and Technology, U. S. Department of Commerce, Gaithersburg, MD 20899.

NBS Circular 590—Methods of Testing Thermocouples and Thermocouple Materials

3. ***Summary—***This document describes the method and equipment for measuring the effectiveness of sleeves required to contain heat. The test also contains the option of monitoring smoke generation time at the conditions specified (see item 6.3.2). A base line is established first by exposing a 338 mm long x 16 mm OD, cartridge heater assembly (w. thermocouple) to the specified temperature. The controlling thermocouple is mounted at the midpoint and top surface of the cartridge heater. During the test, four power readings of the cartridge heater are recorded, one every 15 min after the tube reaches thermal equilibrium. After establishing the base line power readings, the cartridge heater is sleeved with the thermocoupled protective material and tested again. The surface temperature of the sleeve is recorded. There is no need to measure the cartridge surface temperature, since the heater surface temperature is controlled by the source temperature setting. At the operator's discretion, auxiliary thermocouples mounted at points along the sleeve surface monitor additional sleeve temperatures. In both test sequences, measuring the power expended by the heater, along with the heat source temperature and sleeve surface temperatures assures consistent and fair measure of the sleeve's effectiveness. Only the ratio of power unsleeved less the power sleeved, divided by the unsleeved power expressed as a percent, determines a sleeve's thermal efficiency. A significant variation in these values requires repetition of the test sequence.

4. ***Significance and Use***

4.1 Data obtained by this method are applicable to the material under conditions of this test and are not necessarily the same as those obtained in end use applications. The information permits comparison, selection, or qualification of commercially available sleeves where a level of proficiency is desired beyond short time quality control tests.

4.2 The test set-up (see Figure 1) accommodates one test sleeve and relevant thermocouples. Indicate other thermocouple positions and distances from the cartridge heater using item 6.3.3 protocol.

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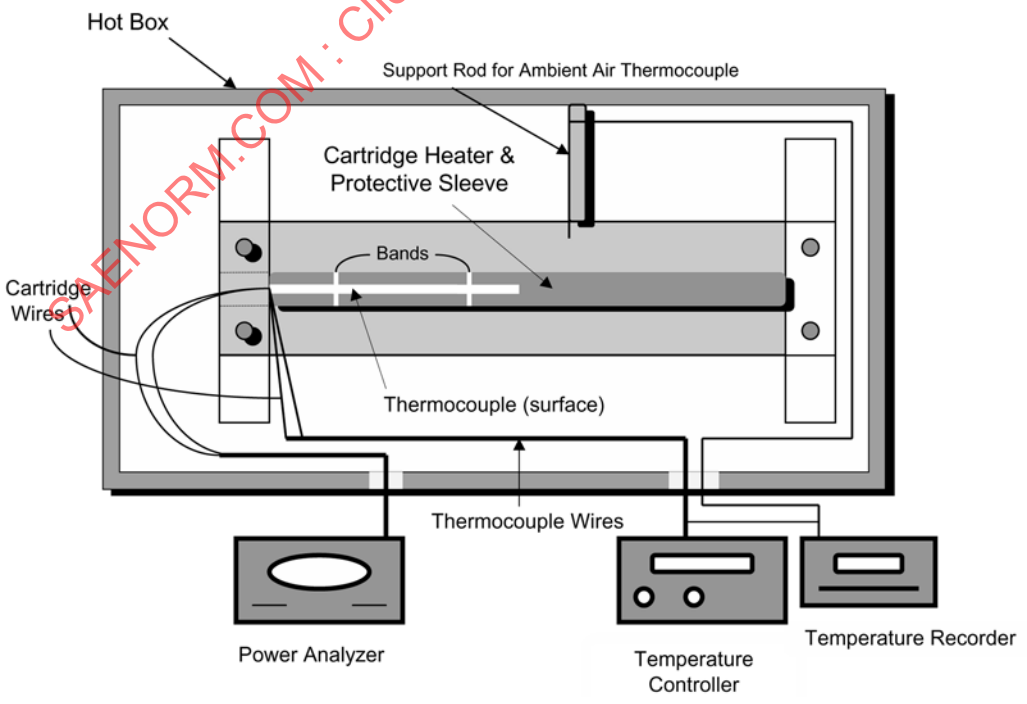

FIGURE 1—TEST SET-UP, TOP VIEW

4.3 Test conditions and requirements using a line code must follow the order of temperature, sequence, and thermocouple position designated by the numbers on a clock. See item 1.4. Bracket all numbers in parenthesis.

