MEETING LOG
DIRECTORATE FOR ENGINEERING SCIENCES

SUBJECT: ANSI Z21/Canadian Gas Association Joint Subcommittee on Standard for Gas Water Heaters

PLACE: International Approval Services, Cleveland, OH

MEETING DATE: July 27-28, 1998

LOG ENTRY SOURCE: Donald W. Switzer DWS

ENTRY DATE: August 31, 1998

COMMISSION ATTENDEES:
Donald W. Switzer ES

NON-COMMISSION ATTENDEES:
See Attached Attendee Sheet

MEETING SUMMARY

The Joint subcommittee consists of representatives of the gas-fired water heaters industry, utilities, regulatory agencies, and other interested parties. It's purpose is to provide technical guidance on water heater issues to the full American National Standards Institute (ANSI) Z21 Committee on Performance and Installation of Gas-Burning Appliances and Related Equipment. Many agenda Items were discussed at this meeting. This meeting log is limited to those items directly pertaining to on-going Commission projects.

Item 4 REPORT FROM WORKING GROUP ADDRESSING SUGGESTED REVISIONS TO REDUCE POSSIBLE IGNITION OF FLAMMABLE VAPORS BY VOLUME I WATER HEATERS

The working group chairman proposed that the subcommittee adopt for public review and comment two test methods (and prefatory statements for each) to certify the performance of flammable vapor ignition resistant water heaters (attached). The subcommittee adopted both methods for review and comment. The subcommittee will meet in February 1999, to review the comments and choose one method to forward to the ANSI Z21 Committee at its April 15, 1999, meeting. CPSC staff has reviewed both methods, and finds that water heaters meeting the requirements of either method will offer significant protection against water heater ignition of flammable vapors in the home.

Attachments (6)

ATTENDANCE RECORD

Z21/(Interim CSA) JOINT WATER HEATER SUBCOMMITTEE

DAY 2 - WEDNESDAY, JULY 29, 1998

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ATTACHMENT (1)

Z21/(Interim CSA) JOINT WATER HEATER SUBCOMMITTEE

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ATTENDANCE RECORD

Z21/(Interim CSA) JOINT WATER HEATER SUBCOMMITTEE
DAY 1 - TUESDAY, JULY 28, 1998

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Z21/(Interim CSA) JOINT WATER HEATER SUBCOMMITTEE

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Z21/(Interim CSA) JOINT WATER HEATER SUBCOMMITTEE

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38.	FRANK A. STANONIK	X	GAMA	703 525-9565	703 525 0718	
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A DIVISION OF CSA

INTERNATIONAL APPROVAL SERVICES

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August 28, 1998

TO: U.S./CANADIAN GAS COMPANIES RECEIVING TEXTS FOR REVIEW AND COMMENT: ORGANIZATIONS AND INDIVIDUALS REQUESTING ALL REVIEW AND COMMENT TEXTS; THE CANADIAN INTERPROVINCIAL GAS ADVISORY COUNCIL AND OTHER CANADIAN GOVERNMENT AGENCIES AND INTERESTED INDIVIDUALS; ACCREDITED STANDARDS COMMITTEE Z21/83; (INTERIM CSA) STANDARDS STEERING COMMITTEE ON GAS APPLIANCES AND RELATED GAS CONTROLS; Z21 SUBCOMMITTEE CHAIRMEN; AND Z21/(INTERIM CSA) JOINT SUBCOMMITTEE ON STANDARDS FOR GAS-FIRED WATER HEATERS

TO MANUFACTURERS OF VOLUME I GAS WATER HEATERS VOLUME III GAS WATER HEATERS GAS-FIRED POOL HEATERS

PROPOSED STANDARDS REVISIONS
FOR REVIEW AND COMMENT

PLEASE RETAIN THE ATTACHED DOCUMENT(S) FOR FUTURE REFERENCE

Action Requested
Review and comment on the enclosed proposed revisions, dated August 1998, and labeled "For Review and Comment Only," to:

American National Standard/CSA Standard for Gas Water Heaters, Volume 1, Storage Water Heaters With Input Ratings of 75,000 Btu Per Hour or Less, Z21.10.1•CSA 4.1;

The Z21.10.1•CSA 4.1 standard provides coverage for automatic storage water heaters with input ratings of 75,000 Btu per hour or less for use with natural, manufactured and mixed gases, liquefied petroleum gases, and LP gas-air mixtures.

Due Date – November 30, 1998

It would be appreciated if your response to this "Review and Comment" document could be made available by the above date so a compilation of all replies may be prepared for consideration by the joint subcommittee.

Comment Procedure
Please use a copy of the attached form when submitting an endorsement, comments or criticisms. Complete a separate form for each comment or criticism, and remember to include a rationale statement for any suggested revisions to the proposed text. Please limit your comments to only the specific proposals contained in the enclosed review and comment texts.

8501 E. Pleasant Valley Road, Cleveland, Ohio U.S.A. 44131-5575

Telephone: (216) 524-4990 • Fax: (216) 642-3463 • website: www.iasapprovals.org

ATTACHMENT (2)

All comments or criticisms will be considered by the joint water heater subcommittee at its next meeting.

Return Comments To

Julie Ann Cairns
Standards Engineer
International Approval Services
8501 East Pleasant Valley Road
Cleveland, Ohio 44131

Background

Reports on flammable vapor ignition incidents involving gas water heaters, led to the formation of a specific ad hoc working group activity under the water heater subcommittee. Independent research efforts also began involving AGA Research, Arthur D. Little (ADL), Gas Research Institute (GRI) and the Water Heater Industry Joint Research and Development Consortium.

Two different test protocols emerged, one involving a gasoline spill method and the other a combination butane-air vapor profile and gasoline spill method. The intent of the joint subcommittee is to consider adding a method of test in the Volume I water heater standard to evaluate a water heater designs ability to resist the ignition of flammable vapors outside the confines of the water heater.

While the intent of the joint subcommittee is to consider adding a method of test in the Volume I water heater standard to evaluate a water heater designs ability to resist the ignition of flammable vapors outside the confines of the water heater, they have not decided which test method to use. As a result, the Joint Z21/(Interim CSA) Subcommittee on Standards for Gas-Fired Water Heaters is distributing both proposed test methods for review and comment to obtain additional input to assist in its decision.

To assist in your consideration of this information, prefatory statements are attached which provide background for each of the proposed test methods [Attachment 1-Prefatory Statement for the GAMA Test Method; Attachment 3- Prefatory Statement for the GRI Test Method].

RATIONALE

"A test methodology is being added to the standard for Volume I water heaters to evaluate the units ability to resist the ignition of flammable vapors outside the confines of the unit."

Appeals

Also enclosed for your information is a notice which sets forth standards procedures and the mechanism for filing an appeal.

Enc.

C: F. Stanonik
D. Switzer
Shelley VanSickle

FAX 216/642-3463

FORM FOR COMMENTS ON PROPOSED STANDARDS REVISIONS

DISTRIBUTED: August 28, 1998

Date: _____ **Name**: _____ **Tel.No.**: _____

Address: _____

Company: _____

American National Standard/CSA Standard for

Gas Water Heaters, Volume I, Storage Water Heaters with Input

Standard Title: *Ratings of 75,000 Btu per Hour or Less* **Standard No.**: *21.10.1•CSA 4.1*

1. Endorse GAMA Test Method proposed revisions: YES _____ NO _____

   Endorse GRI Test Method proposed revisions: YES _____ NO _____

2. **Comment:** YES _____ NO _____

GAMA Test Method

a. Comment (include proposed wording or identification of wording to be deleted):

b. Statement of Problem and Rationale for Comment:

GRI Test Method

a. Comment (include proposed wording or identification of wording to be deleted):

b. Statement of Problem and Rationale for Comment:

_____
Signature

_____
Print Name

Mail to: Julie A. Cairns
IAS U.S.
8501 East Pleasant Valley Road
Cleveland, Ohio 44131

Notice

Accredited Standards Committee Z21/83 is responsible for the development of standards for gas-burning appliances and accessories. Proposed Z21 standards and standards revisions are initially distributed for review and comment and, following consideration of the comments received, are then acted on by the Z21/83 Committee for submittal to the American National Standards Institute (ANSI). Proposed standards and standards revisions submitted to ANSI undergo a 60-day public review period which is announced as a "Call for Comment" in ANSI's Standard Action, published biweekly. Following the public review period, the ANSI Board of Standards Review (BSR) reviews the comments and the responses of the Secretariat and acts on approval of the proposed Z21 standard.

Any concerned party may appeal any action or inaction of the Z21/83 Committee and the BSR. Appeals on such matters prior to submittal of a proposed standard to ANSI for approval should be directed in writing to the Administrative Secretariat of Accredited Standards Committee Z21/83, 8501 East Pleasant Valley Road, Cleveland, Ohio 44131, and the Secretariat will advise the appealing party as to the appeal procedure. Appeals on such matters after submittal of a proposed standard to ANSI for approval should be directed to the Chairman of the BSR, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, and ANSI will advise the appealing party as to the appeal procedure.

Those interested in reviewing and/or commenting on proposed standards during the ANSI public review period should obtain copies of the ANSI Standards Action from ANSI at the above address.

Prefatory Statement for the GAMA Test Method

NOTE: The following material was submitted by theAGAResearch, A Division of Energy International, and adopted by the Z21/(Interim CSA) joint water heater subcommittee for distribution for review and comment at its July 28, 1998 meeting. The information expressed in this Attachment does not reflect any opinion of International Approval Services or the American Gas Association.

1. Objective

The objective of this report is to present the background, development and rationale for a test using gasoline to determine the resistance of gas-fired water heaters to ignite flammable vapors which are outside the appliance. This has been done by reviewing studies sponsored by the Gas Appliance Manufacturers Association (GAMA) and Gas Research Institute (GRI) that were aimed at identifying issues related to flammable vapors incidents. The report also compares and contrasts two test methods that are both currently being considered.

2. Background

The proposed gasoline-based tests to determine the resistance of a water heater to ignite flammable vapors both grew out of two related projects which were funded by the GRI and GAMA. The original test room at AGAResearch (AGAR) was built to support Task 2 of a GAMA project[1] conducted by A. D. Little (ADL). It was later used in support of a GRI project that was intended to develop a test method that uses butane as a surrogate for a flammable liquid spill[2]. The gasoline test method and test room has been improved continuously since then under funding from the Water Heater Consortium (WHC). The development of these test methods is a model of cooperative funding between GRI and the water heater industry.

The Gas Appliance Manufacturers Association (GAMA) began this overall research effort due to documented field problems involving property damage and injury to consumers. GAMA members then undertook a proactive program to improve consumer's awareness of the hazards associated with the misuse of gasoline with the consent of the US Consumer Products Safety Commission (CPSC). CPSC continues to monitor the development of a test to verify the resistance of water heaters to ignite flammable vapors outside the appliance, as well as the development of new water heater conceptual designs that are expected to pass it.

The first organized review of flammable vapors incidents involving gas-fired water heaters was sponsored by GAMA and conducted by ADL[3]. The overall goal of this effort was to develop a comprehensive document detailing the extent of the hazard and the effectiveness of mitigating measures. In performing this task, the following data resources were reviewed:

- 142 detailed incident reports from several sources (CPSC, NFPA & NEISS),
- National and state fire incident databases,
- 26 interviews with persons knowledgeable about incidents and
- Published reports on the subject.

ATTACHMENT (3)

2.1 Typical Scenaris Identified

As a result of analyzing the incidents in a population of 53 million water heaters using the data bases shown above, there appear to be 7 typical scenarios where flammable vapors incidents with water heaters occur:

- 1 bathroom scenario,
- 2 utility room scenarios,
- 3 garage and basement scenarios and
- 1 garage scenario.

