



Designation: F1930 – 13

Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin¹

This standard is issued under the fixed designation F1930; 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 provide predicted human skin burn injury for single layer garments or protective clothing ensembles mounted on a stationary instrumented manikin which are then exposed in a laboratory to a simulated fire environment having controlled heat flux, flame distribution, and duration. The average exposure heat flux is 84 kW/m^2 ($2 \text{ cal/s}\cdot\text{cm}^2$), with durations up to 20 seconds.

1.2 The visual and physical changes to the single layer garment or protective clothing ensemble are recorded to aid in understanding the overall performance of the garment or protective ensemble and how the predicted human skin burn injury results can be interpreted.

1.3 The skin burn injury prediction is based on a limited number of experiments where the forearms of human subjects were exposed to elevated thermal conditions. This forearm information for skin burn injury is applied uniformly to the entire body except for the hands and feet. The hands and feet are not included in the skin burn injury prediction.

1.4 The measurements obtained and observations noted can only apply to the particular garment(s) or ensemble(s) tested using the specified heat flux, flame distribution, and duration.

1.5 This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire-hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.

1.6 This method is not a fire-test-response test method.

1.7 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units or other units commonly used for thermal testing. If appropriate, round the non-SI units for convenience.

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.*

1.9 Fire testing is inherently hazardous. Adequate safeguards for personnel and property shall be employed in conducting these tests.

2. Referenced Documents

2.1 ASTM Standards:²

D123 Terminology Relating to Textiles

D1835 Specification for Liquefied Petroleum (LP) Gases

D5219 Terminology Relating to Body Dimensions for Apparel Sizing

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Transducer

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F1494 Terminology Relating to Protective Clothing

2.2 AATCC Standards:³

Test Method 135 Dimensional Changes of Fabrics after Home Laundering

Test Method 158 Dimensional Changes on Dry-Cleaning in Perchloroethylene: Machine Method

2.3 Canadian Standards:⁴

CAN/CGSB-4.2 No. 58-M90 Textile Test Methods Colorfastness and Dimensional Change in Domestic Laundering of Textiles

CAN/CGSB-3.14 M88 Liquefied Petroleum Gas (Propane)

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709, <http://www.aatcc.org>.

⁴ Available from Standards Council of Canada, Suite 1200, 45 O'Connor St., Ottawa, Ontario, K1P 6N7.

¹ This test method is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.80 on Flame and Thermal.

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2.4 NFPA Standards:⁵

NFPA 54 National Fuel Gas Code, 2009 Edition

NFPA 58 Liquefied Petroleum Gas Code 2008 Edition

NFPA 85 Boiler and Combustion Systems Hazards Code, 2007 Edition

NFPA 86 Standard for Ovens and Furnaces, 2007 Edition

3. Terminology

3.1 For definitions of terms used in this test method use the following documents. For terms related to textiles refer to Terminology **D123**, for terms related to protective clothing refer to Terminology **F1494** and for terms related to body dimensions refer to Terminology **D5219**.

3.2 Definitions:

3.2.1 *burn injury, n*—thermal damage which occurs to human skin at various depths and is a function of local temperature and time.

3.2.1.1 *Discussion*—Burn injury in human tissue occurs when the tissue is heated above a critical temperature (44°C (317.15 K) or 111°F). Thermal burn damage to human tissue depends on the magnitude of the temperature rise above the critical value and the duration that the temperature is above the critical value. The degree of burn injury (second or third degree) depends on the maximum depth within the skin layers to which tissue damage occurs. The first-degree burn injury is considered minor relative to second-degree and third-degree burn injuries. It is not included in the evaluation of test specimens in this test method (see **Appendix X1**).

3.2.2 *fire exposure, n*—in the fire testing of clothing, the fire exposure is a propane-air diffusion flame with a controlled heat flux and spatial distribution, engulfing the manikin for a controlled duration.

3.2.2.1 *Discussion*—The flames are generated by propane jet diffusion burners. Each burner produces a reddish-orange flame with accompanying black smoke (soot).

3.2.3 *flame distribution, n*—in the fire testing of clothing, a spatial distribution of incident flames from burners to provide a controlled heat flux over the surface area of the manikin.