4.3.1 TEMPERATURE AND SEQUENCE PROTOCOL—List single or multiple test temperatures using the appropriate Table 1 condition letter. Condition A cannot use the sequence number 2 or 3 because it is the lowest specified temperature. If a step sequence is desired with Condition A as the upper temperature, use the Z suffix. Using a 2 or 3 test sequence after a B or C condition means the sequence follows the lower temperatures in Table 1. Always use the Z suffix to indicate a departure from the Table 1 temperature sequence. When using the Z suffix, indicate the preferred temperature's in degrees centigrade in parenthesis, separating the temperature's with a slash mark (/) - for example Z2 (100 °C/121 °C).

4.3.2 POSITION PROTOCOL—The letter P, followed by the appropriate number in parenthesis, indicates the circumferential clock position of the auxiliary thermocouple(s) on the surface of the cartridge heater and/or sleeve. If no specified position is stated, no measurement is made. Twelve is at the top surface with numbers proceeding clockwise as observed from the tip end (opposite the wires) of the cartridge heater.

5. Equipment[1]

5.1 **Hot Box—**Fabricated from non-conductive, fire resistant, thermal insulation board material[2], 50 mm x 610 mm x 1220 mm, open at the top with nominal internal dimensions of 500 mm x 500 mm x 500 mm. Angle iron 50 mm x 50 mm x 4 mm supports the box panels (6000 mm total). See detail drawing Figures 2A and 2B.

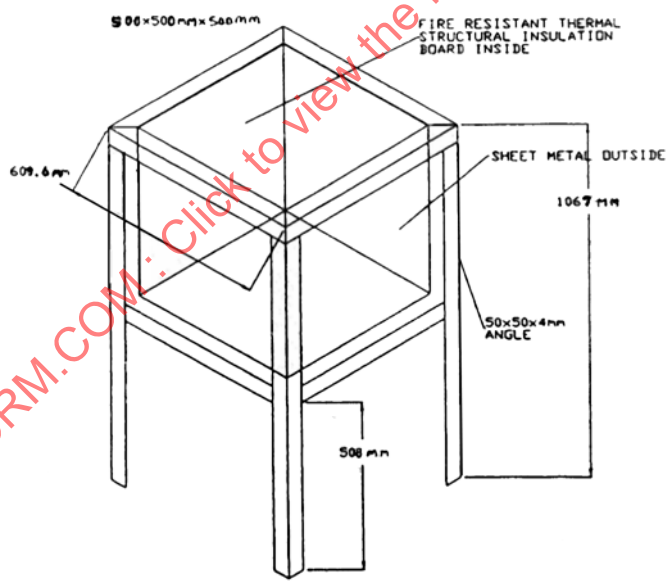

FIGURE 2A—HOT BOX

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1. All are single items, except as indicated.
2. (McMaster Carr 93371K67 or equivalent meets the requirements.)

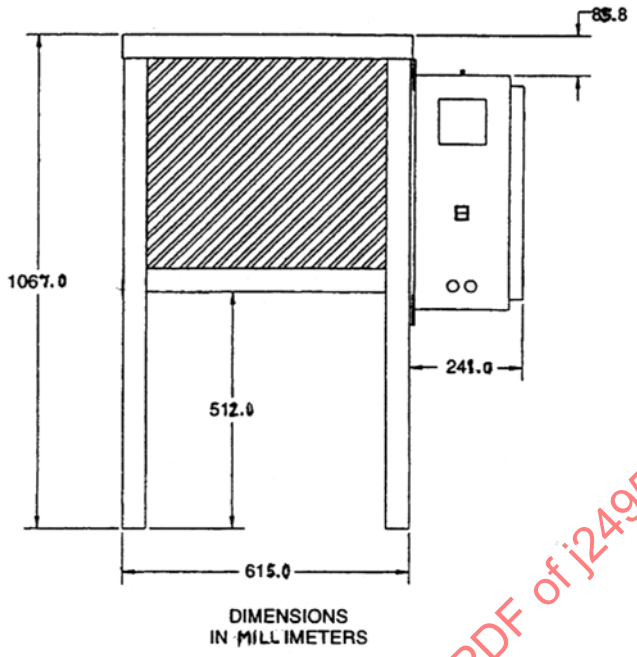

FIGURE 2B—HOT BOX SIDE VIEW WITH CONTROLLER

5.2 Fume Hood—Per appropriate industry approved construction and performance.

5.3 Cartridge Heater—Unit 338 mm long x 16 mm OD, capable of reaching 760 °C. The cartridge length from 292 to 305 mm is heated. No heat zones are located from the sealed tip end to 13 mm toward the flanged base and 38 mm from the lead wire entry point end toward the flange. The cartridge construction consists of a incoloy™ tube (sheath), inside is a wound nickel-chromium wire on a support core of magnesium oxide thermal insulation. The thermal heater output is 1000 to 1100 W, 240 VAC/4.1 A, with surface self-cleaning capability for most applications.[3]