These scenarios occur in rooms ranging in size from small bathrooms up to larger rooms such as a garage. The casualty rate in small bathrooms was more than twice the average for all other gas-fired water heater flammable vapor ignition incidents.

The utility room scenarios are the second smallest room in which incidents were reported. The 2 utility room scenarios were characterized by:

- A 10 ft x 10 ft x 8 ft room,
- 1 gallon of gasoline for Scenario 1, spill outside room,
- 1-5 gallons of gasoline for Scenario 2, spill inside room,
- Movement was involved in Scenario 2 and
- Gas-fired water heater located in corner

In the detailed description of one actual Scenario 1 incident, a person using gasoline to remove stains from trousers performed the cleaning operation outdoors near an open door to the utility room. The day was windy and the person thought that would disperse the vapors. As the person lifted the trousers from the soak pot, a flame from the gas-fired water heater located behind a closed door ignited the gasoline flammable vapors. This incident highlights how air motion can amplify the danger from the flammable vapors.

Three garage and basement scenarios were characterized by:

- A 20 ft x 10 ft x 8 ft room,
- 1 quart - 5 gallons of gasoline,
- Activity or movement in the direct vicinity of the gas-fired water heater and
- Water heater located in corner.

One additional garage scenario was characterized by the following:

- A 20 ft x 10 ft x 8 ft room,
- Slow leakage of gasoline from a fuel tank,
- No activity or movement and
- Water heater in corner.

The incidents in the garage and basement scenarios typically involve use of gasoline as cleaner, accidental spills and leaking storage containers.

2.2 Conclusions

The GAMA Task 1 work identified the following factors as important in incidents involving ignition of flammable vapors by gas-fired water heaters:

- Gasoline is the major cause of incidents;
- Room size and spill size affect the time to ignition and severity; and
- Motion in the room has a strong effect on the mixing of the vapors with the air.

It can be further concluded that the incidents occur in circumstances that include a wide range of unpredictable external variables that come together at the same time. To compound the problem, water heaters will operate on different cycles depending on their design and the owner's usage patterns. So, the water heater's propensity to draw in and ignite vapors varies in time in an unpredictable way as well. Overall, the final flammable vapor test method for gas-fired water heaters will need to be capable of incorporating as many of these factors as possible.

3. Initial Gasoline Test Room Studies

3.1 Gasoline and Lower Flammability Limit (LFL)

For a vapor mixture to be flammable it must reach a composition (mixture of fuel and oxygen) that can ignite and sustain combustion. This range of flammable composition of vapors and air is bounded by a lower and upper concentration of the vapor in air. The Lower Flammability Limit (LFL) is the lowest concentration of vapor that will support a flame. Below this level the mixture is too lean. The Higher Flammability Limit (HFL) is the maximum concentration of vapor that can support a flame, above which level the mixture is too rich.

Gasoline is a mixture of hydrocarbon and other compounds. The component with the highest vapor pressure is butane. Therefore, it is likely that the initial vapor cloud over a gasoline spill will be rich in butane. The LFL of butane is about 1.8% and the HFL about 8.4%. From a description of incidents, it seems that the LFL is the point at which most incidents occur. This is the level that is first achieved following a spill. However, it is also possible that ignition could be avoided somehow immediately after the spill. In this case, the concentration could possibly rise above the HFL. Should this occur, there is also a possibility of ignition as the concentration drops and becomes flammable again. It is also conceivable that the vapor concentration could remain within the flammable region for some period of time. In this case, ignition could occur at any time, until the concentration leaves the flammable region.

The time it takes to reach LFL after a spill is partially determined by the gasoline's volatility. Other factors include the size of the spill and room, temperature, air change rate and room air motion. Volatility refers to how quickly the liquid will evaporate, creating the

flammable vapors*. One measure of the volatility is the Reid Vapor Pressure (RVP). A higher value for the RVP indicates that evaporation will occur faster. The composition of gasoline varies by brand, time and location but there are two generic gasolines that represent the extremes of volatility:

- "Summer blend" gasoline with a Reid Vapor Pressure of about 9 psi and
- "Winter blend" gasoline with a Reid Vapor Pressure of about 12-15 psi.

The winter blend gasoline is essentially, summer blend gas that has had butane added to it to increase the volatility. This presents practical problems for developing a test method using a consistent blend of gasoline. It is well understood that the volatility of the winter blend makes it very difficult to store while preserving it's RVP† since the butane is likely to be lost over time.

3.2 Large and Small Room Tests

Under the auspices of GAMA, 37 gasoline spill tests were conducted in the gasoline test facility, in the presence of operating gas-fired water heaters:

- 21 tests in a 10' x 20' x 8' room,
- 10 tests in a 6' x 10' x 8' room and
- 6 tests in an 8' x 8' x 8' room.

Results of these tests are presented in the GAMA Task 2 Report.

3.3 Conclusions

Task 2 of the GAMA study helped to understand the relative importance of the following factors that influence the potential ignition of flammable vapors by gas-fired water heaters:

- Spill surface,
- Floor and room temperature,
- Room size,
- Flammable vapor liquid composition and
- Ventilation rate.

The room experiments resulted in several conclusions including:

- A gasoline spill near a gas-fired water heater is likely to result in an ignition of the flammable vapors;
- Installation of a water heater on an 18" stand may delay but cannot guarantee elimination of the ignition of flammable vapors and

* The reader is reminded that ***liquid*** gasoline does not burn. It must be in the form of a gas to mix with oxygen and be flammable.

† Recently, a gasoline refinery was located that will provide consistent gasoline blends on a custom basis throughout the year.

- Rags soaked in gasoline can present ignition sources in small rooms.

In addition there were several general observations that provide an insight to these experiments.

- Air motion is an important accelerator of ignition. Without forced convection in the room, the vapors will diffuse slowly away from the spill and be diluted by the room's ventilation. Therefore, without an induced air movement, a false sense of security can result.

- While elevation of the water heater may delay ignition of the vapors, the ignition may release more force than for floor mounted water heaters. This is due to the larger volume of flammable vapors which are then present at the time of ignition.

- Room size, spill size and the ventilation rate have an important combined effect on the vapor profile over time

- Room temperature is not as important as room size, motion and size of the spill.

4. Gasoline Test Room Construction

4.1 History

The current flammable vapor test room at AGAR evolved over several years. The room was originally constructed to support the GAMA Task 2 work of ADL as described above. The structure had two rooms that could be used to perform tests in different volumes. The structure was wood frame with drywall construction and was housed under a plastic film structure. The larger part of the facility was abandoned and sealed off as the smaller room was settled on as the preferred test condition.

During the summer of 1997, construction began on a new, improved and automated structure reflecting the experience gained in the old room. This new room is sheltered under an improved plastic film structure and has proven to be much more reliable.

4.2 Description of Room

Figure 2 shows the floor plan for the test room. The room is:

- Constructed with metal studs covered with sheet metal,
- Foundation is a concrete pad embedded with hydronic heating coils,
- Floor is a single piece stainless steel,
- Pressure relief opening is covered with plastic or foil with perforations to minimize pressure buildup within the chamber,
- Water heater is vented through the back wall. The vent pipe is terminated within the outer plastic structure underneath an 8 inch diameter duct connected to the outside of the

exterior structure. This duct acts to isolate the water heater vent from variable outdoor conditions such as temperature, rain, or wind and

- Mannequin is attached to a pneumatic cylinder with a three foot stroke length. Cylinder movement is manually controlled from the control room.

The following data is taken during a test:

- Temperature:
  1. Test chamber ambient,
  2. Water heater flue before the draft hood,
  3. Water within the heater at a level equal to the location of the T-P Valve
  4. Test chamber floor,
  5. Ambient at the combustion air inlet to the test room.

- Pressure:
  1. Differential between the test room and the exterior structure,
  2. Differential between the water heater vent and the exterior structure.

- Hydrocarbon Concentration (measured as butane) Sample Points:
  1. At the combustion air opening,
  2. At half the height of the water heater on the front,
  3. At half the height of the water heater on the back,
  4. On the top of the water heater near the draft hood.

- Miscellaneous:
  1. Relative humidity in the exterior structure at the combustion air inlet to the test room,
  2. Pilot millivoltage

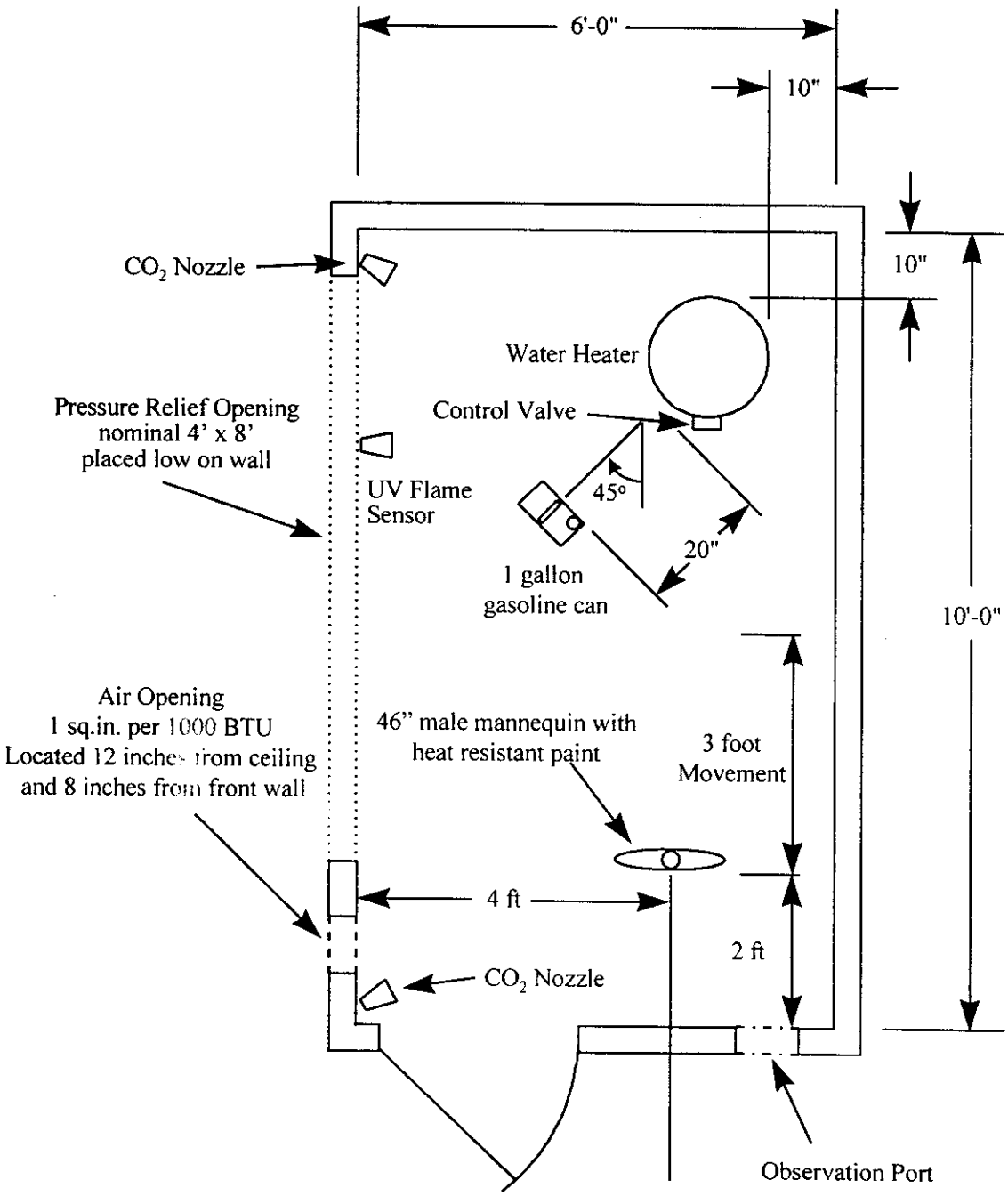


Figure 2 – Diagram of the Current Gasoline Test Room
[Housed Within Exterior Structure (Not Shown) To
Control Surrounding Ambient Conditions]

4.3 Test Results

The new test facility provides a stable platform for performing a variety of tests with gasoline. The results obtained thus far are dependent on the specific water heater - as it should be. In

particular, very different vapor profiles have been observed as different gas water heaters react to the spill. Unfortunately, the test can damage the water heater being tested.