3.2.4 *instrumented manikin, n*—a structure designed and constructed to represent an adult-size human and which is fitted with thermal energy (heat flux) sensors on its surface.

3.2.4.1 *Discussion*—The manikin is fabricated to specified dimensions from a high temperature resistant material. The instrumented manikin used in fire testing of clothing is fitted with at least 100 thermal energy (heat flux) sensors, distributed over the manikin surface. The feet and hands are not normally fitted with sensors. If the feet and hands are equipped with sensors, it is up to the user to define a procedure to interpret the results.

3.2.5 *predicted second-degree burn injury, n*—in the fire testing of clothing, a calculated second-degree burn injury to skin based on measurements made with a thermal energy sensor.

3.2.5.1 *Discussion*—For the purposes of this standard, predicted second-degree burn injury is defined by the burn injury model parameters (see Section **12** and **Appendix X1**). Some laboratories assign an area to each sensor over which the same burn injury prediction is assumed to occur, others do not.

3.2.6 *predicted third-degree burn injury, n*—in the fire testing of clothing, a calculated third-degree burn injury to skin based on measurements made with a thermal energy sensor.

3.2.6.1 *Discussion*—For the purposes of this standard, predicted third-degree burn injury is defined by the burn injury model parameters (see Section **12** and **Appendix X1**). Some laboratories assign an area to each sensor over which the same burn injury prediction is assumed to occur, others do not.

3.2.7 *predicted total burn injury, n*—in the fire testing of clothing, the manikin surface area represented by all thermal energy sensors registering a predicted second-degree or predicted third-degree burn injury, expressed as a percentage.

3.2.8 *second-degree burn injury, n*—in the fire testing of clothing, complete necrosis (living cell death) of the epidermis skin layer.

3.2.9 *thermal energy sensor, n*—a device capable of measuring directly the incident heat flux at its surface or one which gives an output which is used to calculate the incident heat flux.

3.2.9.1 *Discussion*—Types of sensors which have been used successfully include slug calorimeters, surface and buried temperature measurements and thin film heat flux gauges. Some types of sensors approximate the thermal inertia of human skin and some do not. The known sensors in current use have relatively small detection areas. An assumption is made for the purposes of this method that thermal energy measured in these small areas can be extrapolated to larger surrounding surface areas so that the overall manikin surface can be approximated by a minimum number of sensors. The resulting sensors predicted burn injury applies to the extrapolated coverage area. Some laboratories assign different coverage areas to each sensor over which the same burn injury prediction is assumed to apply, others do not (see **6.2.1.1**).

3.2.10 *thermal protection, n*—the property that characterizes the overall performance of a garment or protective clothing ensemble relative to how it retards the transfer of heat that is sufficient to cause a predicted second-degree or predicted third-degree burn injury.

3.2.10.1 *Discussion*—Thermal protection of a garment or ensemble and the consequential predicted burn injury (second-degree and third-degree), is quantified from the response of the thermal energy sensors and use of the skin burn injury prediction model. In addition to the calculated results, the physical response and degradation of the garment or protective clothing ensemble is an observable phenomenon useful in understanding garment or protective clothing ensemble thermal protection.

3.2.11 *third-degree burn injury, n*—in the fire testing of clothing, complete necrosis (living cell death) of the epidermis and dermis skin layers.

⁵ Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

4. Summary of Test Method

4.1 This test method covers quantitative measurements and subjective observations that characterize the performance of single layer garments or protective clothing ensembles mounted on a stationary instrumented manikin. The conditioned test specimen is placed on the instrumented manikin at ambient atmospheric conditions and exposed to a propane-air diffusion flame with controlled heat flux, flame distribution and duration. The average exposure heat flux is 84 kW/m^2 ($2 \text{ cal/s}\cdot\text{cm}^2$) with durations up to 20 seconds.

4.2 The test procedure, data acquisition, calculation of results and preparation of parts of the test report are performed with computer hardware and software programs. The complexity of the test method requires a high degree of technical expertise in the test setup and operation of the instrumented manikin and the associated data collection and analysis software.

