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U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

July 7, 1994

Mr. C. Reuben Autery
President
Gas Appliance Manufacturers Association
1901 North Moore Street
Arlington, VA 22209

Re: Water Heater Ignition of Flammable Vapors

Dear Mr. Autery:

Thank you for bringing to the Commission's attention information about recent efforts by the industry to address the risks posed by water heater ignition of flammable vapors. The Commission staff is reviewing the information you provided by letters to Bert Cottine, Executive Director, (June 14, 1994) and to Chairman Ann Brown, (June 27, 1994).

We appreciate your offer to keep the Commission staff appraised of ongoing developments and to provide opportunities to participate in the process. In order to give the Commission a complete evaluation of the current circumstances, we will need additional information about industry's ongoing and planned activities regarding water heaters igniting flammable vapors. Thus, please provide test protocols (with justification for test conditions), schedules, and draft and final reports of studies or tests to evaluate possible means to address the ignition of flammable vapors by gas-fired water heaters. For example, staff requests this information about the following tests and activities:

1. *Flammable Vapor Ignition Study, Task 2: Analytical Modeling and Experimental Testing*; Arthur D. Little, July 15, 1993;

2. Testing to evaluate the potential of the Bowin Designs Pty.,Ltd., burner to reduce gas-fired water heater ignition of flammable vapors;

3. Testing by International Approval Services to evaluate the potential utility of a sheet metal barrier to prevent flammable vapor ignition of flammable vapors;

4. Efforts sponsored by the Gas Research Institute or others to develop performance test methods to evaluate water heater design resistance to ignition of flammable vapors.

Once the Commission staff has reviewed the material you provide, we plan to request a meeting with the appropriate parties to answer any questions we may have.

Mr. Donald W. Switzer of the Directorate for Engineering Sciences has been assigned responsibility for the technical evaluation and is your contact for technical matters on this issue. Mr. Switzer can be reached at (301) 504-0508, ext. 1303.

Currently, this matter is pending before the Commission and it is therefore important to proceed as quickly as possible to gather your additional information for our review.

Sincerely,

Ronald L. Medford

Ronald L. Medford
Acting Assistant Executive Director
for Hazard Identification and Reduction

E

Gama

1901 North Moore Street • P.O. Box 9245 • Arlington, Virginia 22209 • 703/525-9565

July 28, 1994

Mr. Ronald L. Medford
Acting Assistant Executive Director
for Hazard Identification and Reduction
U.S. Consumer Product Safety Commission
4330 East West Highway
Bethesda, Maryland 20814

Re: Water Heater Ignition
of Flammable Vapors
(Your Letter of July 7, 1994)

Dear Mr. Medford:

In response to your July 7, 1994, letter, the Gas Appliance Manufacturers Association (GAMA) is pleased to provide the following information regarding water heater industry activities to address ignition of flammable vapors by gas-fired water heaters. In your letter, you first request information about the July 15, 1993, Arthur D. Little (ADL) report, "Flammable Vapor Ignition Study, Task 2: Analytical Modeling and Experimental Testing." For your background information, in February 1993, ADL representatives briefed Joseph Fandey and Al Martin on the methodology to be used to conduct the testing; in May 1993, Mr. Martin observed a full day of testing; and on July 15, 1993, Mr. Fandey received two copies of the final report (additional copy enclosed).

GAMA would be happy to have ADL representatives again brief CPSC staff, at our expense, on the test methodology and on the test results. Both subjects could be covered in a single briefing or in two separate briefings, as you see fit. Please let me know at your earliest convenience what date(s) would be acceptable to you and other CPSC staff for the briefing(s).

You also requested information about testing to evaluate the ability of a new burner designed and patented by Bowin Designs Pty., Ltd. to prevent water heater ignition of flammable vapors. That testing is being conducted by ADL at a test facility located at the American Gas Association Laboratories (A.G.A.L.) in Cleveland, Ohio. The testing will determine the effectiveness of the Bowin burner in preventing ignition of flammable vapors without compromising other safety and energy efficiency performance requirements of gas-fired water heaters.

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ADL has informed GAMA that it expects to complete and report on the testing of the Bowin burner on a representative sample of 8 gas-fired water heaters by September 15, 1994.

Enclosed for your information are copies of two basic documents describing what is involved in the testing of the Bowin burner. The first document is a contract dated May 20, 1994, between GAMA and Bowin Designs Pty, Ltd. pursuant to which Bowin (1) agrees to have Gas Consultants Inc. fit the Bowin burner (to the applicable water heater manufacturer's satisfaction) on 8 representative gas-fired water heaters; and (2) agrees to ship the retrofitted water heaters to A.G.A.L. for testing by ADL. The second document, which is a contract dated June 8, 1994, between GAMA and ADL, describes the testing to be conducted by ADL on the water heaters retrofitted with the Bowin burner (see "Statement of Work").