Tests of WHC prototypes in the new room, as it was being developed, show that the facility has been improved. Similar water heaters produce similar results. The tests are also instructive in showing how much the water heater's size or operation can change the resulting vapor profile. The following discussion highlights results obtained in the new room from December 1997 through January 1998. In the interest of protecting the confidentiality of the manufacturers, the specific design differences in each test will not be discussed. But, they are all different and the reader should not expect the results to be exactly the same.

Figure 3 shows the vapor profile results for one test of Prototype 34. The test presented is for summer blend gasoline, without movement. The burner was on at the start of the test.

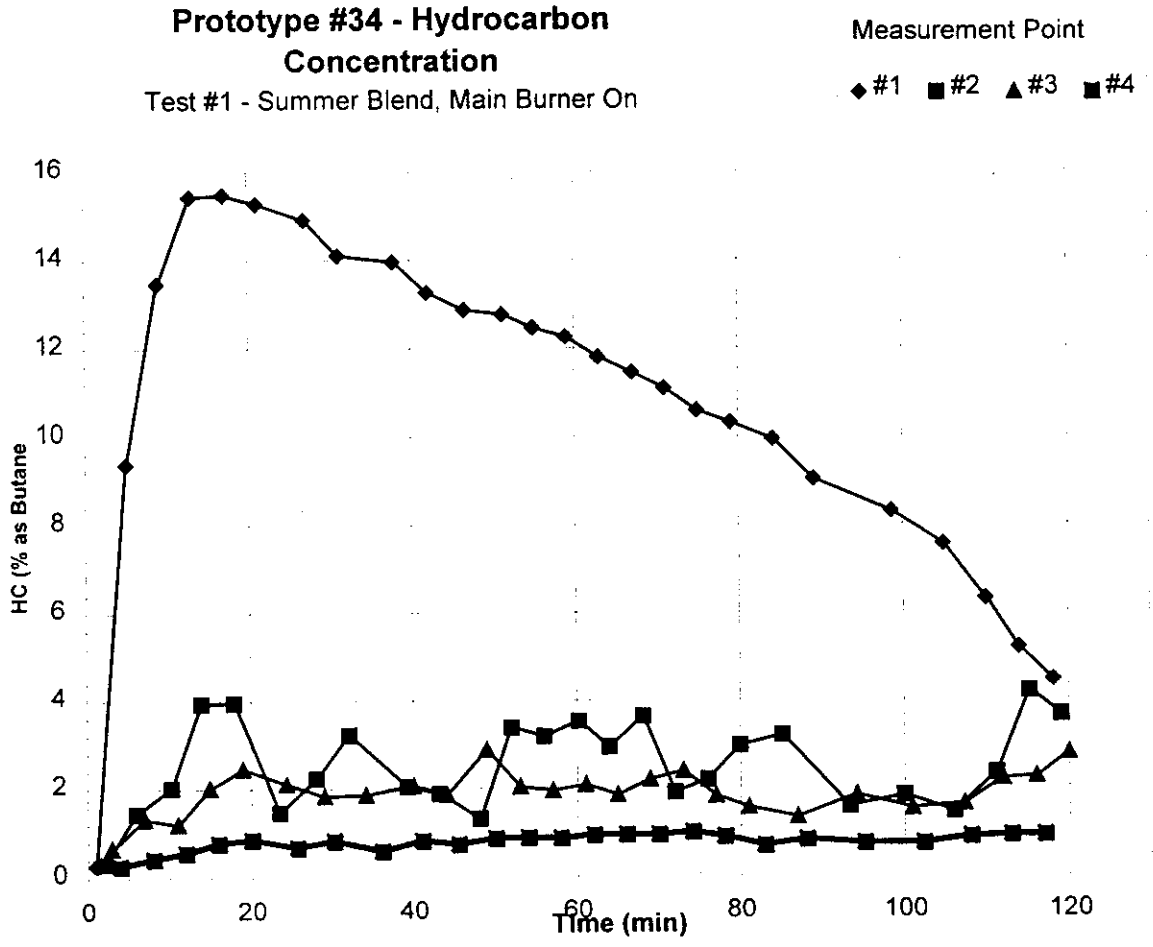


Figure 3

In Figure 3, the four traces are hydrocarbon concentrations at different elevations in the room. The hydrocarbon concentrations are measured as a butane equivalent. The sampling system used

read each measurement point once every 3 to 5 minutes[‡]. The long sampling runs, in use at the time of these tests, also introduce a lag time between what is happening in the test room and when the measurement is recorded. The most important measurement point is #1, which is 3 inches above the floor and is closest to where the vapors are being pulled into the heater. Measurement points 2 to 4 are progressively higher in the room, as described in Section 4.2. Note that, a large difference in concentration exists for an extended period between point 1 and the rest of the room. This is characteristic of a test with no movement. The floor concentration rises immediately and then gradually decreases as the heater consumes the vapors.

Figure 4 presents the same data from a repeated test of the same heater. Comparing Figures 3 and 4, we see a good correspondence between the vapor profiles. And, in the end, the water heater passed the test both times.

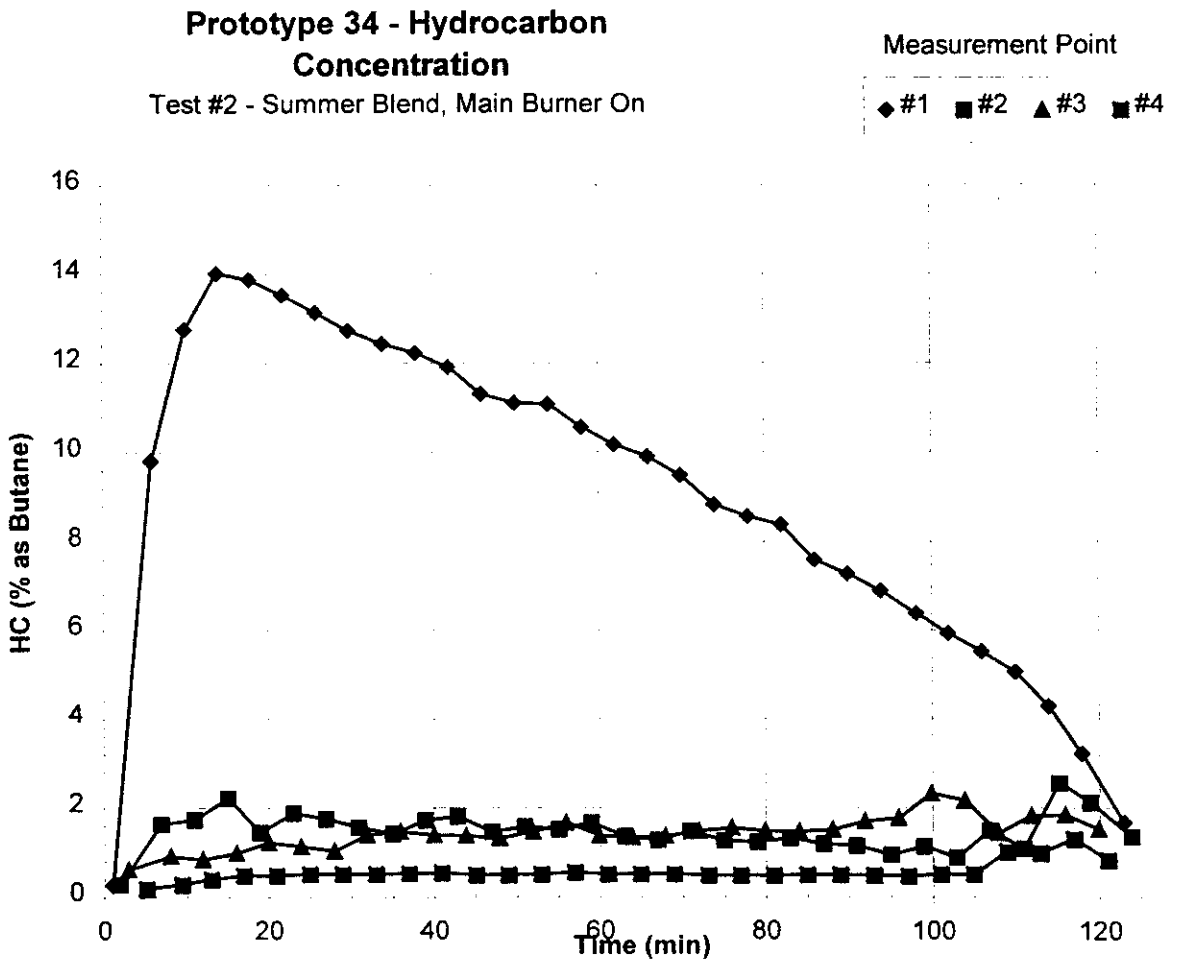


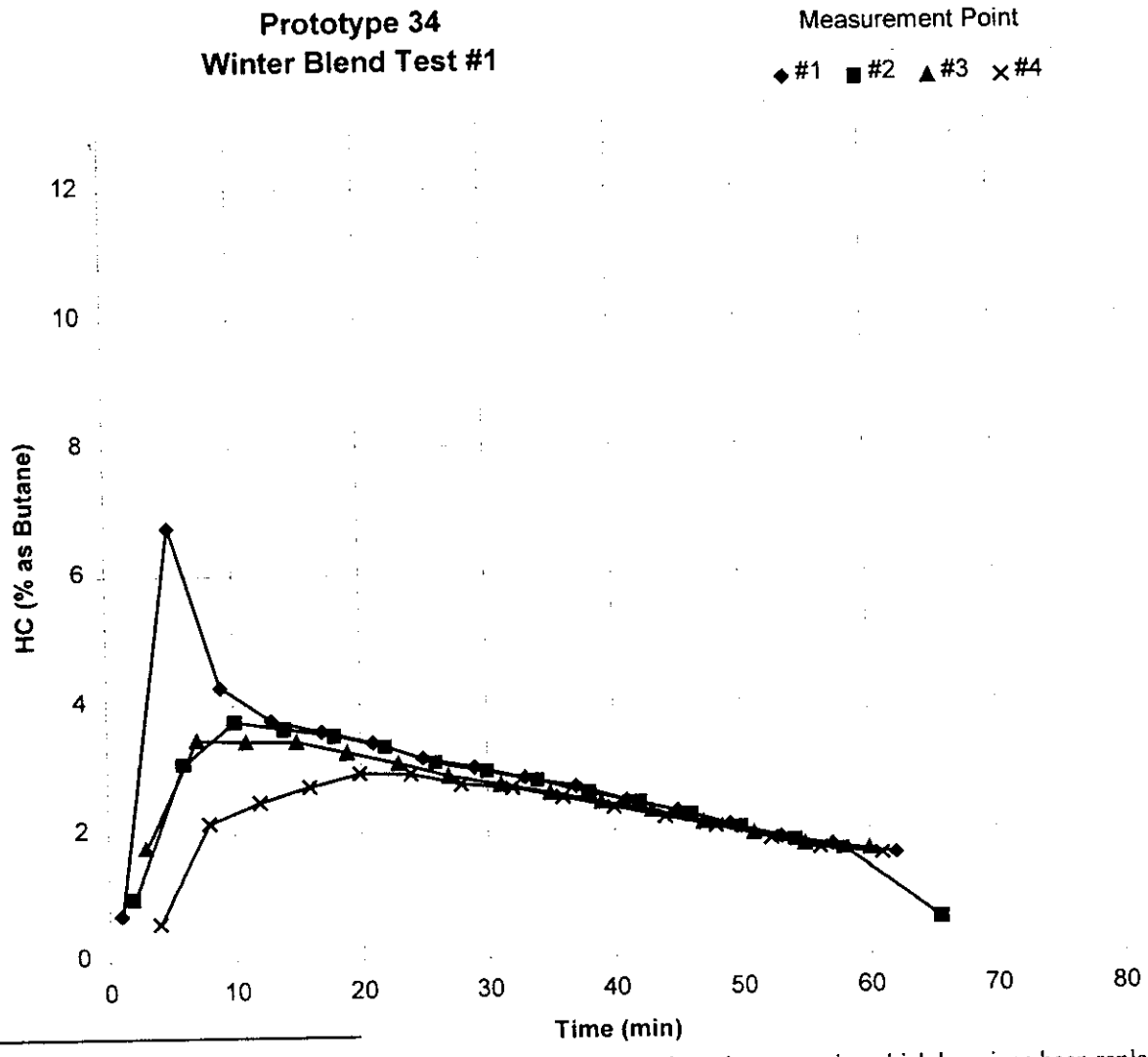
Figure 4

[‡] New hydrocarbon analyzers which allow simultaneous measurements have now been installed and were used in test runs presented in Figures 7 and 8.