4.3 Thermal energy transferred through and from the test specimen during and after the exposure is measured by thermal energy sensors. The sensors are located at the surface of the manikin. They are used to measure the thermal energy absorbed as a function of time over a preset time interval. A computer based data acquisition system is used to store the time varying output from the sensors.

4.4 Computer software uses the stored data to calculate the heat flux and its variation with time at the surface of each sensor. The calculated heat flux and its variation with time at the surface is used to calculate the temperature within human skin and subcutaneous layers (adipose) as a function of time. The temperature history within the skin and subcutaneous layers (adipose) is used to predict the onset and severity of human skin burn injury. The computer software calculates the predicted second-degree and predicted third-degree burn injury and the total predicted burn injury resulting from the exposure.

4.5 The overall percentage of predicted second-degree, predicted third-degree and predicted total burn injury is calculated by dividing the total number of sensors indicating each of these conditions by the total number of sensors on the manikin. Alternately, the overall percentages are calculated using sensor area weighted techniques for facilities with non-uniform sensor coverage. A reporting is also made of the above conditions where the areas that are uncovered by the test specimen are excluded (see 13.5.1 and 13.5.2). This test method does not include the ~12 % of body surface area represented by the unsensored manikin feet and hands. No corrections are applied for their exclusion.

4.6 The visual and physical changes to the test specimen are recorded to aid in understanding overall performance and how the resulting burn injury results can be interpreted.

4.7 Identification of the test specimen, test conditions, comments and remarks about the test purpose, and response of the test specimen to the exposure are recorded and are included as part of the report.

4.8 The performance of the test specimen is indicated by the calculated burn injury area and subjective observations of material response to the test exposure.

4.9 **Appendix X1** contains a general description of human burn injury, its calculation and historical notes.

5. Significance and Use

5.1 Use this test method to measure the thermal protection provided by different materials, garments, clothing ensembles, and systems to a specified fire exposure (see 3.2.2, 4.1, 10.1.3, and 10.1.4).

5.1.1 This test method does not simulate high radiant exposures, for example, those found in electric arc flash exposures, some types of fire exposures where liquid or solid fuels are involved, nor exposure to nuclear explosions.

5.2 This test method provides a measurement of garment and clothing ensemble performance on a stationary upright manikin of specified dimensions. This test method is used to provide predicted skin burn injury for a specific garment or protective clothing ensemble when exposed to a laboratory simulation of a fire. It does not establish a pass/fail for material performance.

5.2.1 This test method is not intended to be a quality assurance test. The results do not constitute a material's performance specification.

5.2.2 The effects of body position and movement are not addressed in this test method.

5.3 The measurement of the thermal protection provided by clothing is complex and dependent on the apparatus and techniques used. It is not practical in a test method of this scope to establish details sufficient to cover all contingencies. Departures from the instructions in this test method have the potential to lead to significantly different test results. Technical knowledge concerning the theory of heat transfer and testing practices is needed to evaluate if, and which departures from the instructions given in this test method are significant. Standardization of the test method reduces, but does not eliminate, the need for such technical knowledge. Report any departures along with the results.

6. Apparatus

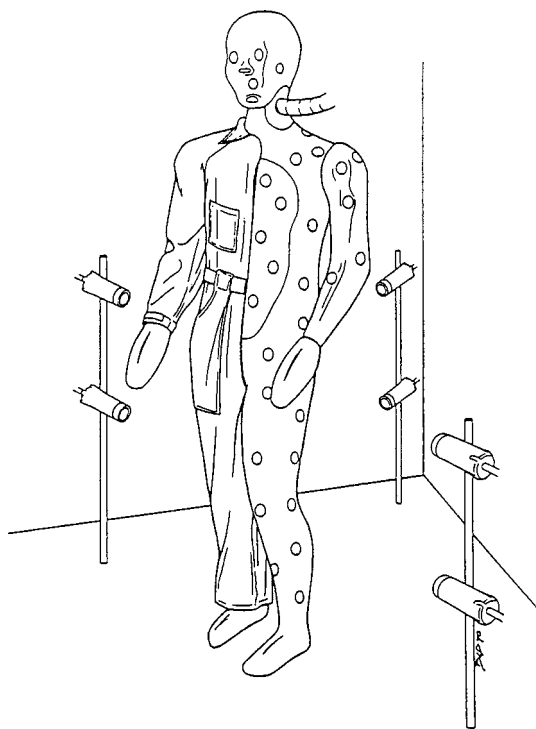
6.1 *Instrumented Manikin*—An upright manikin with specified dimensions that represents an adult human form shall be used (see Fig. 1).

