MEETING LOG
DIRECTORATE FOR ENGINEERING SCIENCES

SUBJECT: Meeting of the ANSI Z21 Water Heater Subcommittee Flammable Vapor Working Group

PLACE: Holiday Inn Select, Toronto Airport, Toronto Canada

MEETING DATE: November 13-14, 1997

LOG ENTRY SOURCE: Donald W. Switzer DWS

ENTRY DATE: November 24, 1997

COMMISSION ATTENDEES:

Donald W. Switzer	ES

NON-COMMISSION ATTENDEES:

Daryl Hosler	Chairman, Southern California Gas Company
Craig Christenson	Mountain Fuel Supply Company
Wilbur Haag	A.O. Smith
Bob Hemphill	Gas Research Institute
Jay Katchka	Robertshaw Controls Company
Eric Lannes	Bradford White Corp.
James Ranfone	American Gas Association
Tim Shellenburger	American Water Heater Company
Drew Smith	State Industries
Frank Stanonik	Gas Appliance Manufacturers Association
Richard Topping	Arthur D. Little
Larry Westling	Nothhwest Natural Gas Company
Jack Langmead	Consultant
Julie Cairnes	International Approval Services
Karen Benedict	Arthur D. Little
Peter Pascatore	Arthur D. Little
Tom Dorfler	Arthur D. Little
John Paisley	GSW Water Heater Company
Jake Hall	Rheem Manufacturing Company

MEETING SUMMARY

The Flammable Vapor Working Group was formed to respond to a proposal to address the hazard of water heater ignition of flammable vapors. At this meeting, two proposed draft test methods to certify water heater resistance to flammable vapor ignition were presented. They are attached. There were a number of concerns about the adequacy of both methods. The working group found that the GAMA-proposed method of spilling gasoline needed more work to assure repeatability. The A.D. Little-

proposed method of mimicking gasoline with butane for a surrogate was found by the working group to need additional work to insure it properly models the interaction between the gasoline vapor cloud resulting from a spill and the water heater.

Staff was asked what action it would take if the working group recommended that no test method be included in the standard. Staff responded that it would likely recommend a method to the full subcommittee. Staff also explained that other options existed, including rulemaking.

The working group voted to send both proposed test methods to the subcommittee without a recommendation as to which was better, and directed the submitters begin testing to resolve the concerns with each method. The working group requested that the testing be completed, and results provided to the working group in time for a May, 1998, working group meeting. The working group also directed that the subcommittee meeting currently scheduled for July, 1998, to be moved up to May.

ITEM 1.
Flammable Vapors Working Group
Meeting, November 13-14, 1997

SUGGESTED REVISIONS TO THE VOLUME I WATER HEATER STANDARD TO REDUCE POSSIBLE IGNITION OF FLAMMABLE VAPORS BY VOLUME I WATER HEATERS

Subject
Review suggested revisions to the Volume I water heater standard intended to reduce possible ignition of flammable vapors by Volume I water heaters.

Work Performed regarding the test methodology since the July 25-26, 1996 meeting
At the July 25-26, 1996 meeting, the joint subcommittee was advised that the flammable vapors working group discussed its plan for utilizing the information in the report issued by the GRI TAG and the need for input from manufacturers concerning how information will be implemented in the standard. The working group was informed that (1) research is ongoing concerning potential designs to help address the reduction of ignition of flammable vapors, (2) much of that information is proprietary and therefore, cannot be shared with the working group at this time.

The working group agreed at the July 1996 meeting that additional information is necessary prior to being able to develop proposed standards coverage.

A copy of the attached suggested draft test method for Flammable Vapors Ignition Resistance applicable to residential gas storage water heaters (i.e., models having input ratings of 75,000 Btu/hr or less) was presented to the joint water heater subcommittee at the August 1997 meeting. This suggested draft test method was submitted by the Technical Committee of the GAMA Water Heater Division for consideration by the Z21/CGA joint water heater subcommittee. The suggested draft test method is based on a draft test method recommended by the Water Heater Industry Joint Research and Development Consortium.

It was noted that the working group needs to meet to discuss the proposed test method since the working group had originally proposed use of the test chamber as outlined in the report issued by the GRI TAG and the proposed test procedure, forwarded by GAMA, utilizes gasoline.

PROPOSED REVISION TO AMERICAN NATIONAL STANDARD FOR GAS WATER HEATER, VOLUME 1, STORAGE WATER HEATERS WITH INPUT RATING OF 75,000 BTU PER HOUR OR LESS

2.38 (ADDED) FLAMMABLE VAPORS IGNITION RESISTANCE

The design of a water heater shall be such that it shall not ignite flammable vapors in the room in which it is installed.

METHOD OF TEST

Test Setup

Install the water heater in a 6 ft. X 10 ft. X 8 ft. high room equipped with a suitable access door. The walls, ceiling and door of the room shall be constructed of fire resistant materials and the floor shall be made of metal. A diagram of the test room is shown in **FIGURE 1.** The test room shall have:

a. Means to control the temperature of the floor to 70 degrees F plus or minus 10 degrees F.

b. A combustion and ventilation air opening of 1 square inch per 1,000 BTUH of input located 12 inches from the ceiling in the area of the wall shown in **FIGURE** 1.

c. Means to spill a measured amount of gasoline onto a specified area of the floor, using the one gallon gasoline can shown in **FIGURE 2.**

d. Provisions to provide pressure relief of the test room as shown is **FIGURE** 1..

e. Means to move the mannequin shown in **FIGURE 3** back and forth over a 3 foot long track at a rate of 3 feet per second.

f. Instruments to measure the average floor temperature, ambient air temperature, water heater flue gas temperature, and the hydrocarbon concentration (measured as Butane) at the 4 points in the room, shown in **FIGURE 4**.

g. Means to observe the water heater under test from outside the room.

h. A suitable fire extinguishing system.

The water heater will be tested with the venting arrangements described in 2.25.5, as shown in **FIGURE 4,** except as follows. When a manufacturer's supplied terminal(s) for either the air intake, vent exhaust, or both is designed for installation so that all combustion air is derived from the outsideatmosphere, or all flue gases discharge to the outside atmosphere, or both, then the terminal(s) shall be installed in accordance with the manufacturer's installation instructions and terminate on the outside of the test chamber.

The tests shall be conducted only at normal inlet test pressure and input rating.

The water heater shall be tested with all access doors in their normal position.