In your letter, you also ask for information about testing by International Approval Services (A.G.A.L.) to evaluate the potential utility of a sheet metal collar around a gas-fired water heater to prevent ignition of flammable vapors. In this regard, please find enclosed a white paper and video tape describing this testing. These materials have been provided by Mr. Richard J. Schulte, Senior Vice President, A.G.A.L.

The last specific subject on which you have requested information is a Gas Research Institute (GRI)-sponsored project to develop performance test methods to evaluate water heater design resistance to ignition of flammable vapors. Enclosed is a copy of a February 14, 1994, proposal from ADL to GRI to develop a "Flammable Vapors Screening Protocol for Gas-Fired Water Heaters," for use in screening new gas-fired water heater designs for susceptibility to ignition of flammable vapors.

GAMA understands that GRI is ready to contract with ADL to develop such a screening protocol once GRI and ADL have received indemnification agreements from water heater manufacturers. GRI and ADL are seeking assurances that water heater manufacturers will defend and indemnify them should they be named as additional defendants in a product liability lawsuit alleging a faulty water heater design based on use of the screening protocol. A draft model indemnification agreement is now being reviewed by water heater manufacturers and, when approved, will be submitted for review and approval by respective legal counsel for GRI and ADL. Once the model agreement has been approved by GRI and ADL, individual agreements between manufacturers and ADL and between manufacturers and GRI will be signed. Resolution of the indemnification issue and signing of indemnification agreements could take a few more weeks. We will keep you informed of progress on this issue.

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During our visits with the members of the Commission late last month, we were asked if we had any information concerning the effectiveness of the GAMA Water Heater Division's Consumer Safety Awareness Campaign. As you know, a principal purpose of this campaign has been to educate consumers about the proper storage and use of gasoline. The other focus of the campaign is on prevention of hot water scald injuries. We are separately submitting to Chairman Brown, Commissioner Jones-Smith and Commissioner Gall a July 15, 1994, Follow-Up Report on the results of the Campaign prepared by Loran Nordgren & Company. This report summarizes the results of the Campaign for the period January 1 thru June 30, 1994.

GAMA is pleased to assist CPSC staff in understanding what the water heater industry has been doing to address the ignition of flammable vapors issue. We think the industry has been moving aggressively in this area, and we look forward to CPSC support of the industry's efforts.

Very truly yours,

C. Reuben Autery
President

CRA:gjr-1
Enclosures

F

Gama

1901 North Moore Street • P.O. Box 9245 • Arlington, Virginia 22209 • 703/525-9565

August 1, 1994

Mr. Donald W. Switzer
Project Manager, Fire/Gas
Voluntary Standards
4330 East West Highway
Bethesda, Maryland 20207

Dear Mr. Switzer:

The following is in response to your request for information detailed in your July 26, 1994 letter.

QUESTION 1. What was the purpose of Task 1 and Task 2 of the Arthur D. Little Flammable Vapor Hazards Ignition Study?

ANSWER: The purpose of the Phase I study was to investigate and characterize the extent of the flammable vapor hazard. Task 1 collected and analyzed incident reported and data bases. We also contacted everyone involved whom we could find who might have useful information or informed opinions. The result was the conclusion that the hazard was serious enough for the industry to respond to and investigate in more detail. Task 1 also identified scenarios which represented the vast majority of the cases to set the stage for experimental investigation in Task 2.

In Task 2, we conducted a comprehensive, well documented, controlled experimental investigation of the character of spills and ignitions, including a close look at the effect of water heater elevation. Over 35 tests were run in three room sizes with varying spill quantities, room temperatures and with/without movement. We concluded that ignition is likely to occur in certain scenarios; that water heater elevation may delay but not eliminate the possibility of ignition; and that temperature is a factor but is not as important as motion, room size or spill amount. We also strongly suggested that additional work be done to validate these conclusions due to the variability and uncertainly associated with investigating situations of this nature.

/Continued . . .

QUESTION 2. Is this work viewed by GAMA as suitable for development of a standards test method?

ANSWER: The Phase I work sets the stage for development of a test method, or protocol. The analysis in Task 1 led to the development of an initial test plan which was used in Task 2 to investigate the factors leading to ignition. Phase I was not intended to investigate solutions in any comprehensive way or to establish a statistically valid protocol to assess design options or other means to reduce the ignition hazard. The latter goal is the intent of the GRI sponsored work just beginning. However, the Phase I findings have been instrumental in planning the new work.

QUESTION 3. Why were Task 2 tests run with the floor temperature higher than the ambient room temperature?