6.1.1 *Size and Shape*—The manikin shall be constructed with a head, neck, chest/back, abdomen/buttocks, arms, hands, legs, and feet. The manikin's dimensions shall correspond to those required for standard sizes of garments because deviations in fit will affect the results. A male manikin consisting of the sizes given in Table 1 has been found satisfactory to evaluate garments or protective ensembles. The sizes for a female manikin have not yet been set.

6.1.2 The manikin shall be constructed of flame resistant, thermally stable, nonmetallic materials which will not contribute fuel to the combustion process. A flame resistant thermally stable, glass fiber reinforced vinyl ester resin at least 3 mm ($\frac{1}{8}$ in.) thick, has proven effective.

6.2 *Apparatus for Burn Injury Assessment:*

6.2.1 *Manikin Thermal Energy Sensor Layout*—A minimum of 100 thermal energy sensors shall be used to measure



NOTE 1—Only six of eight burners are shown.

FIG. 1 Schematic of Instrumented Manikin and Burner Placement

distribution is given in Table 2. They shall be distributed as uniformly as possible within each area on the manikin.

6.2.1.1 *Discussion*—It is acceptable to have the sensor layout as one of uniform spacing or of non-uniform spacing. With uniform spacing each sensor is located in the center of an area, the areas being of uniform size over the surface of the manikin. The non-uniform spacing results in sensors being located in the center of an area, but the areas are not uniform over the surface of the manikin. With the non-uniform spacing laboratories have the option of area weighting their reported values. When reporting predicted second-degree, predicted third-degree and predicted total burn injury and the percentages as required in 13.5, laboratories shall state the basis on which the calculations are made.

6.2.2 *Thermal Energy Sensors*—Each sensor shall have the capacity to measure the incident heat flux over a range from 0.0 to 165 kW/m² (0.0 to 4.0 cal/s•cm²). This range permits the use of the sensors to set the exposure level by directly exposing the instrumented manikin to the controlled fire in a test without the test garment or protective clothing ensemble and also have the capability to measure the heat transfer to the manikin when covered with a test garment or protective clothing ensemble.

6.2.2.1 The sensors shall be constructed of a material with known thermal and physical characteristics that shall be used to indicate the time varying heat flux received by the sensors. The minimum response time for the sensors shall be ≤0.1 s.

6.2.2.2 The sensor surface shall have an absorptivity of at least 0.9. Coating the sensor with a thin layer of flat black high temperature paint with an absorptivity of at least 0.9⁶ has been found effective.

6.3 *Thermal Energy (Heat Flux) Calibration Sensor*—Use a traceable heat flux measuring device⁷ to calibrate the energy source used to calibrate the thermal energy (heat flux) sensors. Pure radiant, convective, or a combination of energy sources have been found effective for these calibrations. Understanding the energy source, thermal energy (heat flux) sensor interaction is critical to obtaining accurate calibrations.

6.3.1 The calibration determined in 10.2.1.3 for each thermal energy (heat flux) sensor shall be recorded and the most recent calibration results used to carry out the burn injury analysis.

6.3.2 *Discussion*—Refer to E511 for guidance if copper constantan circular foil heat flux transducers are used.

6.4 *Data Acquisition System*—A system shall be provided with the capability of acquiring and storing the results of the measurement from each sensor at least two times per second for the data acquisition period.

6.4.1 *Discussion*—The data acquisition rate of two readings per second from each sensor is the minimum necessary to obtain adequate data. Higher sampling rates are desirable during the flame exposure period. Laboratories sample up to ten samples per second per sensor during this period. The minimum rate of two samples per second per sensor is adequate after the flame exposure.