If the lighting instructions call for the opening or removal of any door (s) to light the pilot, and if the main burner(s) will operate with those door(s) removed or opened, the test shall be repeated with removable door(s) removed, and sliding or hinged door(s) left in a fully open position unless self-closing.

The water heater shall be supplied with water at a temperature of 70 degrees F plus or minus 10 degrees F. The water heater shall be equipped with means to control the water flow through the water heater and discharge the water outside the test room. The tests shall be conducted with the water heater thermostat set at

the 120 F mark.

The tests shall be conducted with summer blend gasoline with a Reid Vapor Pressure of no more than 8 PSI and winter blend gasoline with a Reid Vapor Pressure not less than 13 PSI.

Winter Blend Test

Fill the water heater with water at a temperature of 70 degrees F plus or minus 10 degrees F, and initiate operation. Operate the water heater until gas supply to the main burner(s) is reduced to a minimum. Then, draw off water until the main burner(s) come ON. After the main burner(s) has been on for one (1) minute, winter blend gasoline shall be spilled from a full one gallon container with the opening near the floor, as shown in Figure 2, in the direction of the water heater. The gasoline container shall be at a distance of 20 inches from the water heater as shown in Figure 1, before being tipped over. Immediately, begin to record the hydrocarbon concentration in the room. If the water heater cycles off and the gas supply to the main burner(s) is reduced to a minimum, repeat the draw off cycle procedure until, either a) the water heater main burner(s) and pilot (if equipped) are inoperative, and flammable vapors no longer burn within the water heater, or b) the hydrocarbon concentrations at all four sensors shown in Figure 4 are below 50 per cent of the lower flammability limit (LFL) of 1.5 percent butane.

At one (1) minute after the spill, move the mannequin three (3) times back and forth over a three (3) foot path at a speed of 3 feet per second. Repeat the mannequin movement after one (1) minute elapses and at one (1) minute intervals until the end of the test.

Following this test, it shall be determined that either the water heater is not be capable of being returned to normal operation or, if the water heater is capable of normal operation, there is no damage other than that of a superficial nature to the water heater wiring and controls, and no safety control (function) has been rendered inoperative.

Summer Blend Test

If the water heater is capable of normal operation, use the water heater for this test. Components intended by the manufacturer to be field serviceable may be replaced between tests. If the water heater is not capable of being returned to normal operation, a new test sample shall be used for this test.

This test is the same as the winter blend test except:

a. Use summer blend gasoline

b. There shall be no movement of the mannequin, and

c. The direction of the gasoline spill shall be away from the water heater with the opening near the floor..

If the water heater is capable of being returned to normal operation at the completion of the winter blend and summer blend tests, it shall be tested and shall comply with section 2.4 Combustion.

RATIONALE:. *The following provides further information on the details of the test. The size of the test room reflects the fact that a room of this size was shown to represent the majority of cases where an incident occurred between flammable vapors and a gas-fired water heater according to a study sponsored by Gas Appliance Manufacturers Association (GAMA), "Flammable Vapors Hazards Ignition Study, Task 1 Report", GAMA, Arlington, VA. June 16, 1993.*

This test room is representative of real situations and is appropriate for this test. The GAMA Task 1 study also showed that the majority of incidents between flammable vapors and gas-fired water heaters occurred in the warm months, or in warm climates. Therefore, a floor temperature of 70 degrees F is specified. Further, the floor temperature is important to the rate of evaporation of a flammable liquid that is spilled onto the floor; therefore a +/- 10 degrees F control of the floor temperature is specified.

The test specifies one combustion air supply opening in the room located 12 inches from the ceiling and sized at 1 sq. in. per 1000 Btu's of input to the water heater. This is based on the indoor combustion and ventilation air supply requirements for confined spaces specified in the National Fuel Gas Code. Those requirements specify 2 openings, one at 12 inches from the ceiling and one at 12 inches from the floor sized at 1 sq. .in. per 1000 Btu's input. Only one high opening is specified, rather than the 2 specified by the NFGC, to prevent flammable vapors from spilling out of the test room through the low opening.

The GAMA Task I Report shows that gasoline vapors were the major cause of incidents between flammable vapors and gas-fired water heaters. Gasoline vapor profile studies conducted for the Gas Research Institute (GRI), by A. D. Little Inc., "Flammable Vapor Test Methodology Development for Gas-Fired Water Heaters", GRI Report 96-0102, April 1996, showed that the type of gasoline significantly influences the profiles. Summer blend gasoline generally has a Reid Vapor Pressure of 7-9 psi, while winter blend gasoline has a Reid Vapor Pressure of 13-15 psi. The study identified that the vapor profiles reached the lower explosive limit of gasoline vapors at different times at different heights and that they exhibited both mixed and stratified profiles, (see test scenarios #2 and #7 in the GRI April 1996 report). Also, as outlined in that report, a can containing one gallon of either winter or summer blend gasoline, is spilled either toward or away from the water heater. Therefore, 2 test conditions are specified: a Winter Blend Test and a Summer Blend Test to represent the extremes of vapor profiles exposed to the gas-fired water heater. Further, to insure different gasolines are used in the tests, an upper limit of 8 psi Reid Vapor Pressure is specified for the summer blend gasoline; and a lower limit of 13 psi is specified for the winter blend gasoline.

The construction material of the room, the specification for a pressure relief means a fire extinguishing systems are to provide for operator safety.

The use of a child sized mannequin is based on the fact that the GRI April 1996 report showed no statistical difference in the gasoline profile between the use

of a child-sized and adult-sized mannequin. Further the GAMA June 16, 1993 report showed most of the incidents between flammable vapors and gas-fired water heaters involved children. Therefore, the test specifies using a child-sized mannequin moving at walking speed, 3 ft./sec. to mix the gasoline vapors for the Winter Blend Test, as shown in FIGURE 3.

All tests are to be conducted using the spillage test stack installed on the water heater, except that special venting systems should be installed in accordance with the manufacturers installation instructions.

Since any unit must comply with all provisions of this standard, there is no need to conduct these tests on other than normal test pressure and input rating.

Since access doors which must be opened or removed during the normal lighting process may not be closed or replaced and therefore, these tests should be conducted with those doors opened or removed.