Figures 5 and 6 present continued tests of the same water heater. In this case, the two tests use winter blend gasoline, with room air motion caused by the flat mannequin.[+] Both tests illustrate the different vapor profile caused by room air motion. In these tests, the vapor concentration rises quickly near floor level, represented by point 1. Note that the difference between the concentration near the floor and higher in the room diminishes more quickly compared to a test with no room air motion.

In these two tests, the vapor profiles are qualitatively quite similar. The difference in the absolute concentration is probably the result of the way the gasoline splashes at the start of the test. Despite the differences, the gasoline vapor at the level where the vapors can enter the heater was in the flammable range and the water heater passed the test both times.

It is certainly possible to design a standard way of spilling the gasoline. However, it is believed that spilling the gasoline by tipping over the container increases the realism of the test because of



[+] Early winter blend gasoline tests used a flat wooden silhouette shaped mannequin, which has since been replaced by a department store mannequin.

the splashing it creates.

Figure 5

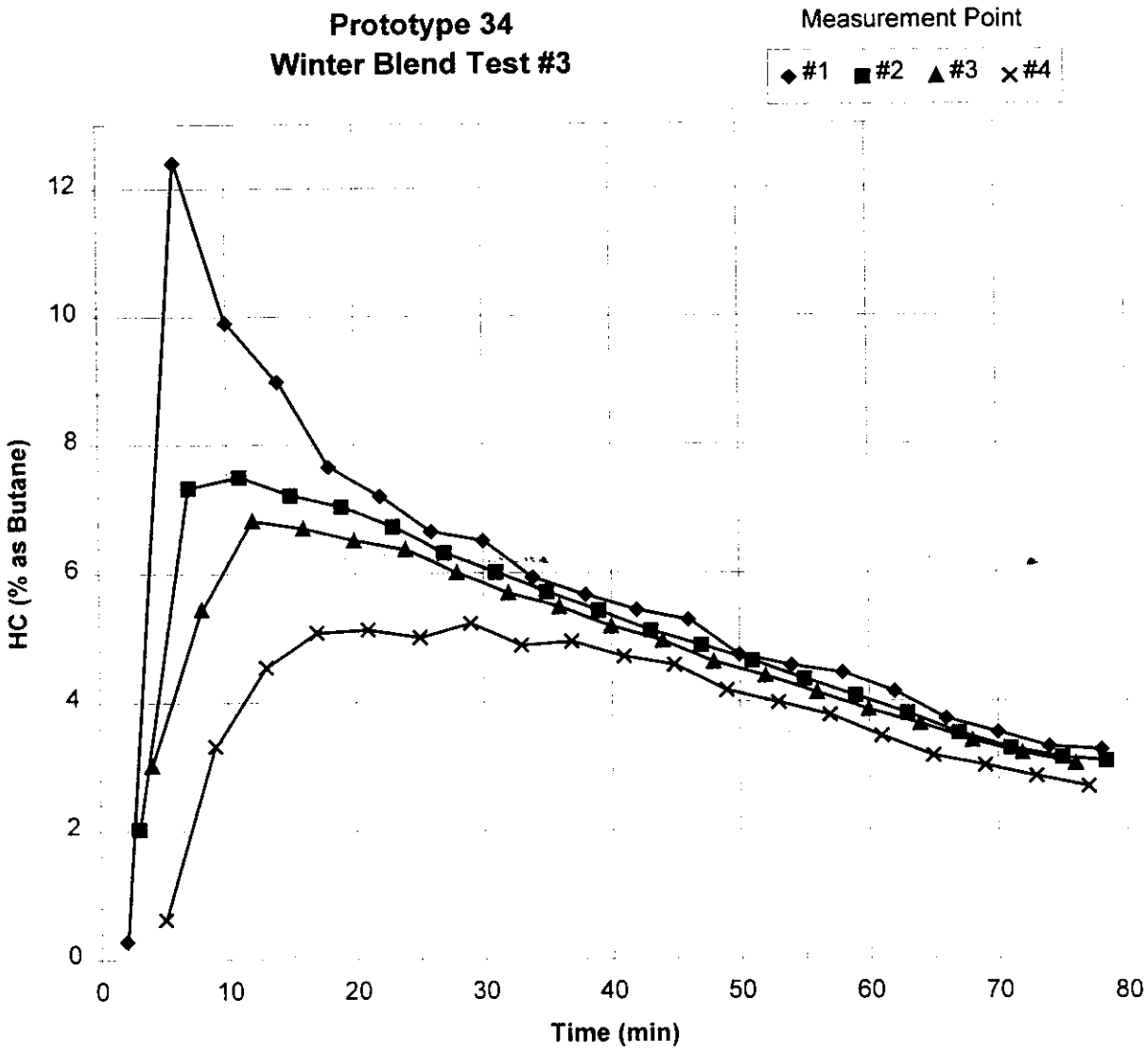


Figure 6

Recent tests also show that the vapor profiles can be changed by relatively minor heater design changes. Figures 7 and 8 present the results of two Summer blend tests. The same heater was used in each test, except they had slightly different burners that were being evaluated. In Figure 7, instrumentation indicated that gasoline vapors were burning in the combustion chamber. However, eventually all combustion was extinguished and the pilot dropped out. At this point, no subsequent ignition was possible and the test was terminated. In Figure 8, the test began much like the previous test. Gasoline vapor combustion occurred in the water heater but

eventually ceased. However, in this case, the pilot did not drop out and the heater's main burner continued to cycle. This test was terminated after two hours with no ignition of the vapors in the room.

The tests in Figures 7 and 8 illustrate another important point. There are several different possible test outcomes which are all "passing." These possibilities include:

- All combustion in the heater is extinguished soon after the spill because the flammable vapors are above the higher flammable limit;
- Combustion of flammable vapors occurs in the heater for a period and then extinguishes itself and the normal burners; and
- Combustion of flammable vapors occurs in the heater until the source of the vapors is depleted.

In each case, there is no ignition in the room. So, from a safety aspect, the outcomes are equivalent.

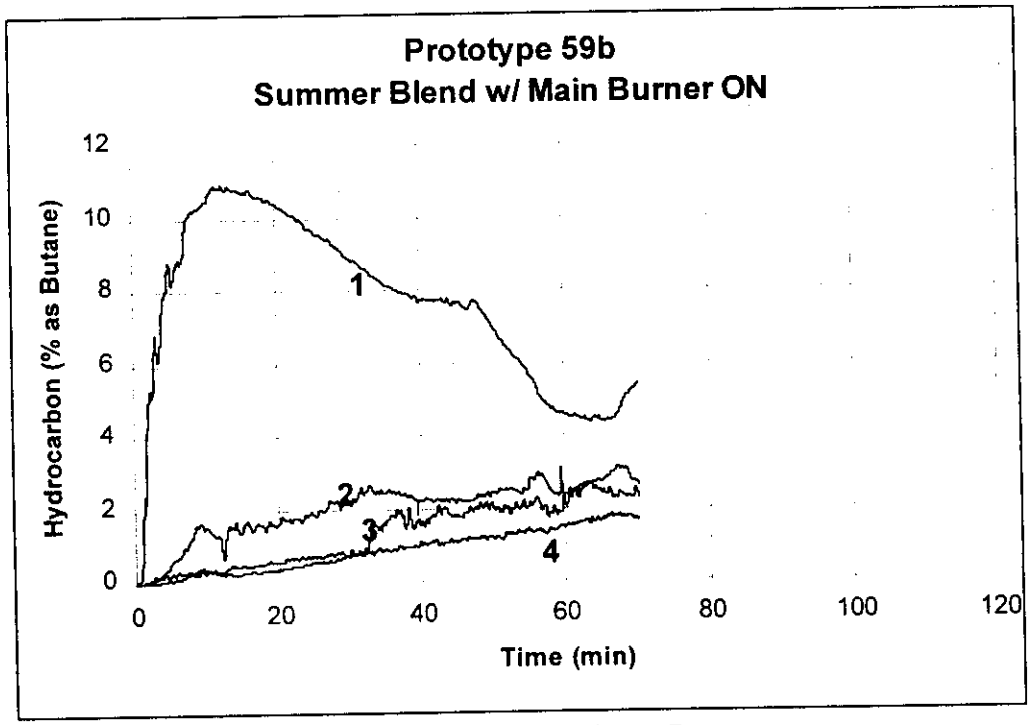


Figure 7

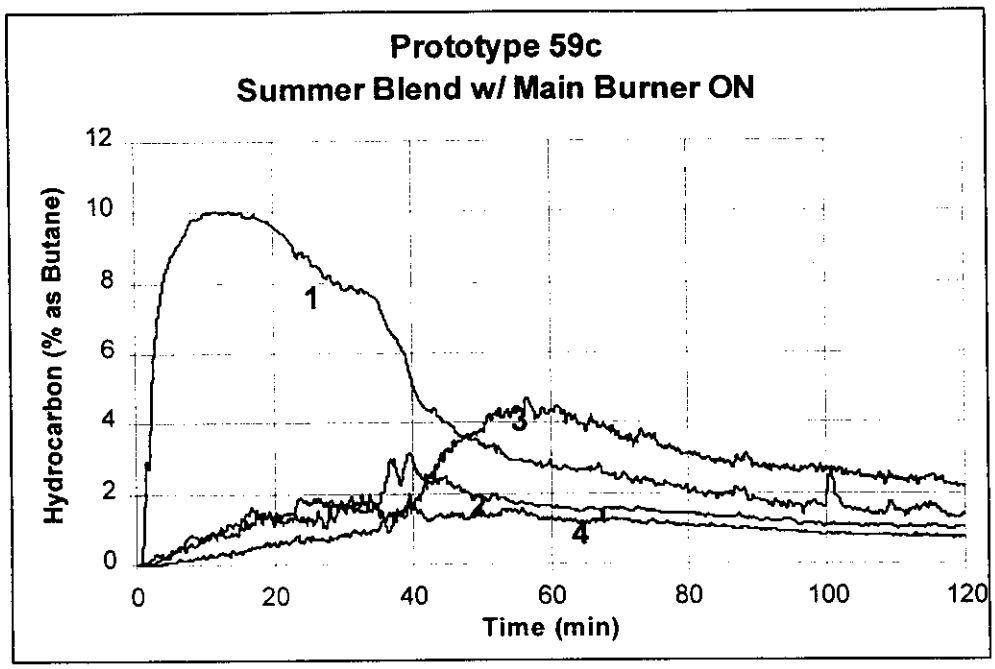


Figure 8

5. Conclusions

The gasoline test room, with a real gasoline spill, is more useful for the practical testing of water heaters in a way that includes the many design specific parameters of the appliances and, is most appropriate for testing water heaters in the latter stages of development and for certification purposes.