6.5 *Burn Assessment Program*—A computer software program shall be used that has the capability of receiving the output of the thermal energy sensors, calculating the time dependent surface heat flux, calculating the temperatures within the skin and subcutaneous layers (adipose) as a function of depth and time, and predicting second-degree or third-degree burn injury for each sensor utilizing a skin burn injury model. The total predicted burn injury and the percentage predicted burn injury shall be calculated using only the sensors having a calculated second-degree and third-degree burn injury. The calculation requirements of this program are identified in Section 12.

6.5.1 *Discussion*—The computer software program, shall, as a minimum, calculate the predicted skin burn injury at the epidermis/dermis interface and the dermis/subcutaneous (adipose) interface.

6.5.2 *Incident Heat Calculation*—The total thermal energy absorbed and average heat flux to the surface of the manikin

⁶ Krylon # 1618 BBQ and Stove; Krylon #1316 Sandable Primer; Krylon #1614 High Heat and Radiator paint have been found to be effective. See ASTM Study "Evaluation of Black Paint and Calorimeters used for Electric Arc Testing", ASTM contract #F18-103601, Kinectrics Report:8046-003-RC-0001-R00, August 22, 2000.

⁷ National Institute of Standards and Technology (NIST) or similar standards body.

TABLE 1 Measurements for Male Manikin

Measurement Location	Centimetres	Inches
Height	180.3 ± 1.3	71 ± 0.5
Chest circumference at largest value (chest girth)	102.9 ± 1.9	40.5 ± 0.75
Center of base of rear neck to wrist measured across shoulder and along outside of arm (cervicale to wrist length)	79.4 ± 2.5	31.25 ± 1.0
Top of shoulder to wrist along arm (arm length).	61 ± 2.5	24 ± 1.0
Arm circumference at largest diameter between shoulder and elbow (upper-arm girth)	30.5 ± 0.6	12 ± 0.25
Waist circumference at narrowest position (waist girth)	85 ± 1.3	33.5 ± 0.5
Crotch to heel along the inside of the leg (crotch height minus ankle height)	86.4 ± 2.5	34 ± 1.0
Hips circumference at the largest dimension (hip girth)	101.6 ± 1.9	40 ± 0.75
Base of center of rear neck to waist (center back waist length)	42.5 ± 1.9	16.75 ± 0.75
Waist to base of heel (waist height)	115.6 ± 5.0	45.5 ± 2.0
Thigh circumference at largest dimension between crotch and knee (thigh girth)	58.4 ± 1.3	23 ± 0.5

TABLE 2 Percentage Area of Male Manikin Form Represented by Sensors

Body Area	Percent
Head	7
Trunk	40
Arms	16
Thighs	22
Lower legs/Shanks	15
Hands/Feet	0
Total	100

shall be determined by exposing the unclothed manikin for four seconds unless the testing is to be done for shorter intervals. In that case the incident fire exposure total thermal energy absorbed and average heat flux to the surface of the manikin shall be determined for the actual duration. The total and average value of all sensors shall be determined taking into account the sensor calibrations and characteristics. The average heat flux value reported is the average of the averages for each of the sensors for the steady region of the exposure duration (see Fig. 2). The incident heat flux values calculated for each sensor at each time step shall be placed in a file for future use in estimating the temperature history within the skin and subcutaneous layers (adipose) for the burn injury calculation.

6.5.3 Burn Injury Calculation—The predicted time necessary to cause second-degree and third-degree burn injury for each sensor shall be calculated (see Section 12).

6.5.4 Burn Injury Assessment—The sum of the sensors that received sufficient heat to result in a predicted second-degree burn shall be the predicted second-degree burn assessment. The sum of the sensors that received sufficient heat to result in a predicted third-degree burn shall be the predicted third-degree burn assessment. The sum of all sensors registering a burn injury shall be the total predicted burn injury resulting from the exposure to the fire condition.