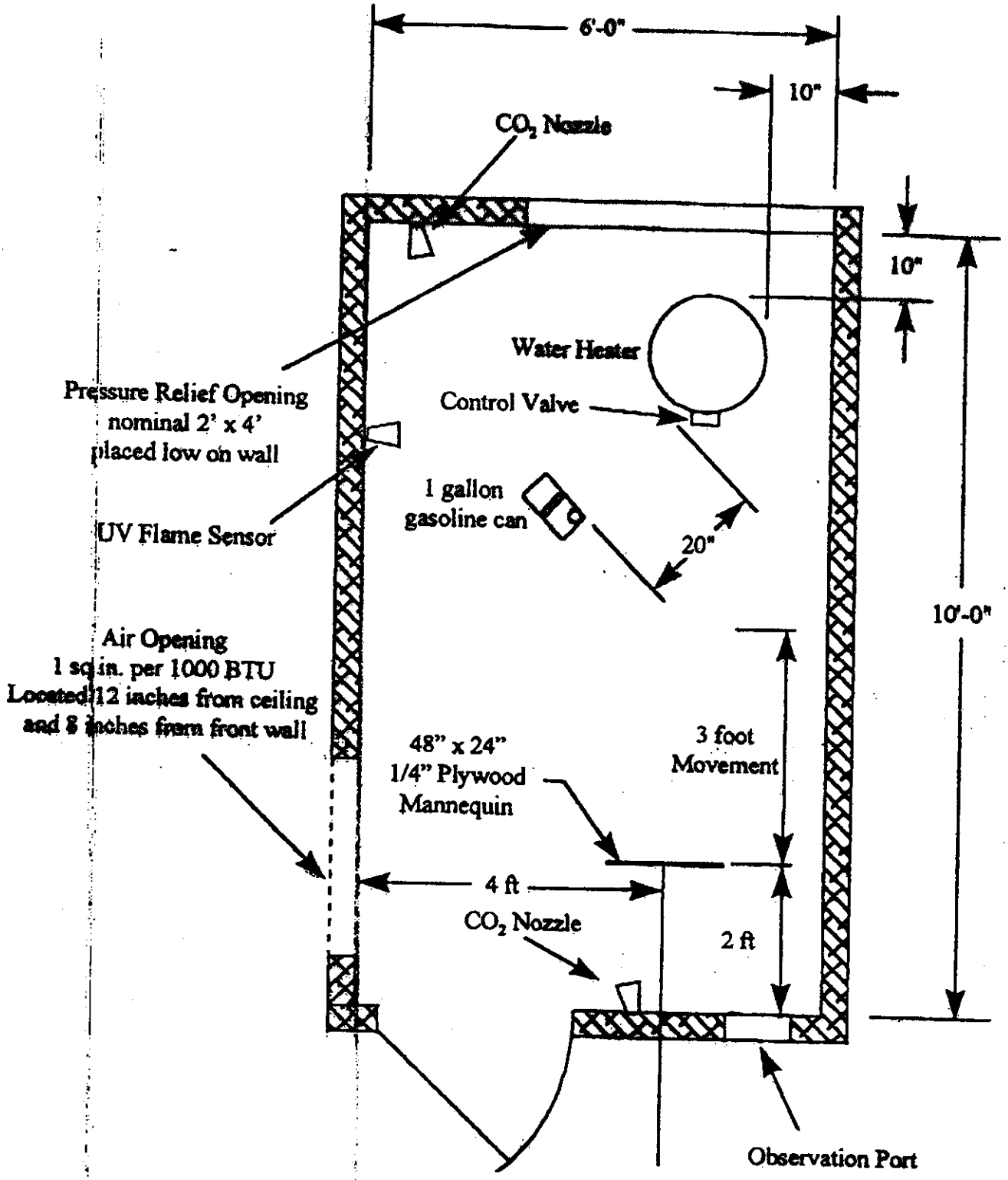
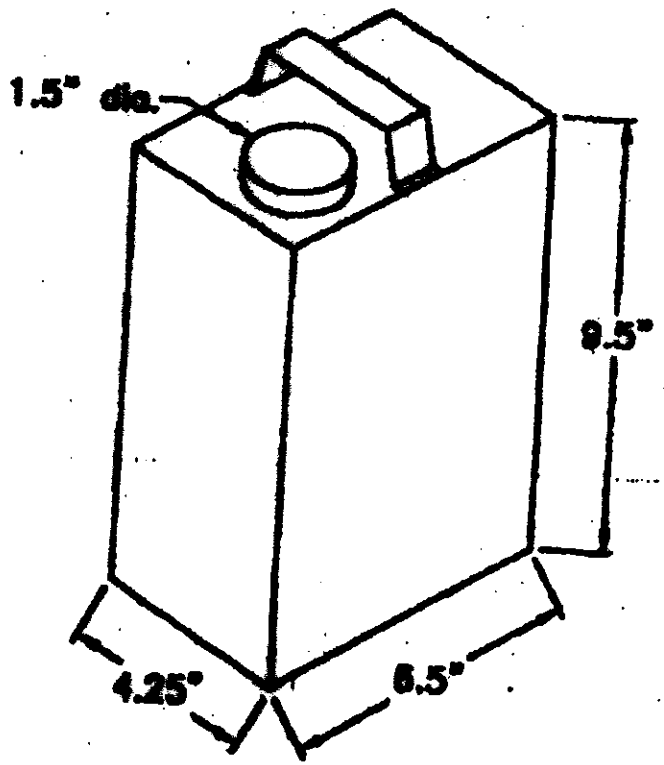