References

[1] Flammable Vapor Hazards Ignition Study, AD Little, July 15, 1993, GAMA Task 2 Report

[2] R.F. Topping and K.R. Benedek, Flammable Vapor Test Methodology Development for Gas-Fired Water Heaters, Arthur D. Little, Inc, Cambridge, Massachusetts, April, 1996, GRI-96/0102.

[3] Flammable Vapors Hazards Ignition Study, AD Little, June 16, 1993, GAMA Task 1 Report.

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 outside of the water heater created by the spilling of both winter and summer blends of gasoline on to the floor of the test room described in the following method of test. This provision does not apply to water heaters for installation in recreational vehicles only.

METHOD OF TEST

These tests shall be conducted at normal inlet test pressure and input rating . The tests shall be conducted under the following three conditions 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.

TEST CONDITION 1

The water heater shall be installed 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 and leveled to prevent the gasoline from forming puddles. 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. A mannequin resembling a young boy and measuring approximately 48 inches in height. The mannequin shall be standing with its' legs spread a distance of approximately 14 inches with hands on hips. The depth of the mannequin shall be approximately 9 inches. The mannequin shall be
f. equipped with a means to move it back and forth over a 3 foot long track at a rate of 3 feet per second.
g. Instruments to continuously 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 3.**
h. Means to observe the water heater under test from outside the room.
i. A suitable fire extinguishing system.
j. Means to verify the Reid vapor pressure of the gasoline prior to testing.

The water heater shall be located in the test room in the location shown in **FIGURE -1.** The water heater shall be tested with the venting arrangements described in 2.25.5, as shown in **FIGURE 3,**

ATTACHMENT (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 outside atmosphere, 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 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 tests 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.
A quick acting valve shall be located outside of the test room and shall be adjusted or constructed so as to maintain a flow rate of 5 gallons per minute. The quick acting valve shall be arranged so that it will open automatically when the appliance thermostat reduces the gas supply to the burner(s) to a minimum and will close when the appliance thermostat functions.

The water heater thermostat shall be set at the 120 F mark and the water heater operated until the gas supply to the main burner(s) is reduced to a minimum. Initiate water draw off and allow the thermostat to function and ignite the main burner(s). Wait one (1) minute before spilling winter blend gasoline 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. 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 . Allow the test to continue 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.

Following this test, it shall be determined that either the water heater is not 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. If the water heater is capable of normal operation it shall be used for the remaining tests described in this section. 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 the remaining tests.

The previous test shall then be repeated using the summer blend gasoline. The test procedure is the same as that described above for the winter blend gasoline except for the following:

a. Summer blend gasoline replaces the winter blend
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.

TEST CONDITION 2

The appliance shall be installed as described under **TEST CONDITION 1**. The water heater the thermostat shall be set at the 120F mark and the appliance permitted to operate until the thermostat acts to reduce the gas supply to the main burner(s) to a minimum. The quick acting water valve located in the outlet of the water heater shall be rendered inoperative. Winter blend gasoline shall then be spilled on to the floor of the test room in the manner described under **TEST CONDITION 1**. Immediately after spilling the gasoline the quick acting water valve is returned to service and a draw equal to 5 gallons per minute is placed on the heater. 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. Allow the test to continue 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.. 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. If the water heater is capable of normal operation it shall be used for the remaining tests described in this section. 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 the remaining tests.

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a. Summer blend gasoline replaces the winter blend
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.

TEST CONDITION 3

The appliance is installed as described under **TEST CONDITION 1** and operated until the thermostat acts to reduce the gas supply to the main burner(s) to a minimum. The Main burner is then prevented from operating by placing the gas control in the PILOT position or through similar means. Winter blend gasoline shall then be spilled on to the floor of the test room in the manner described under TEST **CONDITION 1** . One (1) minute after the gasoline is spilled, 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. Allow the test to continue until, either a) the pilot (or other ignition means if so equipped) is inoperative, and flammable vapors no longer burn within the water heater, or b) 2 (two) hours have elapsed since the spilling of the gasoline and no ignition of flammable vapors has occurred. 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. If the water heater is capable of normal operation it

shall be used for the remaining tests described in this section. 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 the remaining tests.

The previous test shall then be repeated using the summer blend gasoline. The test procedure is the same as that described above for the winter blend gasoline except for the following:

a. Summer blend gasoline replaces the winter blend
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.