6.5.4.1 Discussion—The calculated results report the burn injury assessment as a percentage (%) based on the total number of sensors (entire manikin) and the total covered by the test specimen only (see 13.5). The hands and feet are not included in any burn injury assessment. For manikin systems that do not have a uniformly spaced sensor layout, the laboratory shall report whether or not the values are area weighted.

6.6 Exposure Chamber—A ventilated, fire-resistant enclosure with viewing windows and access door(s) shall be provided to contain the manikin and exposure apparatus.

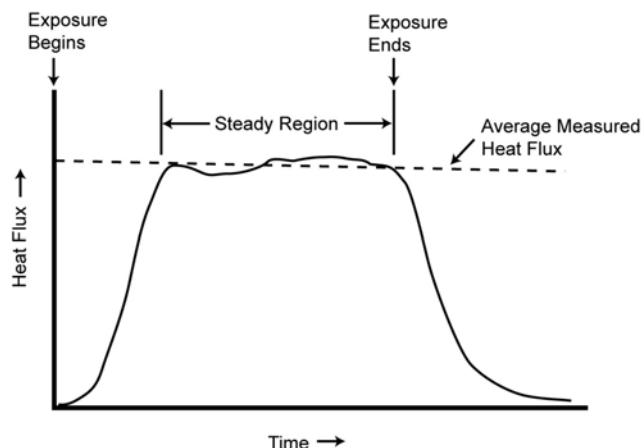


FIG. 2 Average Heat Flux Determination for a Nude Exposure

6.6.1 Exposure Chamber Size—The chamber size shall be sufficient to provide a uniform flame engulfment of the manikin and shall have sufficient space to allow safe movement around the manikin for dressing without accidentally jarring and displacing the burners. The minimum interior dimensions of the chamber shall be 2.1 by 2.1 by 2.4 m (7.0 by 7.0 by 8.0 ft). There is no maximum chamber size, but all chambers shall meet the requirements in 4.1, 10.1.3, and 10.1.4 in repeated exposures.

6.6.1.1 Discussion—There is no limitation on maximum size provided the operators are safely isolated from the chamber during and after the exposure when toxic gases are likely to be present.

6.6.2 Burner and Manikin Alignment—Apparatus and procedures for checking the alignment of the burners and manikin position prior to each test shall be available.

6.6.3 Chamber Temperature—The chamber temperature prior to a test shall be between 15°C (58°F) and 30°C (85°F).

6.6.4 Chamber Air Flow—The chamber shall be isolated from air movement other than the natural air flow required for the combustion process so that the pilot flames, if fitted, and the exposure flames are not affected before and during the test exposure. The isolation from air movement shall continue during the data acquisition period after the exposure flames are extinguished. A forced air exhaust system for rapid removal of combustion products after the data acquisition period shall be provided.

6.6.4.1 *Discussion*—The unaided air flow within the chamber shall be sufficient to permit the combustion process needed for the required heat flux during the exposure period and shall be controlled to provide a quiet atmosphere for the data acquisition period. Openings to the exterior of the test chamber shall be provided for the passive supply of adequate amounts of air for safe combustion of the fuel during the exposure. The forced air exhaust system for rapid removal of combustion products after the data acquisition period shall conform to NFPA 86 (1999), Section 5-4.1.2. Due to their nature the products of combustion from diffusion flames contain toxic materials such as unburned fuel, carbon monoxide and soot.

6.6.5 *Chamber Safety Devices*—The exposure chamber shall be equipped with sufficient safety devices, detectors and suppression systems to provide safe operation of the test apparatus. Examples of these safety devices, detectors and suppression systems include propane gas detectors, motion detectors, door closure detectors, hand held fire extinguishers and any other devices necessary to meet the requirements of local codes. A water deluge system and an interlocked “LEL/Exhaust” system have been found effective. LEL is the Lower Explosion Limit. For pure propane gas in air the value is 2.1 % by volume (1).⁸

6.6.5.1 Additional information on safety devices is available from NFPA 54 and NFPA 85 or equivalent local standards.

6.7 *Fuel and Delivery System*—The chamber shall be equipped with fuel supply, delivery, and burner systems to provide reproducible fire exposures.