5.4 Temperature Controller—1/4 DIN, digital indicating controller with an accuracy of ±3 °C up to 700 °C. Auto tuning based microprocessor for primary output. Four to Twenty mA output. Operating environment 0 °C to 65 °C. Sensor input must accept type K thermocouple.[4] Supplies electrical current to heat cartridge.

5.5 Electric Power Demand Analyzer[5] and Current Probe[6]—Digital indicating analyzer with an accuracy of ±3 °C up to 700 °C. Auto tuning based microprocessor for primary output. Four to Twenty mA output. Operating environment 0 °C to 65 °C. Sensor input must accept type K thermocouple. Monitor's voltage and current, display's power used.

5.6 Temperature Recorder—Computer controlled data analyzer.[7] Optional manual data recorder with a digital indicator.[8] Ten channel sensor input selector. Will accept type K thermocouple. Operating environment 0 °C to 55 °C. Accuracy of ± 3 °C up to 700 °C.

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3. Power Modules Inc., cartridge heater 4960921-E or 4960811 or equivalent, meets the requirements.
4. Watlow Series 945-1FA1-A000, 965 and 93 or equivalent, meets the requirements.
   INCOLOGY™ is a trademark of International Nickel
5. Dranetz Model 808 Power Analyzeror equivalent, meets the requirements.
6. Dranetz Current Probe, Model TR2012A or equivalent, meets the requirements.
7. Fluke Hydra Data Logger 2625A or equivalent, meets the requirements.
8. Watlow #8D45-0080-0-600 or equivalent, meets the requirements.

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5.7 Type K Thermocouple (Wire)—American National Standards Institute (ANSI) code K (yellow) with chromel/alumel base metals. Choose approximately 50 m of solid bare wire, diameter (gauge) at 0.81 mm (AWG 20). Insulation, glass braided over glass wrap or other that meets or exceeds 700 °C capability.[9]

5.7.1 THERMOCOUPLE CONNECTOR—"K" Type, plug, (3). Attaches to thermocouple leads for connection into module for cartridge heater.[10]

5.7.2 THERMOCOUPLE CONNECTOR—"K" Type, socket. Permits insertion of plug with thermocouple leads into module for cartridge heater.[11]

5.8 Surface Probe—Ceramic tip (spring loaded), (3). Permits surface contact of thermocouple to sleeve.[12]

5.9 Enclosure Panel Box—A unit, 510 mm x 410 mm x 200 mm[13], with a sub panel 430 mm x 330 mm[14] for mounting the temperature controller, temperature indicator, circuit breaker, transformer, lights and switches. See Figure 2B.

5.9.1 TRANSFORMER—500VA, 240/120 VAC to control any in rush currents.[15]

5.9.2 FUSE HOLDER AND FUSES—Panel mount, 2 pole and 1 pole - 250 VAC holder, with two six amp and one three amp fuses.

5.9.3 SWITCH, SELECTOR—2 position maintained 10 A rating (oil tight) for on/off control.

5.9.4 PILOT LIGHT—120 VAC, red, to indicate on and off condition.

5.10 Circuit Breaker—2 pole, 240 V, 15 A through door mount to panel box.[16]

5.11 SCR Power Control—240 V, 15 A, zero voltage firing (signal control = 4-20 mA).[17]

6. Test Requirements

6.1 Specimen—The test sleeve length must be 280 mm to 300 mm long with a 19 mm nominal ID. Measure the sleeve i.d. using a plug gauge. The sleeve may or may not incorporate a seam. Seamed sleeves are tested with the seam at the bottom (6 o'clock) of the cartridge heater.

6.2 Unless otherwise specified, testing shall be conducted following a specimen conditioning period of 24 h minimum at 23 °C ± 2 °C and 50% R.H. ± 5% R.H.