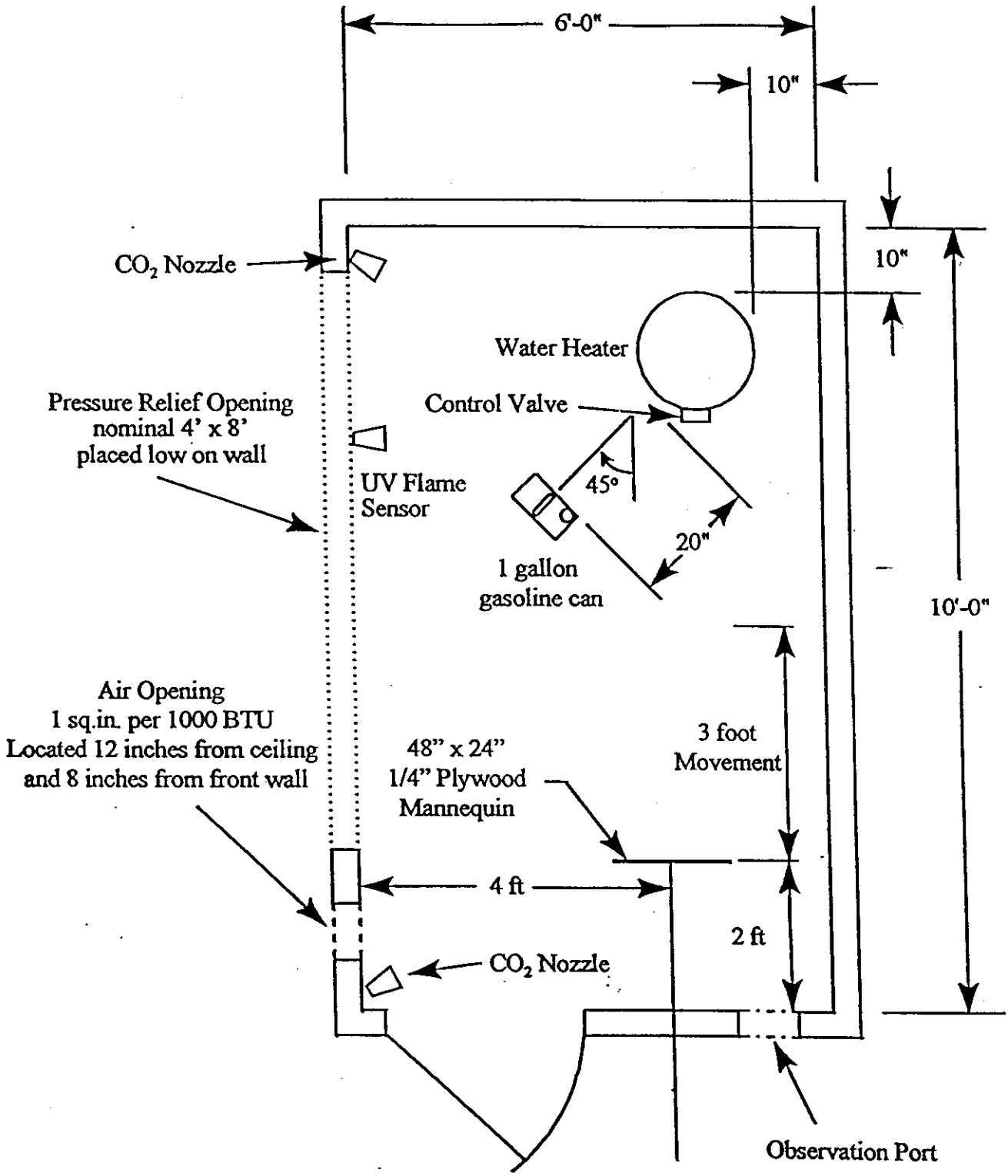


Figure 1 -Flammable Vapors Test Room

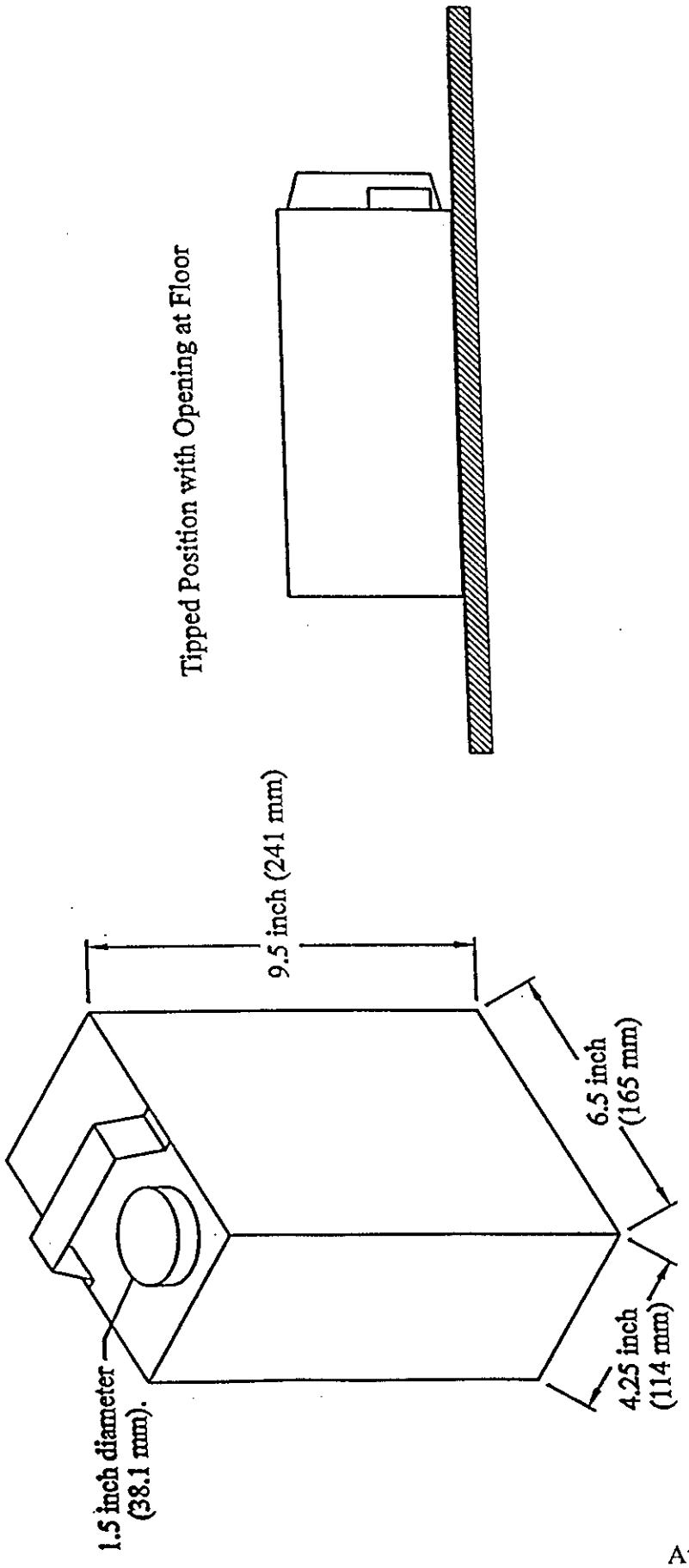


Figure 2 - Standard One Gallon Gas Can

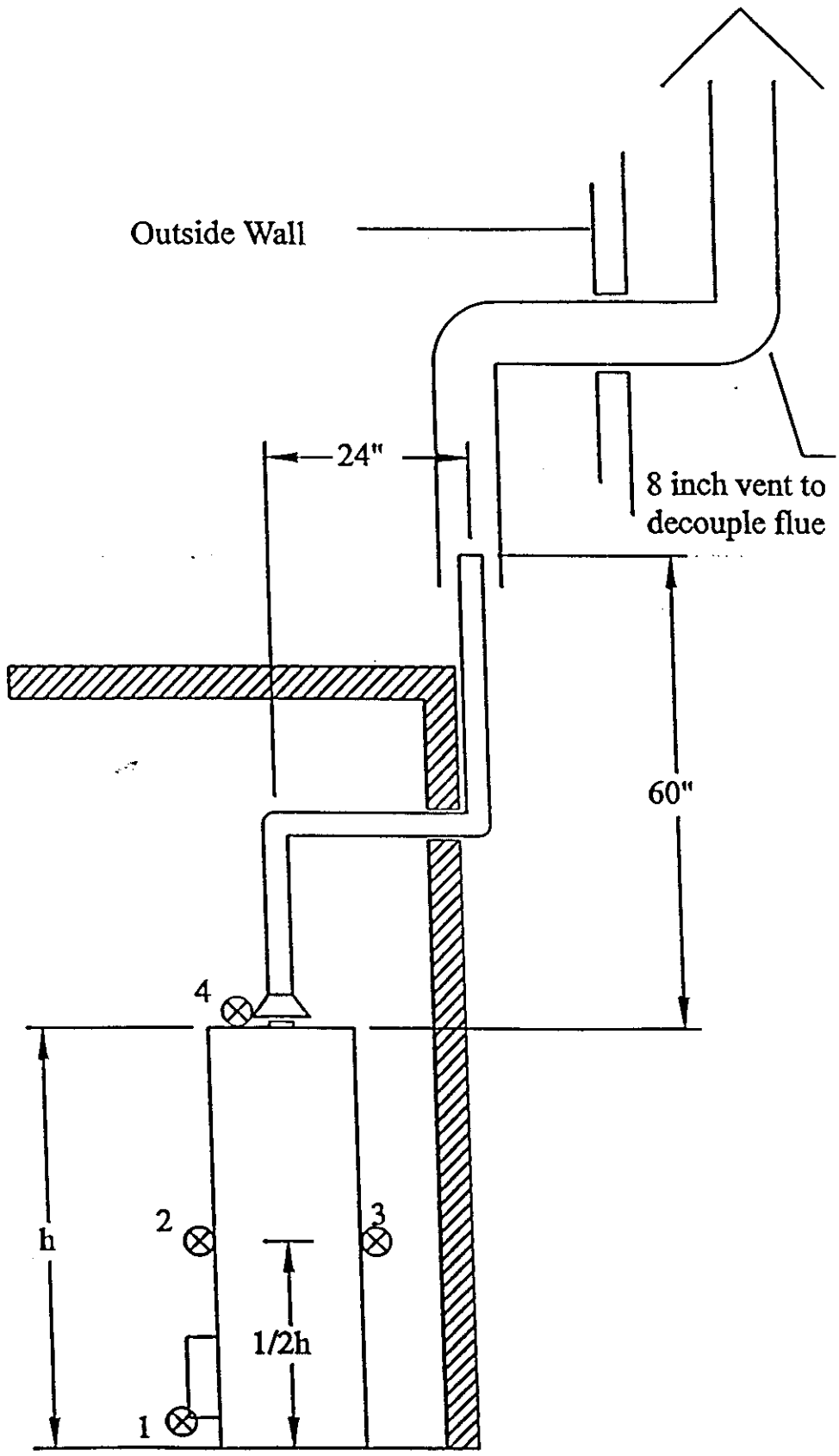


Figure 3 - Setup for Vent and Location of Hydrocarbon Sampling Points

Prefatory Statement for the GRI Test Method

NOTE: The following material was submitted by the Gas Research Institute, and adopted by the Z21/(Interim CSA) joint water heater subcommittee for distribution for review and comment at its July 28, 1998 meeting. The information expressed in this Attachment does not reflect any opinion of International Approval Services or the American Gas Association.

Test Method A

1. Background

From the results of a Gas Appliance Manufacturers Association (GAMA)-sponsored flammable vapors hazards ignition study, "Flammable Vapor Hazards Ignition Study, Task 1 Report", GAMA, Arlington, VA. June 16, 1993, gasoline was identified as the flammable substance involved in a vast majority of incidents. Based upon this, a Gas Research Institute (GRI) sponsored program was structured to include a series of statistically designed experiments intended to assist in a better understanding of the vapor conditions that may occur after a gasoline spill in a room with a gas-fired water heater present. Generally, the range of conditions observed varied widely in concentration levels around a water heater depending upon spill amount, gasoline formulation, the presence or lack of movement and water heater operation (pilot only mode or main burner on).

2. Results of Gasoline Spills

Tests show that concentrations of vapors can rise to flammable concentrations very rapidly. For example, vapor concentration near the floor can rise from 0 to 2% in less than 30 seconds. The vapor can reach steady state concentrations of 0.5% to 5%, depending on the variables listed above. Peak vapor concentrations can reach up to 10% near the floor for periods of time up to 10 - 15 minutes. With movement in the room, vapors can reach heights of 54" off the ground. The analysis of the data indicated that spills can result in vapor concentrations near the stoichiometric fuel/air mixture (~ 3%) for short periods of time, as concentrations rise or fall through this critical concentration, or for extended periods of time. It was clear that a wide variety of vapor conditions can and do occur from gasoline spills and that a water heater must be able to withstand a wide variety of vapor conditions in order to be resistant to ignition of flammable vapors.

3. Test Facility

Having identified the wide range of vapor conditions observed after the specific spill scenarios in this test series, a test facility was designed and built which could repeatably and safely deliver any of the observed vapor ranges around a gas fired water heater. Part of this process included the identification of an appropriate test gas for use in such a test facility.

4. Test Gas Selection

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

ATTACHMENT (5)

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 to its individual components. Compared to a multi-component blend, such as gasoline, the advantages of a one-component test gas include assurance 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 Test Method A. 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. This fact was observed through measurements taken after 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 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.

5. Facility Safety and Repeatability

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.

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. Computer controlled mass flow controllers are used to deliver the butane vapor/air mixtures safely and repeatably. Overall system operation allows for ease of use of such a testing method with minimal input from the test operator. Maintaining repeatable and consistent flow conditions during Test Method A is very important to insure that water heaters are tested under the same conditions.

The design of the test enclosure was based upon results gained from consequence modeling. Consequence modeling predicted potential overpressure after an ignition of 6 -10 psig. Employing reasonable factors of safety in the design of such a chamber led to a cylindrical test enclosure with three main components: The pressure containment chamber which surrounds the water heater being tested, the flue gas vent for the gas fired water heater and the blowout panels that release the pressure after vapor ignition.

6. Flammable Vapor Environment

Since a wide range of vapor profiles were observed in gasoline spill experiments, combustion principles were employed to define a set of vapor profiles which would encompass this range of observed conditions. These profiles were selected based on two sets of criteria: 1) The vapor profiles could result from the types of gasoline spills analyzed in the GAMA and GRI studies; and 2) The vapor profiles are conditions that will test the effectiveness of a flammable vapor ignition-resistant technology. The set of profiles are presented in Figure 4 and explained below.

After allowing the water heater to come up to temperature from a cold start, all surfaces are at their highest temperatures under normal operation. The initial stage of the test calls for a 0.5% vapor cloud around the water heater. This condition will test for flashback through, for example, a sealed, premixed burner. The second test stage of 2.2% butane completely surrounding the water heater ensures that every water heater is at least tested in an environment which is flammable. Water heaters will thus be fully checked for the presence of leaks that could result in vapor ignition. The third stage of 3.2% butane to a 30" height is intended to appropriately test designs which consume the vapors in the combustion chamber. This stage, also referred to as endurance burning if the candidate test unit employs a flame arrestor technology, for example, creates conditions which are most likely to result in flashback due to the higher burning temperature and increased flame speeds present at this butane concentration. The final stage of 10% butane near the floor is to test the base of the unit for leaks. Many spills without movement result in very high vapor concentrations near the floor. If a unit is designed with sealed combustion, for example, a small leak of high vapor concentration could result in ignition of the vapors. This region tests for the seal integrity of the combustion chamber. All stages of the vapor test are initiated with a rapid vapor rise rate that will test the effectiveness of any design utilizing a sensor/control technology.

7. Summary

In summary, Test Method A is intended to evaluate the resistance of a water heater to flammable vapor ignition during various stages of operation and over a range of observed external vapor environments. The test is intended to thoroughly evaluate a design to the extent that there is confidence that ignition is highly unlikely under any foreseeable circumstance. In Test Method B, two spill tests, using two different blends of gasoline and two different spill conditions,

provide additional confidence that testing in accordance with this standard demonstrates compliance with flammable vapor ignition resistance requirements.

Test Method B

The following provides further information on the details of the Test Method B. The size of the test room reflects the fact that a room of this size was shown to be typical where an incident occurred between flammable vapors and a gas-fired water heater according to the GAMA Task 1 Report. 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° 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° F control of the floor temperature is specified.

The test specifies one combustion air supply opening in the room located 12 inches form 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 (NFGC). Those requirements specify 2 openings, one at 12 inches from the ceiling and one at 12 inches form 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 involving flammable vapors and gas-fired water heaters. Gasoline vapor profile studies conducted for the Gas Research Institute (GRI), by Arthur 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 a range 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 many flammable vapors ignition incidents involving 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.

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 test should be conducted with those doors opened or removed.

GRI Test Method

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. This provision does not apply to water heaters for installation in recreational vehicles only.

METHOD OF TEST

Test Method A: Vapor Profile Testing

Test Setup

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 flammable vapor 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 and videotape 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.

ATTACHMENT (6)

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 accommodate 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.

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):