Figure 1 -Flammable Vapors Test Room

Figure 2 - Standard One Gallon Gasoline Can



Tipped Position with Opening at Floor

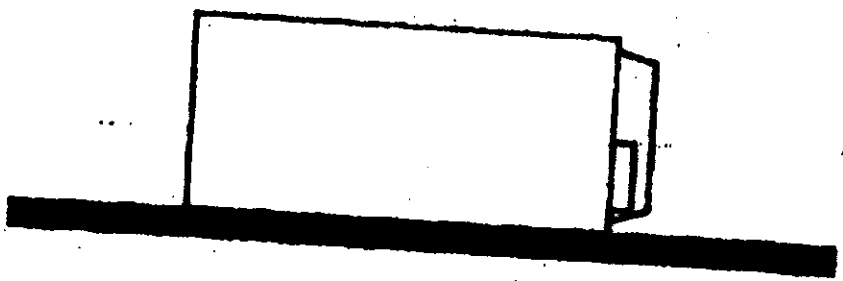
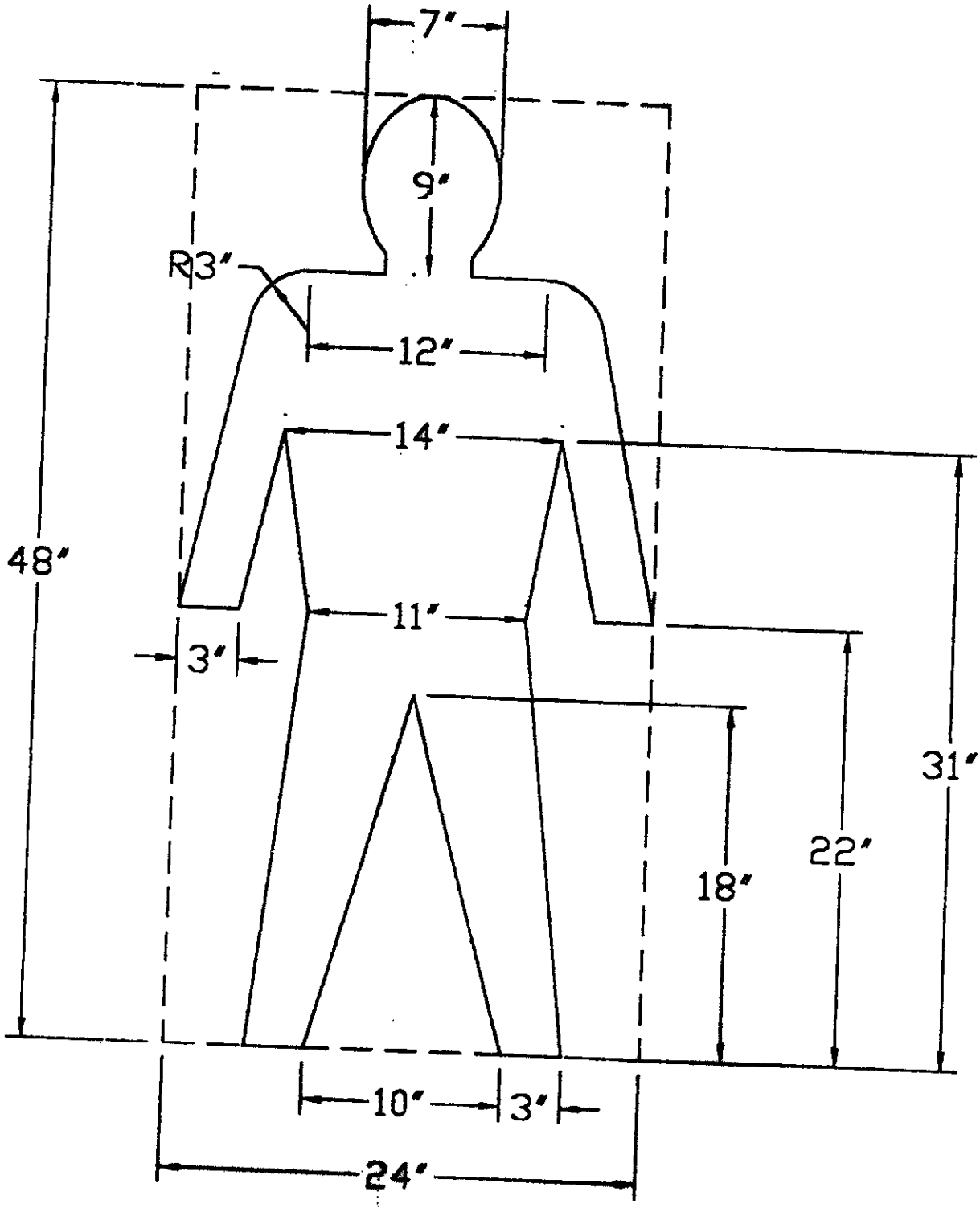
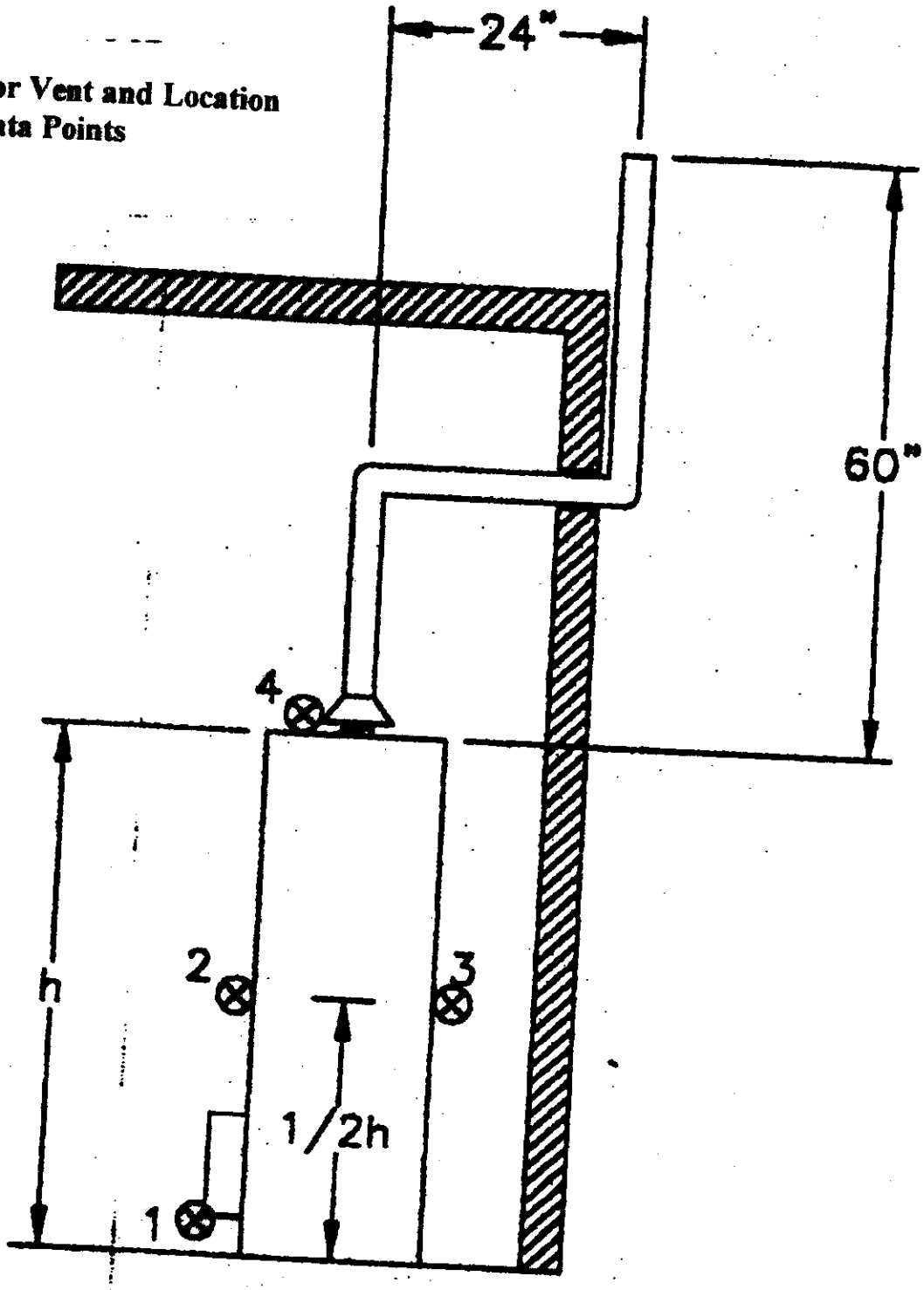