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9. Omega GG-K-20 (solid) or equivalent, meets the requirements.
10. Cole-Parmer E-83840-52 or equivalent, meets the requirements.
11. Cole-Parmer E-93840-53 or equivalent, meets the requirements.
12. Cole-Parmer L-08439-12 or equivalent, meets the requirements.
13. Hoffman D-3L20H1608LPB or equivalent, meets the requirements.
14. McMaster Car 75545K92 or Hoffman (OR) AZOP16 or equivalent, meets the requirements.
15. Jefferson 636-1191 or equivalent, meets the requirements.
16. Square "D" Co. FAL-22015 or equivalent, meets the requirements.
17. Halmar/Robicon 115Z-C or equivalent, meets the requirements.

6.3 Temperatures—For standardization purposes, select one or more of the following test temperature conditions:

TABLE 1—TEMPERATURE CONDITIONS

Condition	Temperature °C	Available Sequence Numbers
A	260	1
B	427	1,2
C	537	1,2,3
D	700	1,2,3,4
Z	As specified within the limits of this standard.	

6.3.1 SEQUENCE—For standardization purposes, select one of the following test sequences:

TABLE 2—SEQUENCE

Sequence	Condition
1	Dedicated test at specified isothermal temperature.
2	Two step sequence using specified temperatures.
3	Three step sequence using specified temperatures.
4	Four step sequence using specified temperatures.
9	As specified within the limits of this standard.

6.3.2 Use the letter 'S,' after the temperature condition letter in Table 1, to designate smoke generation and time in seconds in parenthesis. See item 4.3.2.

6.3.3 POSITION AND DISTANCE—indicate the circumferential position of your auxiliary thermocouple(s) relative to the cartridge heater using the positions of the clock. The twelve o'clock thermocouple position (top) is standard, on the surface of the test sleeve. Indicate other positions (P) on individual part or component drawings per item 4.3.2. Distance (D) is measured in centimeters from the wire/flange end of the cartridge heater to the opposite end. Indicate the number in parenthesis for each auxiliary thermocouple.

6.4 Do not use or interpret the sequence conditions as a repetitive cycle test.

6.5 The specimen must be free of any visible defects that would effect the test results.

6.6 Test in a “passive” hood environment. Air flow must not influence test measurements.

6.7 Thermocouple Mounting

6.7.1 CARTRIDGE HEATER—Position the thermocouple touching the outside surface of the cartridge heater, at the midpoint of the heat zone (144 mm)/ of entire length (287 mm), and at the 12 o’clock position. See Section A.1 for repair attachment procedure the thermocouple junction. As a purchased option, with the thermocouple attached, the heat source thermocouple must be at the midpoint of the cartridge heater shown in Figure 3A. Don’t wrap or twist the thermocouple wires around the rod and risk breaking the integrity of the contact junction.

6.7.2 TEST SLEEVE—Position the thermocouple ±10 mm to the left or right (offset) of the cartridge heater thermocouple position at the top of the test sleeve mounted to the cartridge heater (Figure 3A). Position sewn sleeves on the cartridge heater with the seam 180 degrees away from the top. The junction point must be in direct contact with the surface of the material. The spring loaded surface probe with ceramic tip (item 5.7) with adjustable mounting bracket, permits surface contact of thermocouple from a variety of angles. If this is not available, secure the thermocouple to the sleeve using a fine copper magnet wire wrap or fiberglass thermal tape capable of surviving the test temperatures. Make sure the wire or tape doesn’t touch the end of the thermocouple.

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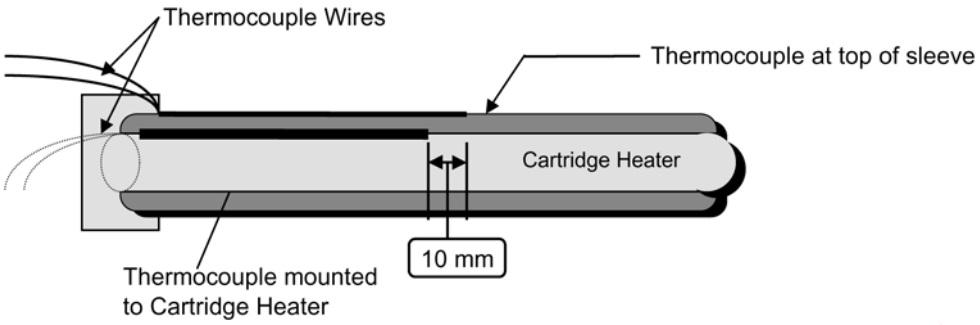

FIGURE 3A—CROSS SECTION SHOWING THERMOCOUPLE OFFSET

6.7.3 THERMOCOUPLE LOCATION—The midpoint location is required for measurement since thermal data of the recommended cartridge heater has shown that only in the center do you get temperature output equivalent to the controller set temperature.