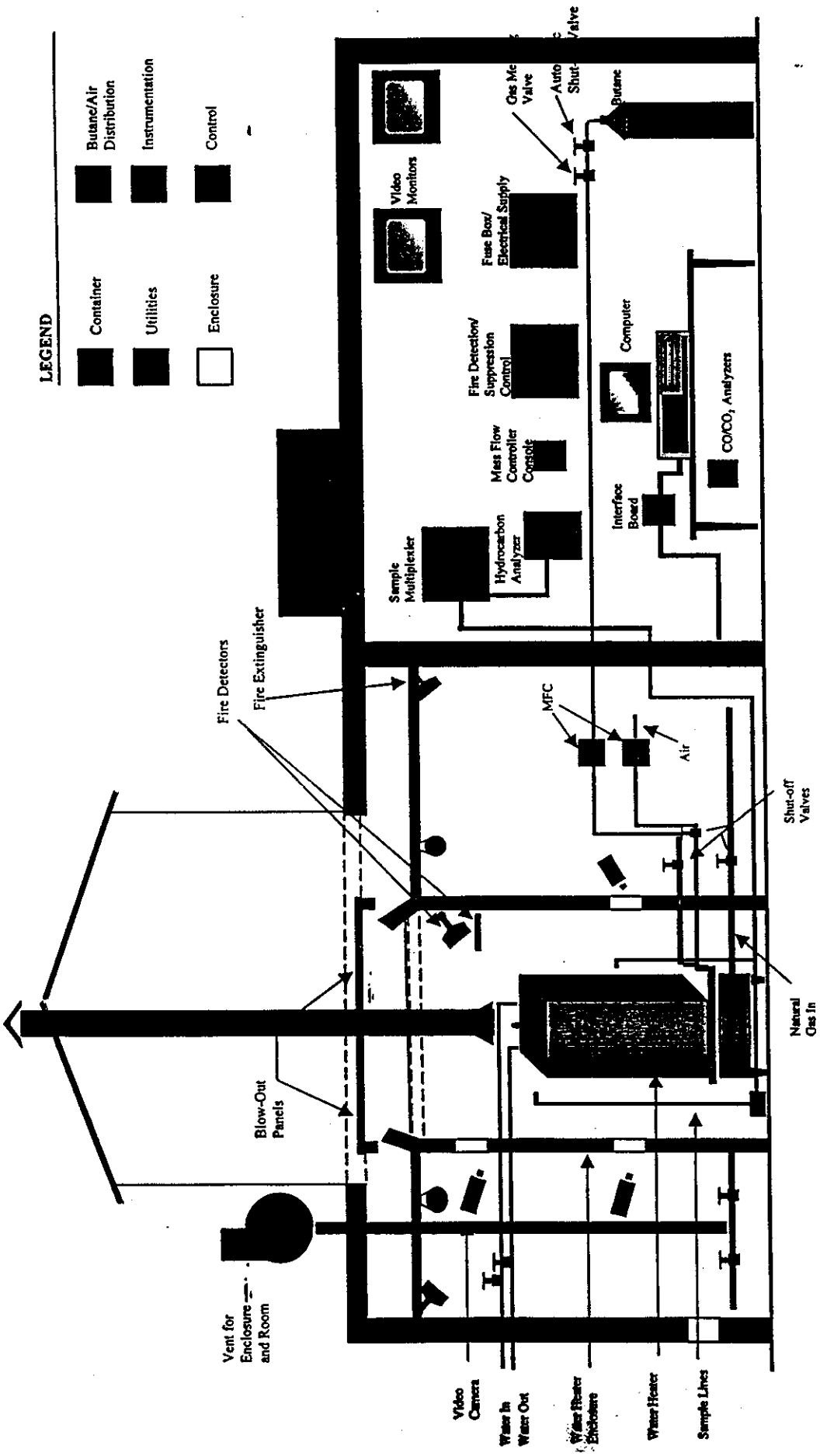
Disable the main burner by switching the thermostat to the "PILOT" position. Introduce a butane/air mixture to match the profile in Figure 4.

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

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 to match the profile in Figure 3. 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.

Figure 1: Schematic Representation of Flammable Vapor Ignition Test Facility



Attachment 4-3

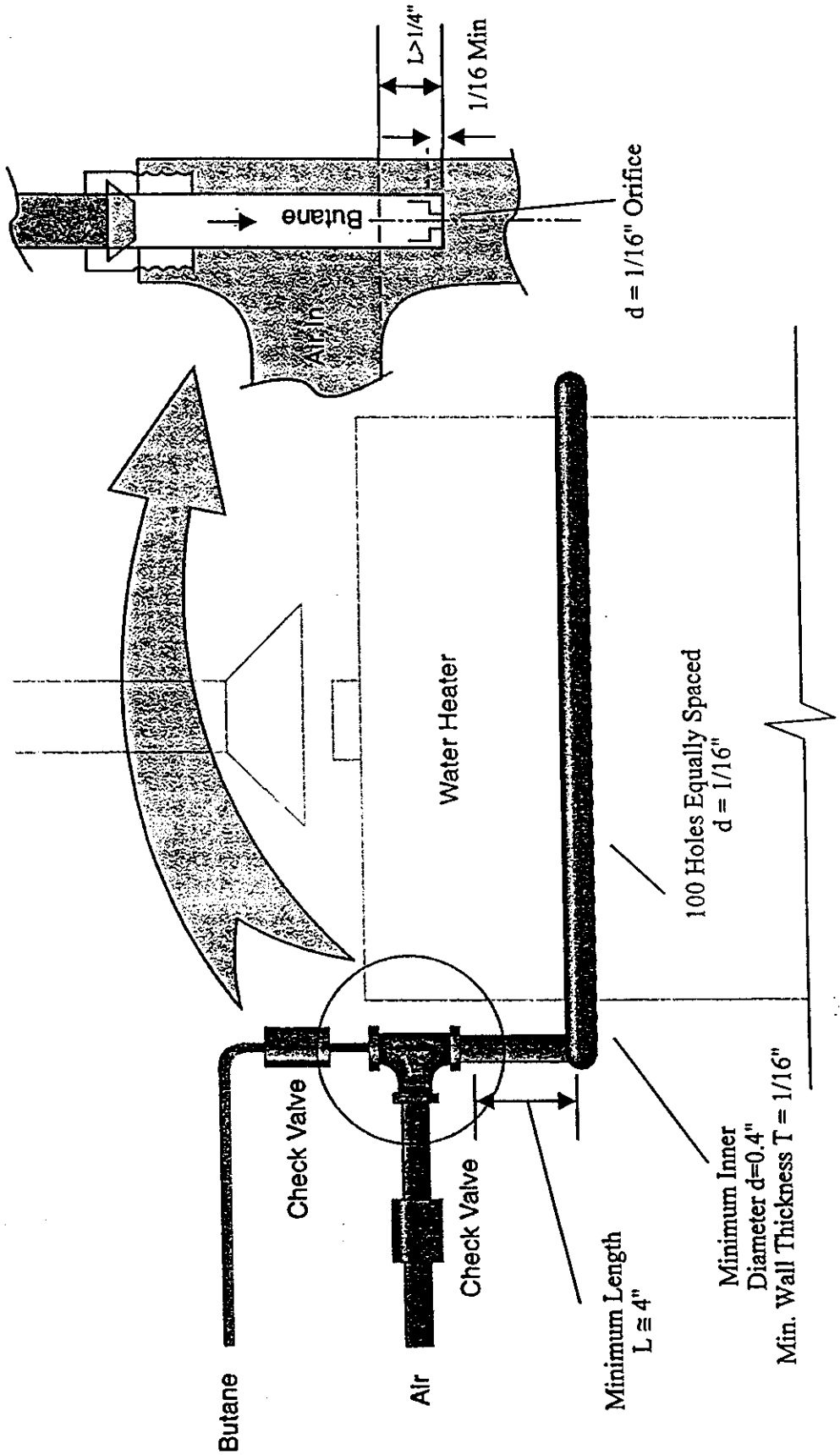
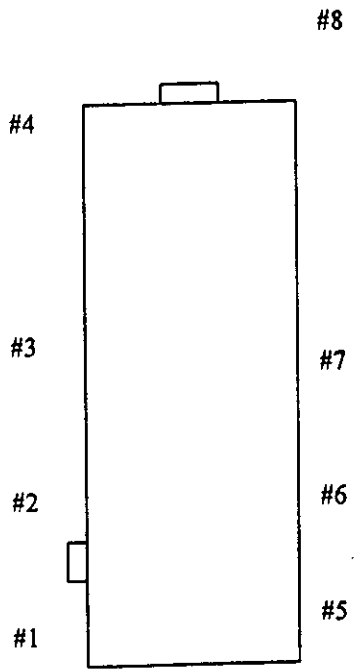


Figure 2: Butane Distribution Ring

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, 6" Height
#6 - 12:00, 18" Height
#7 - 12:00, 30" Height
#8 - 12" Above Heater



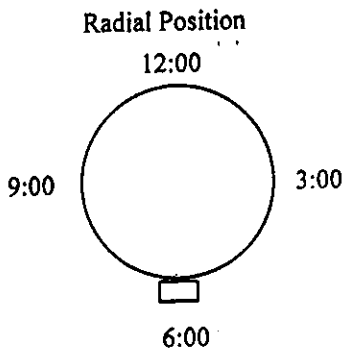
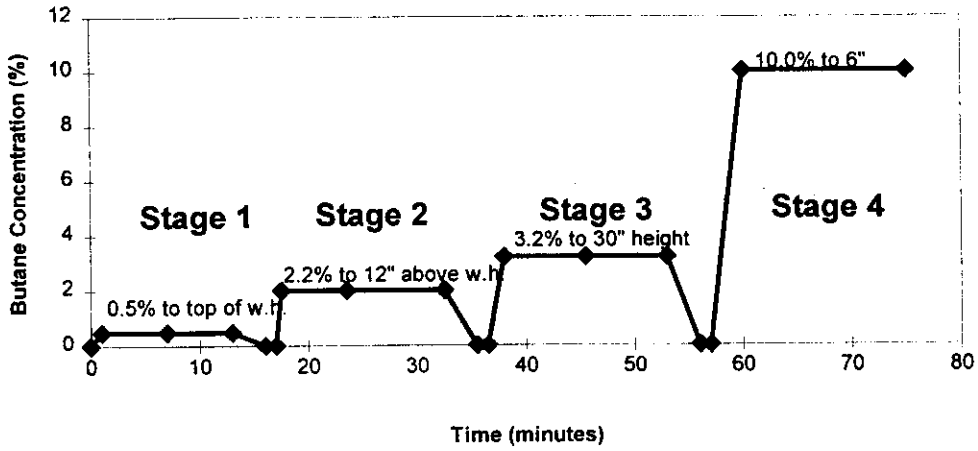


Figure 4 - Flammable Vapor Protocol



(All vapor concentrations levels are +/- 0.3%).

Times to Desired Concentration

Stage 1 Time to 0.5%		Stage 2 Time to 2.2%		Stage 3 Time to 3.2%		Stage 4 Time to 10%	
3"	<30 seconds	3"	<30 seconds	3"	<1 minute	3"	3-5 minute
18"	1-2 minutes	18"	3-5 minutes	18"	7-8 minutes	18"	6-8 minutes
30"	2-3 minutes	30"	4-6 minutes	30"	9-11 minutes	18" and above	N/A
36"	3-4 minutes	36"	5-7 minutes	36" and above	N/A		
54"	5-6 minutes	54"	8-10 minutes				
12" above w.h.	N/A	12" above w.h.	10-12 minutes				

N/A - Desired concentrations not to be achieved at this height.

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 both the pilot only and burner cycling tests until the complete profile has been generated with no ignition outside of the unit. If all flames should extinguish at any stage during either test, vent the enclosure and relight the water heater under test and restart the vapor profile test at the next stage in Figure 4.

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 occurred through review of the test video(s) and test data.

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

c) If the water heater is capable of normal operation; i.e., 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 Method B: Gasoline Spill Tests

This test is a modification of the draft test method submitted by the Technical Committee of the GAMA Water Heater Division to the Joint Subcommittee on Standards for Gas Water Heaters in July 1998.

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 and leveled to prevent the gasoline from forming puddles. A diagram of the test room is shown in Figure 5. The test room shall have:

a) Means to control the temperature of the floor to 70° F +/- 10° F.
b) A combustion and ventilation air opening of 1 in^2 per 1000 Btu/hr of input located 12 inches from the ceiling in the area of the wall shown in Figure 5.
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 6.
d) Provisions to provide pressure relief of the test room as shown in Figure 5.
e) A mannequin resembling a young boy and measuring approximately 48 inches in height. The mannequin shall be standing with its legs spread a distance of approximately 14 inches with hands on hips. The depth of the mannequin shall be approximately 9 inches. The mannequin shall be equipped with a means to move it back and forth over a 3 foot long track at a rate of 3 feet per second.
f) Instruments to continuously 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 7.
g) Means to observe the water heater under test from outside the room.
h) A suitable fire extinguishing system.
i) Means to verify the Reid vapor pressure of the gasoline prior to testing.

The water heater will be tested with the venting arrangements described in 2.25.5, as shown in Figure 7, except as follows.