Figure 3 - Mannequin



* or material of equivalent rigidity

Figure 4 - Setup For Vent and Location of Hydrocarbon Data Points



Supplement to ITEM 1.
Flammable Vapors Working Group
Meeting, November 13-14, 1997

SUGGESTED REVISION TO THE DRAFT TEST METHOD FOR EVALUATION OF FLAMMABLE VAPORS IGNITION RESISTANCE

Subject
Review additional suggested revision to the draft test method for evaluation of flammable vapors ignition resistance.

Background
Under letter dated November 6, 1997, Mr. Frank Stanonik, Gas Appliance Manufacturers Association, submitted an additional suggestion from the residential water heater manufacturer members of GAMA regarding the draft test method attached to Item 1. The following is an excerpt from Mr. Stanonik's letter:

> "The residential water heater manufacturer members of GAMA have an additional suggestion regarding the draft test method which we submitted. Specifically, it is recommended that the test method be modified to include an evaluation of the water heater in a 'pilot-only' operating mode for a two-hour period while exposed to gasoline vapors. "

ITEM 2.
Flammable Vapors Working Group
Meeting, November 13-14, 1997

SUGGESTED ALTERNATIVE TEST METHOD FOR EVALUATION OF FLAMMABLE VAPORS IGNITION RESISTANCE

Subject
Review suggested alternative test method for evaluation of flammable vapors ignition resistance.

Background
Under letter dated November 3, 1997, Mr. Peter Pescatore, Arthur D. Little, submitted the attached proposed alternative test method for evaluation of flammable vapors ignition resistance, for consideration by the flammable vapors working group.

PROPOSED REVISION TO AMERICAN NATIONAL STANDARD FOR GAS WATER HEATER, VOLUME 1, STORAGE WATER HEATERS WITH INPUT RATING OF 75,000 BTU PER HOUR OR LESS

2.38 (ADDED) FLAMMABLE VAPORS IGNITION RESISTANCE

A water heater shall be designed such that it will not ignite flammable vapors outside the appliance.

METHOD OF TEST

These tests shall be conducted in a test facility as described in the Gas Research Institute document entitled "Design and Construction of a Flammable Vapors Ignition Testing Facility for Gas-Fired Water Heaters" (Reference 1) and shown schematically in Figure 1. The water heater shall be centered in the test enclosure which consists of three main components:

1. A 1/8" thick stainless steel cylindrical pressure containment chamber, which surrounds the water heater, with one half movable and the other half fixed, clamped together as shown in Reference 1,
2. A flue gas vent for attachment to the water heater, and
3. Blowout panels designed to burst at 1/2 psi overpressure for pressure relief in the enclosure.

The enclosure shall be equipped with:

a) Means to control the temperature of the enclosure to within 75°F +/- 10°F (23.9°C+/-6°C):
b) Two 8"x12" combustion and ventilation air openings as described in Reference 1, with means to block said openings in the event of an ignition:
c) Means of supplying a measured amount of butane/air mixture around the water heater through a distribution ring, as shown in Figure 2, located 3" off of the floor of the enclosure:
d) Provisions to provide pressure relief with blowout panels designed to burst at 1/2 psi overpressure:
e) Instruments to measure the average ambient air and water heater flue gas temperatures;
f) A hydrocarbon measurement and sequencing system, described in Reference 1, which measures butane concentrations at 8 locations around the water heater, as shown in Figure 3:
g) Additional continuously monitoring butane detectors located at the combustion and ventilation air openings and outside the enclosure:
h) Windows for viewing and means to remotely observe the water heater under test from at least two angles, as shown in Figure 1;
i) A suitable fire extinguishing system, such as that described in Reference 1;
j) Means of measuring the voltage output from the pilot thermocouple:
k) Means of measuring gas pressure to the main burner.
l) A computer based data acquisition and control system as described in Reference 1.

Water heater flue gas venting arrangements shall be as generally described in Figure 1 except as noted below:

When a manufacturer's supplied vent terminal for either the air intake, vent exhaust, or both is designed for installation so that all the combustion air is derived directly from the outside atmosphere, or all flue gases discharge to the outside atmosphere, or both, then the terminal shall be isolated from the vapor concentration and the vent system shall be installed in accordance with the manufacturer's instructions. In order to accomodate these installation requirements, one blow out panel of the enclosure may be modified as shown in Reference 1.

The test shall be conducted with all access doors in their normal position. If the lighting instructions call for the opening or removal of a door(s) to light the pilot, and if the main burner(s) will operate with the door(s) removed or opened, the tests shall be repeated with the removable door(s) removed, and any sliding or hinged door(s) left in a fully open position, unless self-closing.

A flow control device shall be installed on the outlet connection of the water heater and shall be adjusted or constructed so as to maintain a flow rate of 3 gallons per minute (11.36 l/min).

Each test shall be conducted in:

a) Pilot Only Mode (Only for units equipped with a standing pilot) and
b) Burner cycling mode.

Components intended by the manufacturer to be field serviceable by the manufacturer may be replaced between tests.

After completion of Test Conditions A and B, the appliance shall comply with Section 2.4, Combustion, provided the following apply:

a) The appliance is capable of normal operation, or
b) Specific steps have been followed to place the appliance back in operation per the manufacturer's operating instructions.

Test Condition A
Simulation of a Winter Blend Gasoline Spill with Movement (Mixed Vapor Environment)

The water heater shall be filled with water at 70°F +/-10°F (21.1°C+/-6°C). The thermostat shall be adjusted to 120°F +/-5°F (48.9°C+/-3°C) and the appliance operated at normal inlet pressure until the gas supply to the main burner(s) is reduced to a minimum.