7. Calibration

7.1 The instrument manufacturer or certified agent should calibrate all recorders to the appropriate National Institute of Standards and Technology (NIST) document for accuracy claimed and the appropriate label displayed on the instrument. Calibration by the test facility is appropriate if substantiated by data measured by calibrated instruments traceable to NIST (formerly NBS).

7.2 Calibrate thermocouples by the comparison method utilizing procedures based upon those described in NBS Circular 590, Methods of Testing Thermocouples and Thermocouple Materials. Pre-calibrated thermocouples are available from the manufacturers.

8. Procedure

8.1 Establish the base line (no sleeve) measurements by placing the cartridge heater in the Hot Box. Position and secure the thermocouples using the techniques described in item 6.7. The cartridge heater has a flange with holes for easy attachment to an "L" shaped self-supporting base for positioning on the "H" platform inside the bottom of the box. A thermocouple for ambient temperature measurement is supported by a lattice frame work in the box, using metal rods and joint fittings found in most lab equipment catalogs. Position the parts in the hot box according to Figures 4A and 4B. Unless otherwise specified, the thermocouple test position is at the top (see item 6.3.3). Connect the thermocouple to the temperature recorder.

8.2 Check for ground loops, reversed connections and the integrity of all connections. Re-calibrate if required. Begin a test sequence at 23 °C ± 2 °C air temperature as indicated by the thermocouple recording the temperature inside the hot box. Inspect the thermocouple connection to the cartridge heater every five to ten heats. If contact is lost, repair the connection by rotating the cartridge heater and remount the thermocouple contact to the new center site with new weld (Section A.1).

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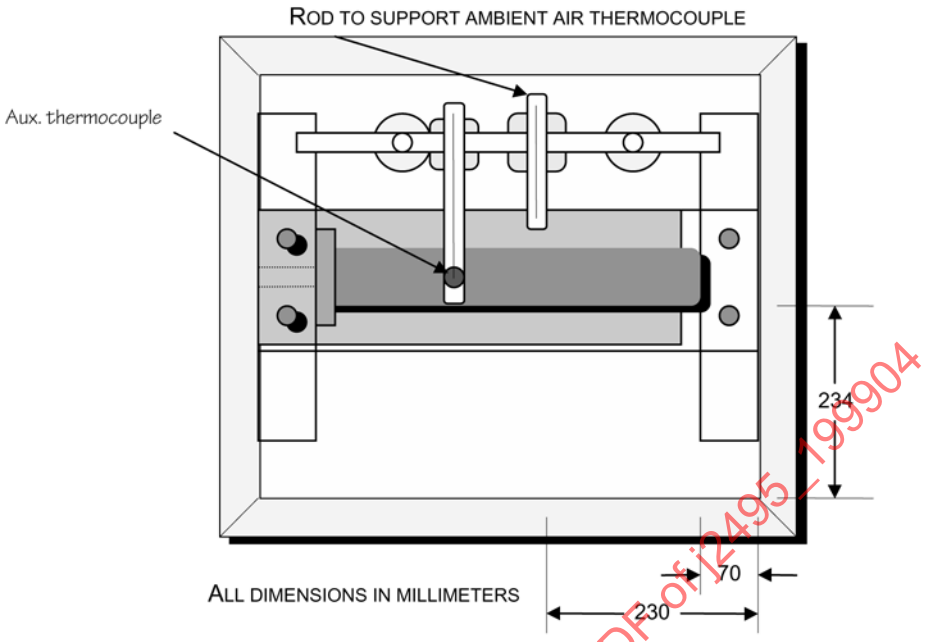