When a manufacturer' supplied vent terminal(s) for either the air intake, vent exhaust, or both is designed for installation so that all combustion air is derived directly from the outside atmosphere, 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° F +/- 10° F. A quick acting valve shall be located outside of the test room and shall be adjusted or constructed so as to maintain a flow rate of 5 gallons per minute. The quick acting valve shall be arranged so that it will open automatically when the appliance thermostat reduces the gas supply to the burner(s) to a minimum and will close when the appliance thermostat functions. 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° F +/- 10° 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) comes 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 6, 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 5, 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 the flammable vapors no longer burn within the water heater, or b) the hydrocarbon concentrations at all four sensors shown in Figure 7 are below 50 percent 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 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;
c) The direction of the gasoline spill shall be away from the water heater with opening near the floor; and

d) The water heater shall be tested in pilot-only mode (for units equipped with a standing pilot).

After completion of Test Methods 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.

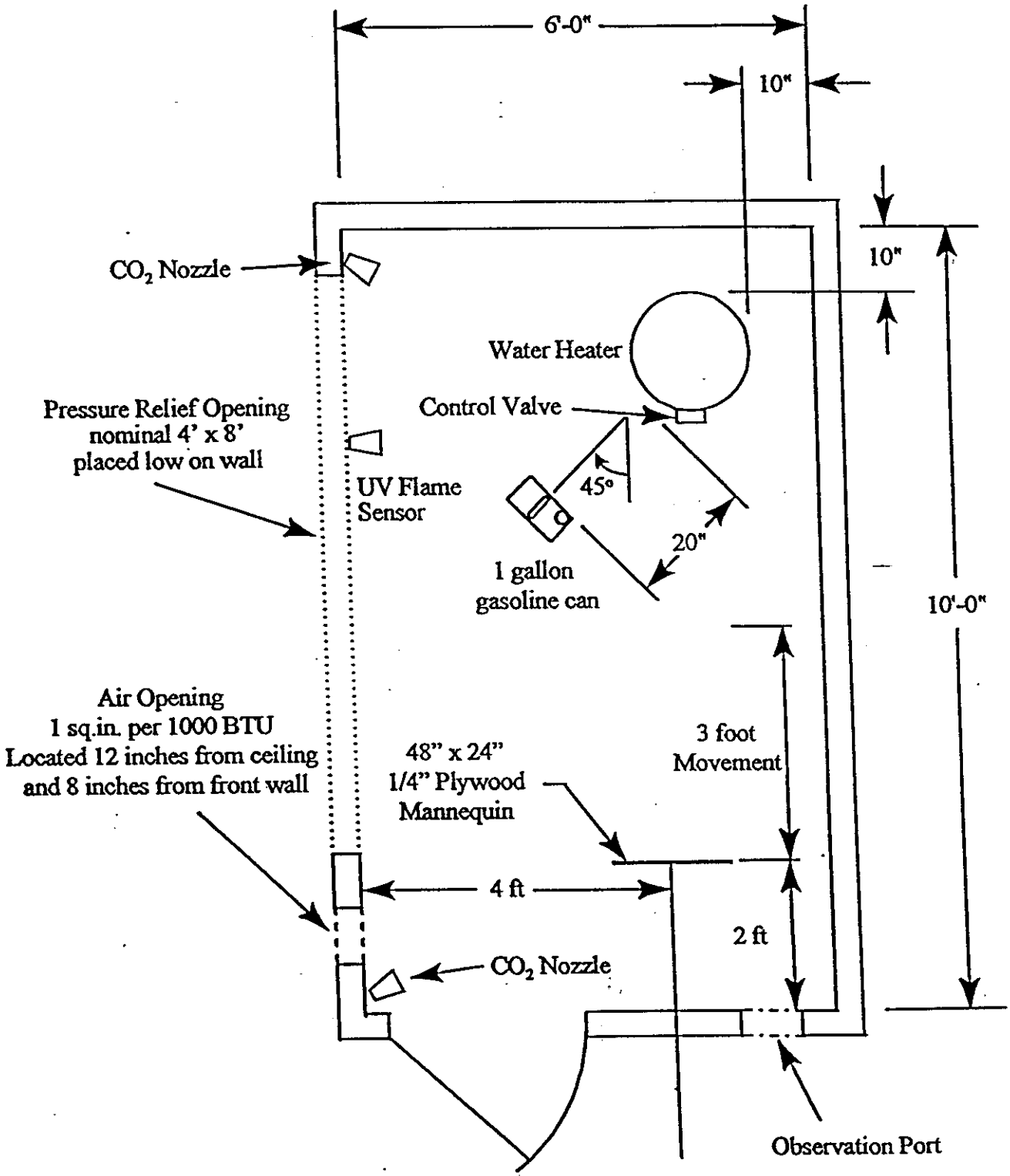


Figure 5 -Flammable Vapors Test Room

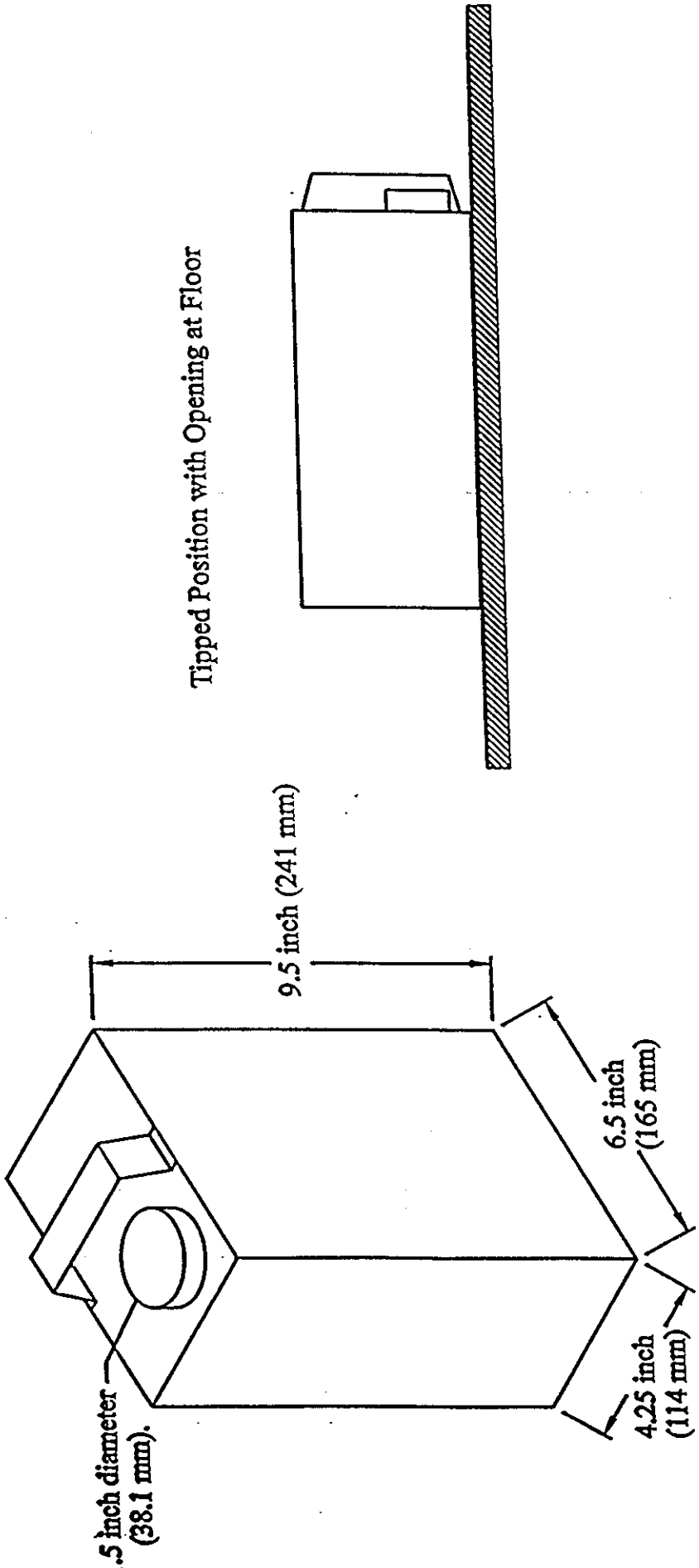


Figure 6 - Standard One Gallon Gas Can

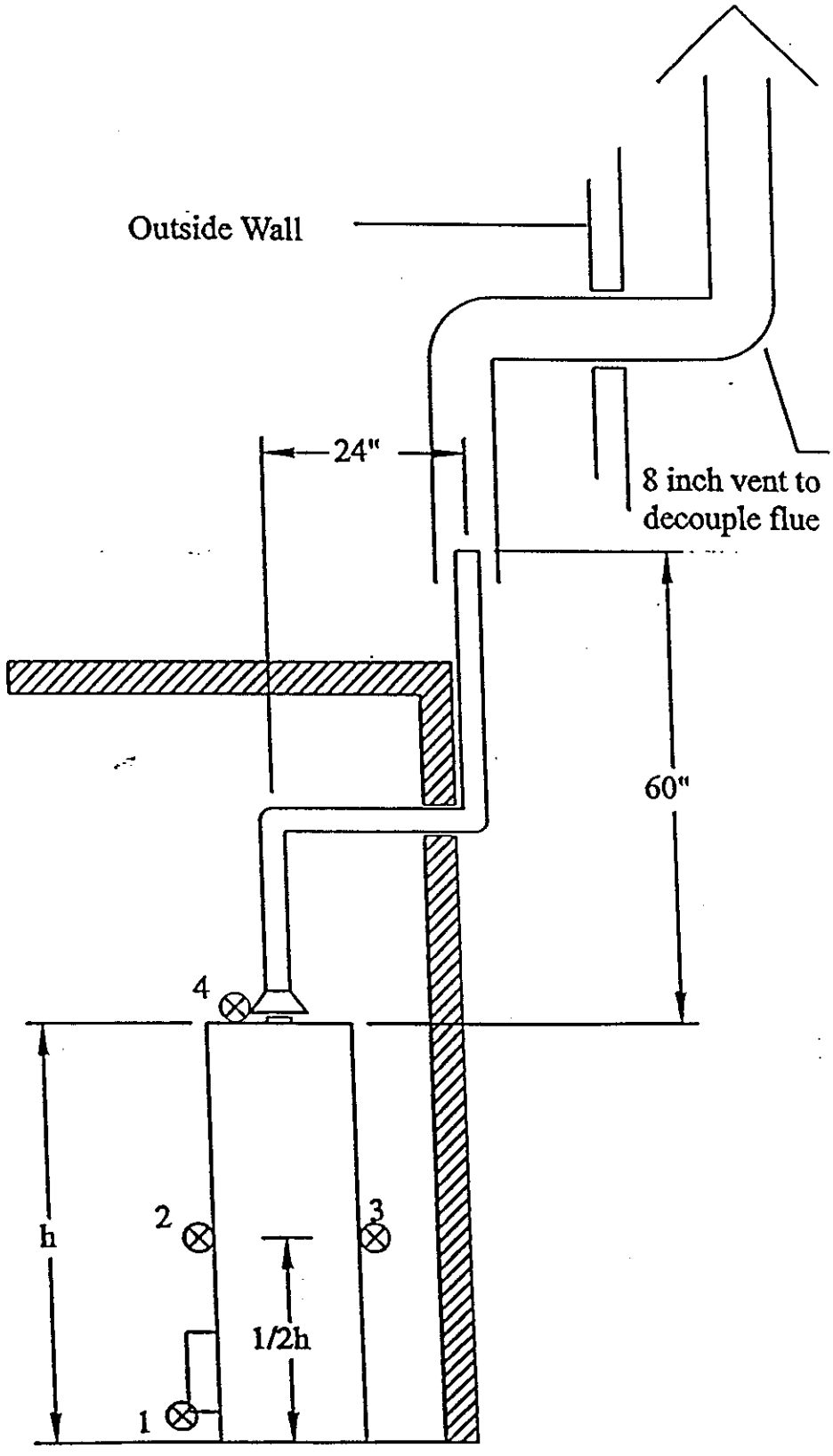


Figure 7 - Setup for Vent and Location of Hydrocarbon Sampling Points