For Pilot Only Mode (Only for units equipped with standing pilot):

Disable the main burner by switching the thermostat to the "PILOT" position. Introduce a butane/air mixture according to the schedule in Table 1.

For Burner Cycling Mode:

Water shall be immediately drawn at the rate of 3 gallons per minute (11.36 l/min) until the thermostat functions. Immediately introduce a butane/air mixture according to the schedule in Table 1. If the gas supply to the main burner(s) is reduced to a minimum, repeat the draw cycle until the main burner ignites, or 50% of the tank volume has been drawn off. ***For units equipped with an Intermittent Ignition System,*** the butane/air mixture shall be introduced simultaneously with the water draw.

Throughout the test, record the water heater's flue gas temperature, the hydrocarbon concentrations in the enclosure, water heater operation and thermocouple output voltage. Continue the test until:

Table 1
Butane/Air Distribution Schedule
Winter Blend Gasoline with Movement Simulation

Time (mins.)	Air (cfm)	% Butane
0	4.5	10
0.7	3	7
5	6	5
10	5.5	5
30	5	4.5
35	5	4
40	5	3.5
45	5	3
50	5	2.5
55	5	2
60	End	End

For units with a standing pilot

1. All flames are extinguished, or
2. The hydrocarbon concentrations at all levels in the enclosure are below 0.9% or
3. Butane concentrations over 0.9% are detected at any of the continuously monitoring butane detectors located at the combustion and ventilation air openings and outside the enclosure, or
4. Butane outside of the water heater has been ignited.

For unit with Intermittent Ignition Systems

1. All flames are extinguished and 60 minutes has been reached, or
2. The hydrocarbon concentrations at all levels in the enclosure are below 0.9% or
3. Butane concentrations over 0.9% are detected at any of the continuously monitoring butane detectors located at the combustion and ventilation air openings and outside the enclosure, or
4. Butane outside of the water heater has been ignited.

At the conclusion of the test, a visual inspection shall be conducted to determine:

a) If any ignition of the vapors outside of the unit has occured through review of the test video(s).

b) If any component of the water heater shows signs of damage, the water heater shall not be capable of being returned to normal operation.

c) If the water heater is capable of normal operation there shall be no signs of damage other than that of a superficial nature to the water heater wiring and controls and no safety control (Function) has been rendered inoperative.

Test Condition B
Simulation of a Summer Blend Gasoline Spill with Movement (Stratified Vapor Environment)

The water heater shall be filled with water at 70°F +/-10°F (21.1°C+/-6°C). The thermostat shall be adjusted to 120°F +/-5°F (48.9°C+/-3°C) and the appliance operated at normal inlet pressure until the gas supply to the main burner(s) is reduced to a minimum.

For Pilot Only Mode (Only for units equipped with standing pilot):

Disable the main burner by switching the thermostat to the "PILOT" position. Introduce a butane/air mixture according to the schedule in Table 2.

For Burner Cycling Mode:

Water shall be immediately drawn at the rate of 3 gallons per minute (11.36 l/min) until the thermostat functions. Immediately introduce a butane/air mixture according to the schedule in Table 2. If the gas supply to the main burner(s) is reduced to a minimum, repeat the draw cycle until the main burner ignites, or 50% of the tank volume has been drawn off. *For units equipped with an Intermittent Ignition System,* the butane/air mixture shall be introduced simultaneously with the water draw.

Throughout the test, record the water heater's flue gas temperature, the hydrocarbon concentrations in the enclosure, water heater operation and thermocouple output voltage. Continue the test until:

For units with a standing pilot
1. All flames are extinguished, or
2. The hydrocarbon concentrations at all levels in the enclosure are below 0.9%
3. Butane concentrations over 0.9% are detected at any of the continuously monitoring butane detectors located at the combustion and ventilation air openings and outside the enclosure

For unit with Intermittent Ignition Systems
1. All flames are extinguished and 60 minutes has been reached, or
2. The hydrocarbon concentrations at all levels in the enclosure are below 0.9%, or
3. Butane concentrations over 0.9% are detected at any of the continuously monitoring butane detectors located at the combustion and ventilation air openings and outside the enclosure, or
4. Butane outside of the water heater has been ignited.

Table 2
Butane/Air Distribution Schedule
Summer Blend Gasoline without Movement Simulation

Time (mins.)	Air (cfm)	% Butane
0	1	13
5	1	12
10	.75	11
15	.75	10
20	.85	9
25	.9	8
30	.95	8
35	.95	7
38	.85	6
41	.8	6
44	.75	5
47	.75	4
50	.75	3
53	.7	2
56	.65	1.5
60	End	End

At the conclusion of the test, a visual inspection shall be conducted to determine:

a) If any ignition of the vapors outside of the unit has occured through review of the test video(s).
b) If any component of the water heater shows signs of damage, the water heater shall not be capable of being returned to normal operation.
c) If the water heater is capable of normal operation there shall be no signs of damage other than that of a superficial nature to the water heater wiring and controls and no safety control (Function) has been rendered inoperative.

Appendix to Proposed ANSI Standard

Butane Justification

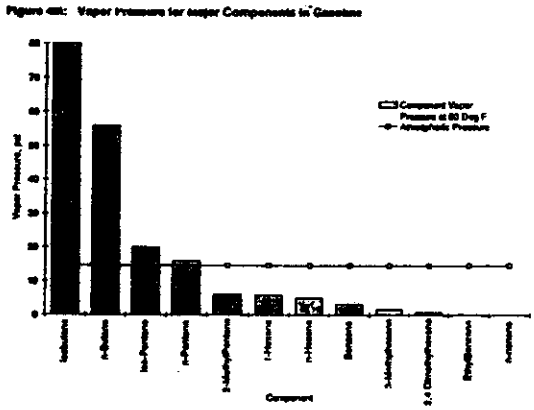
The identification of an appropriate test gas for a standard is a challenging one. Gasoline is a complex fuel that is difficult to characterize. Summer, winter and reformulated blends can differ significantly in constituent concentrations. Gasoline composition can also vary according to location and by season. Therefore, the identification of an appropriate test gas to represent gasoline needs to be carefully based on analysis of the gasoline vapor evolution from a spill and the ignition properties of the ensuing vapor cloud.