FIGURE 4A—TOP VIEW SHOWING SAMPLE POSITION

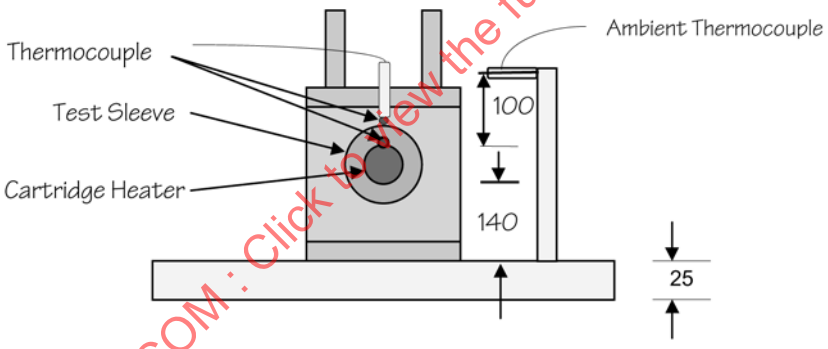

FIGURE 4B—END VIEW SHOWING SPECIMEN MOUNTING

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8.3 Turn on the power to the controller, power analyzer, bare cartridge heater, and recorder. Set the controller to the required temperature (see Table 1, item 6.3). Allow the apparatus sufficient time to stabilize at the selected isothermal temperature. Steady state is defined as three consecutive readings within ±3 °C of the set temperature. The starting point for determining the initial reaching of steady state is when the continuous readout (temperature recorder) shows the first indication of the temperature to be measured. As the temperature increases to each set point, there may be a slight over-shoot of the setting. Record the first steady state set value as it is reached and ignore the slight rise.

8.4 After stabilizing the temperature set by the controller, start recording the cartridge heater surface temperatures. Record at 3 min intervals for 30 min after reaching steady state. Continue to record the air temperature inside the hot box.

8.4.1 At the end of this period, if additional steps are required (see Table 2, item 6.3.1), adjust the controller to the specified sequence condition in Table 2 and repeat the data acquisition steps. After establishing the base line performance, end the test. Continue to record the air temperature inside the hot box.

8.5 After the test set-up has cooled, remove the set-up from the Hot Box and slide the protective sleeve on the cartridge heater. Don't dislodge the thermocouple on the cartridge. Place a second thermocouple on the outer surface of the sleeve, offset by ±10 mm and above the bare cartridge heater thermocouple (12 o'clock high). Place the sleeved cartridge heater back in the Hot Box in the proper orientation. To help prevent dislodging of the thermocouples, mount them on the test sleeve positioned on a second rod whose height is the same as the test. Carefully slide the sample onto the bare rod after butting the rod ends together to ease the transfer to the test rod. If you use the spring contact to surface method, slide the non-thermocoupled test sleeve onto the cartridge heater then position the contact locator and disengage the spring to permit contact. If applicable, position the sleeve seam pointing to the bottom.

8.6 Repeat the sequence described in item 8.3. Begin the test sequence when the cartridge heater surface temperature is less than or equal to 26 °C, as indicated by the center thermocouple. During the warm-up phase, be prepared to record the smoking time of the sample. Start the timer when smoking is visually observed. Record the temperature that smoking started. Do not wait for the set temperature to be reached before starting smoke timing. Stop timing when no more smoke is observed. Report the time with a stop watch, in minutes and seconds. From early lab experience, initial runs on the cartridge heater at all three temperatures took from eighteen to twenty-four minutes to reach steady state. Continue to record the air temperature inside the hot box. Do not use steady state measurements as part of the ten data points.

8.7 After reaching the stable isothermal setting per 8.3, repeat steps 8.4 and if applicable, 8.4.1.

8.8 Reliable repeat measurements can only be made on the same sleeve at the lowest test temperature (condition A).

9. Calculation

9.1 For each test, determine the power difference expended by the heater without and with the tested sleeve during steady state at the chosen temperature(s). The number of specimens tested is between the requester and the tester. If the requester fails to designate a number of specimens, the lab will test three randomly sampled specimens from different manufacturing runs or machines.

9.2 Calculate the final arithmetic mean from the three power readings (CP_f), on the bare cartridge heater and mean of sleeved power readings (SCP_f) from all sleeved samples run in item 9.1.

9.3 Calculate the containment effectiveness of the sleeve material, expressed in percent thermal efficiency (%TE) as the power difference between the final mean unsleeved cartridge heater (CP_f) and the final mean sleeved cartridge heater (SCP_f) at each source isothermal temperature setting divided by the final mean unsleeved cartridge heater power (CP_f) times 100. See Equation 1.

$$\%T_E \text{ (at temperture °C)} = CP_f - SCP_f \div CP_f \times 100 \qquad \text{(Eq. 1)}$$

9.4 If it is desirable to measure the sleeve surface temperature at positions other than the center, measure the surface temperature of the unsleeved heater at the corresponding position. Note the cartridge heater surface temperatures are not uniform and differ considerably from the set temperature. Do not place thermocouples in the cartridge heater no heat zones.

10. report

10.1 The report shall include the following:

10.1.1 Description of the specimen, giving the identification number of the material and date of test.

10.1.2 The final unsleeved and sleeved cartridge heater power (CP_f) readings per item 9.1.

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