6.7.1 *Fuel*—The propane fuel used in the system shall be from a Liquefied Petroleum (LP) Gas supply with sufficient purity and constancy to provide a uniform exposure.

6.7.1.1 *Discussion*—Fuels meeting the HD-5 specifications (See Specification D1835, CAN/CGSB 3.14 M88, or equivalent) have been found satisfactory. Liquefied Petroleum (LP) Gas is commonly referred to as propane fuel or propane gas. Propane gas are the words used in this standard to identify the LP Gas.

6.7.2 *Delivery System*—A system of piping, pressure regulators, valves, and pressure sensors including a double block and bleed burner management scheme (see NFPA 58) or similar system consistent with local codes shall be provided to safely deliver gaseous propane to the ignition system and exposure torches. This delivery system shall be sufficient to provide an average heat flux of at least 84 kW/m² (2.0 cal/s•cm²) for an exposure time of at least 5 s. Fuel delivery shall be controlled to provide known exposure duration within ±0.1 s of the set exposure time.

6.7.3 *Burner System*—The burner system shall consist of one ignition system for each exposure burner, and sufficient burners to provide the required range of heat fluxes with a flame distribution uniformity to meet the requirements in 10.1.3, 10.1.4, 10.2.2.1, and 10.2.2.2.

6.7.3.1 *Ignition System*—Each exposure burner shall be equipped with an ignition system positioned near the exit of the burner, but not in the direct path of the flames so as to interfere

with the exposure flame pattern. The ignition system shall be interlocked to the burner gas supply valves to prevent premature or erroneous opening of these valves. Any electrical-magnetic-field generated by the ignition system shall be small enough so as not to interfere with the quality of the data acquisition and recording process. Standing pilot flames have been found to perform satisfactorily.

6.7.3.2 *Exposure Burners*—Large, induced combustion air, industrial style propane burners are positioned around the manikin to produce a uniform laboratory simulation of a fire. These burners produce a large fuel rich reddish-yellow flame. If necessary, enlarge the burner gas jet, or remove it, to yield a fuel to air mixture for a long luminous reddish-yellow flame that engulfs the manikin. A minimum of eight burners shall be used and positioned to yield the exposure level and uniformity as described in 10.1.3, 10.1.4, 10.2.2.1, and 10.2.2.2. A satisfactory exposure has been achieved with eight burners, one positioned at each quadrant of the manikin at the knee level, and one positioned at each quadrant at the upper thigh level (see Fig. 1). Variations in exposure chamber size and air flow detail might require use of additional burners to achieve the desired flame distribution. Some laboratories have found it necessary to use twelve burners with two each on six stands positioned at approximately 60° intervals around the manikin to achieve the desired flame distribution.

6.8 *Image Recording System*—A system for recording a visual image of the manikin before, during, and after the flame exposure shall be provided. The front of the manikin shall be the primary record of the burn exposure, with a manikin rear record optional.

6.9 *Safety Check List*—A check list shall be included in the computer operating program to ensure that all safety features have been satisfied before the flame exposure can occur. This list shall include, but is not limited to, the following: confirm that the manikin has been properly dressed in the test specimen; confirm that no person is in the burn chamber; confirm that the chamber doors are closed; and all safety requirements are met. The procedural safety checks shall be documented.

6.10 *Garment Conditioning Area*—The area shall be maintained at 21 ± 2°C (70 ± 5°F) and 65 ± 5 % relative humidity. It shall be large enough to have good air circulation around the test specimens during conditioning.

6.10.1 *Discussion*—The permitted variation in the conditioning temperature and relative humidity is larger than other ASTM textile testing standards. This larger range was set to reflect present practice. Some manikin-fire laboratories are at isolated sites and do not have conditioning rooms that can meet the more stringent requirements.

6.11 *Computer Software Requirements*—In addition to monitoring and controlling the operation of the fire, data acquisition systems, and carrying out the skin burn injury calculations, the computer software shall be used to prepare some of the materials for the report, sensors calibrations etc. Appendix X2 is a list of recommended safety, control, data acquisition, calculation, report preparation and supporting programs.

⁸ The boldface numbers in parentheses refer to a list of references at the end of this standard.