Key properties in such an analysis include: vapor pressure, concentration in a gasoline vapor cloud, flammability limits, laminar burning velocity, minimum ignition energy, quenching distance and auto ignition temperature. It is important that the test gas have properties similar to gasoline as a whole, and its individual components. Compared to a multi-component blend, such as gasoline, the advantages of a one-component test gas include that it can be:

- consistent in composition
- well defined;
- easily delivered;
- metered and detected;
- readily acquired;
- stored and safely used.

Butane was chosen as the test gas to represent flammable vapors around a water heater in this test standard. The choice of butane was based on 1) the high concentration of butane in a typical gasoline vapor cloud, 2) the similarity of butane's critical ignition/combustion properties to gasoline vapor and individual gasoline components; and 3) the convenience and safety of butane for appliance testing given that it is a gas at room temperature, has been well characterized with regard to its combustion characteristics, and is readily available and can be safely handled.

Because of their higher vapor pressures, the lighter hydrocarbons, such as butane and pentane, will be major constituents in a vapor cloud that evolves from a gasoline spill. Heavier hydrocarbons will eventually evolve from gasoline spills, but will be in lower concentrations and will evolve from the liquid long after the lighter fractions. The figure below illustrates the vapor pressures of the various constituents in gasoline.



The properties of butane associated with vapor ignition (flammability limits, laminar burning velocity, minimum ignition energy, quenching distance and autoignition temperature) are very similar to those of the range of hydrocarbons found in gasoline.

The design of a safe and reliable flammable vapor ignition test facility is highly dependent on the ability to predict the behavior of a combustion wave once the vapor has been ignited. From flame speed predictions and flame propagation models, it is possible to predict a pressure rise associated with vapor combustion and design a water heater test facility accordingly. It is therefore critical that the properties of the test gas be consistent and uniform. It is particularly useful to use a vapor that does not condense or require heating during delivery or metering to ensure that the desired volume of gas is delivered to the test enclosure. Because of these factors, butane is particularly well suited to be a test gas for flammable vapor water heater testing.

Test Facility Considerations

Once butane was defined as the most appropriate representative vapor to simulate gasoline vapor after a spill, a safe and repeatable flammable vapor ignition test facility was designed to deliver this vapor around a water heater in a safe, repeatable and controlled manner. Since pressure rises occur as a consequence of vapor combustion, it is important that such a facility be designed to handle the range of vapor combustion conditions which can occur with no risk to the facility or its operators. In addition it is of great importance that there be a high degree of repeatability in the vapor delivery around a water heater so that all units can be assured of being tested under the same external conditions, regardless of facility location, time of year, type of water heater design being tested, etc. Butane vapor/air mixtures can be delivered around a water heater in a tightly controlled and repeatable manner. Computer controlled mass flow controllers are used to deliver the mixtures safely and repeatably. Overall system operation allows for ease of use of such a testing method with minimal input from the operator.

Repeatability

Maintaining repeatability and consistent flow conditions is very important so that all water heaters are tested under the same conditions. The use of butane negates the impact which would likely result from testing gasoline with different formulations, brands, and additives that are prevalent across North America.

Figure 1: Schematic Representation of Flammable Vapor Ignitor Test Facility

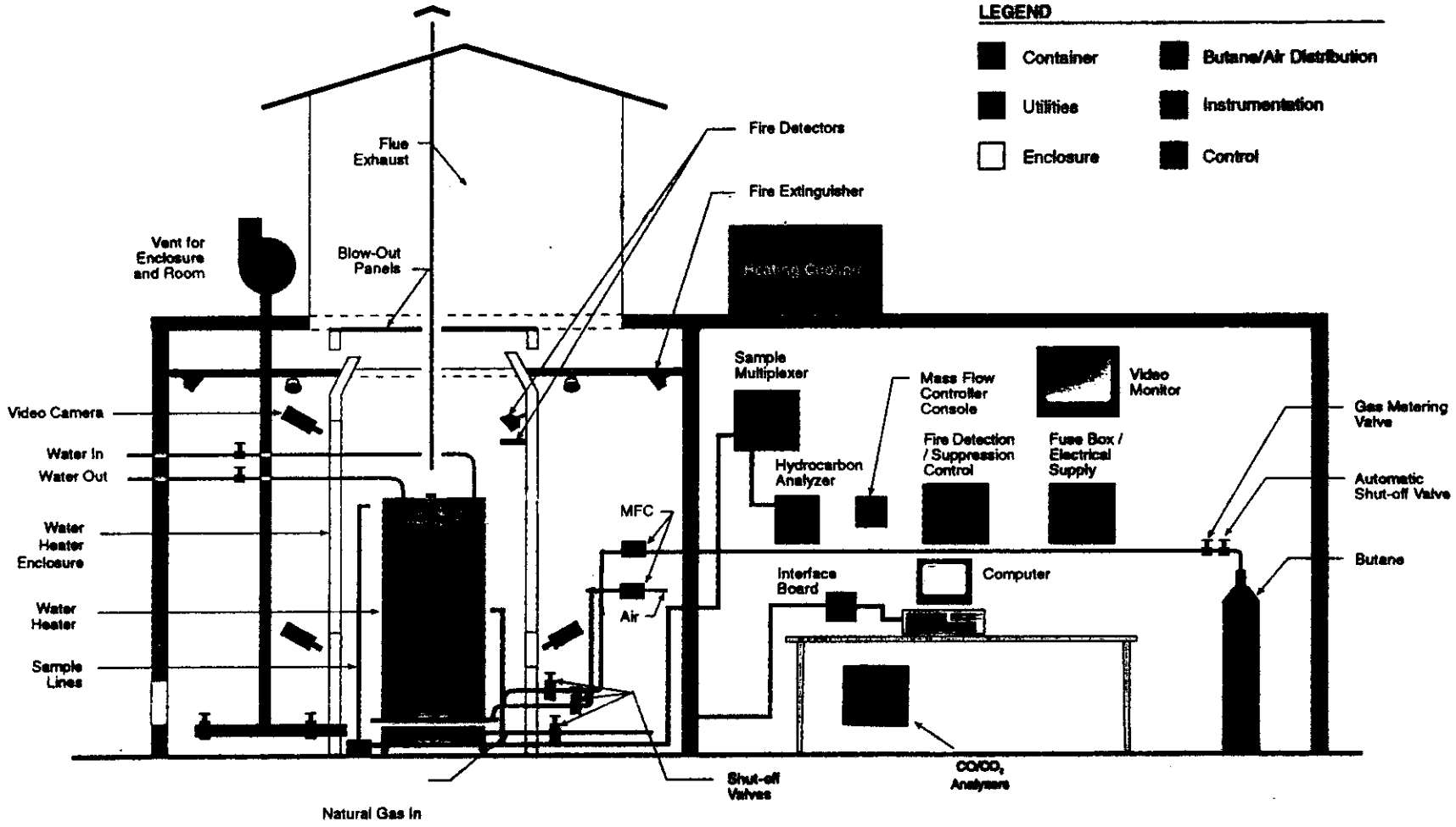
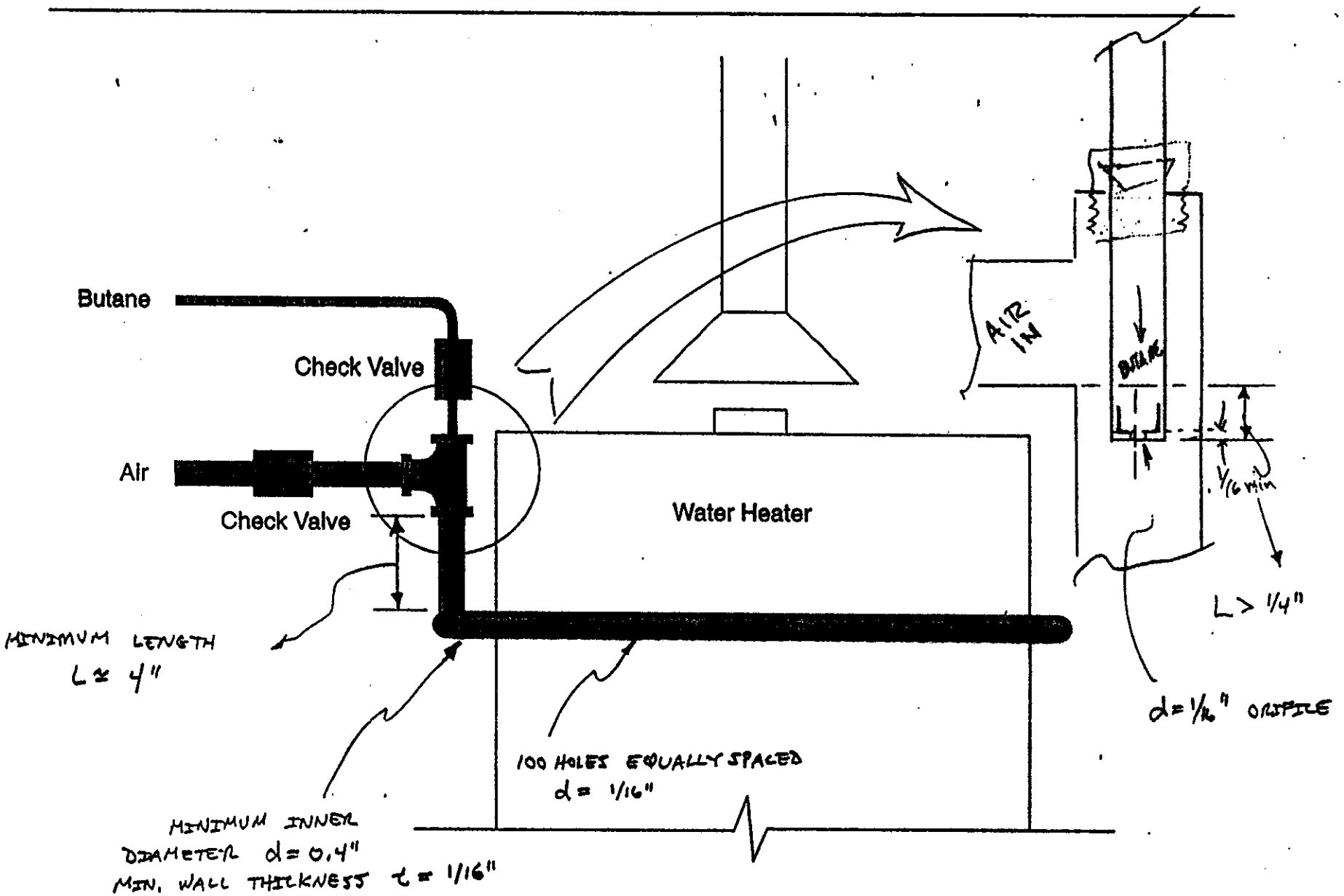


Figure 1: System Schematic

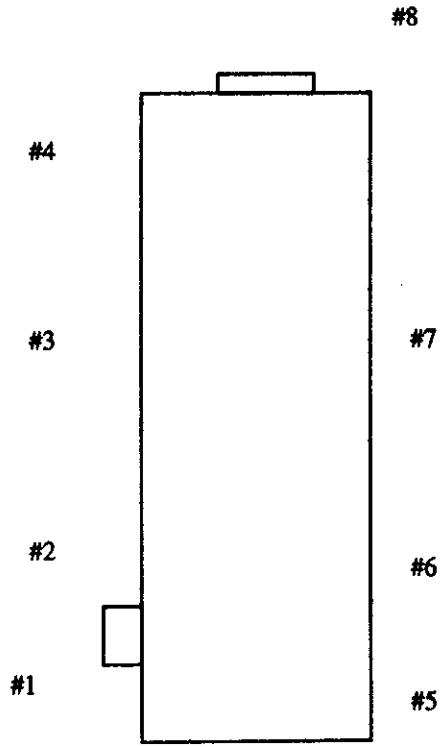


Sketch: 47465-SK10
Butane/Air Distribution

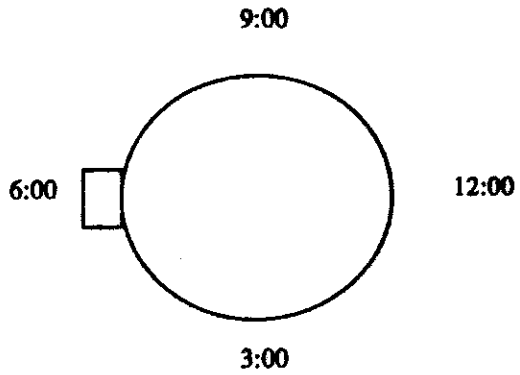
Figure 3
Hydrocarbon Sample Locations

Sample Locations

#1 6:00, 3" height
#2 6:00, 18" height
#3 6:00, 36" height
#4 6:00, 54" height
#5 12:00, 3" height
#6 12:00, 18" height
#7 12:00, 36" height
#8 6" above heater



Radial Position



November 2, 1997