ANSWER: In general, we were investigating the effect of room and floor temperature on ignition potential as part of the detailed experimental investigation. Also, our earlier analysis of incidents had shown that a large number occur in the summer months and in the Southern states.

The main method we had to heat the test room was by heating the floor which had a combination of electric wires and hot water tubes underneath. Control was therefore somewhat imprecise leading to differences in floor and room temperatures. Average numbers were reported. (Also, note that there were a few errors in the Tables corrected in a subsequent letter to GAMA). The floor temperatures was not usually higher than the room temperature as implied by CPSC staff's proposal; floor temperatures were significantly higher than room temperatures in well less than half of the tests. Also, temperature was ultimately found to have only a secondary effect on vapor generation/transport and ignition.

QUESTION 4. Why was the floor heated in some of the Task 2 tests?

ANSWER: See response to Question 3.

/Continued . . .

QUESTION 5. Why were some of the tests in Task 2 terminated more quickly than others? In some cases the tests continued for as long as 4 hours (#24) without a fire, and in other cases the tests were terminated in less than 1 hour (#20).

ANSWER: Test time was determined by observing the amount of time required to generate and transport the flammable vapor to the vicinity of the water heater, which was determined by the test variables, such as room size, spill amount, movement, etc. The Flame Ionization Detector (FLD) was used to monitor flammable concentration. When readings from the device indicated that ignition could no longer occur (i.e., concentrations stabilized below the LEL or rose and fell below the LEL without ignition) the test was terminated.

QUESTION 6. When does GAMA estimate that work on the proposed Development of Flammable Vapor Screening Protocol for Gas-Fired Water Heaters will begin?

ANSWER: Provided there are no more snags in the indemnification agreement between water heater manufacturers, ADL and the Gas Research Institute (GRI), work should begin by September 1, 1994

QUESTION 7. Please provide a graphic depicting all the steps, and the anticipated beginning and completion dates of each step, from initiation of the proposed Development of a Flammable Vapor Screening Protocol for Gas-Fired Water Heaters to publication and implementation of performance requirements to address this hazard.

ANSWER: See attached graph which also has supplemental notes on ANSI standards revision process attached.

QUESTION 8. What provisions will GAMA and the industry provide to allow CPSC staff to participate in the standards development program?

ANSWER: GAMA will recommend to GRI that Donald W. Switzer be appointed as a member of the GRI Technical Advisory Group (TAG), which will meet regularly throughout the duration of the project and provide input into its direction.

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QUESTION 9. If the Bowin burner testing indicates that it will prevent water heater ignition of flammable vapors, how long does GAMA estimate it will take to bring water heaters using this technology to market?

ANSWER: This is a question that only GAMA members will be able to answer in the future. Considerable time and effort will be required to determine that the design (1) does not ignite flammable vapors; (2) still satisfies all safety and efficiency requirements; and (3) is a producible product. It must be remembered that, should the design prove feasible, 100 percent of all gas water heater models available will have to be redesigned to accommodate the new burner. Each model will then have to be tested for safety, first by the manufacturer, and then by a third party testing agency. After production has started, each model will then have to be retested to verify its efficiency rating to comply with Federal standards. Currently there are about 579 different water heater models available. The cost involved in such a change will be extremely large, and because of limited manpower and laboratory facilities, a significant amount of time will be required. Some limited number of models could be made available in the "near-term" after a revised standard is finalized; however, it will require considerably more time before all models could be redesigned, certified and produced to comply with the revised standard.

You can be assured that if their project determines that the Bowin burner design works, is safe and producible, it will be brought to the market as fast as possible.

QUESTION 10. Is GAMA aware of any other technological fixes being examined to address the problem of flammable vapor ignition?

ANSWER: There is no technology being actively examined under the auspice of GAMA; however, we plan to evaluate all other known technological fixes as part of the GRI project to develop a test protocol.

/Continued . . .

Don, your letter suggested a briefing by ADL on this subject 3 weeks after the full information package is available to CPSC. I will be on vacation until August 26. Can we schedule our briefing for August 30? I will work towards that date until I hear from you. If CPSC Staff has further questions, please do not hesitate to contact me.

Sincerely,

J. P. Langmead
Vice President and Director
Technical Services

JPL/ljb
Attachment

NOTES ON ANSI STANDARDS REVISION PROCESS (ANSI Z21.10.1):

Task 15: Z21/CGA Joint Subcommittee on Standards for Gas-Fired Water Heaters - Review and Comment Process

Once the joint subcommittee adopts the proposed revisions to ANSI Z21.10.1 for distribution for review and comment at its next scheduled meeting, this process should only take about 6 months to complete. The review and comment process culminates at the subcommittee's next meeting, at which the subcommittee reconsiders the proposal in light of comments received. If the subcommittee can resolve negative comments without making substantive revisions to the proposal, the subcommittee will recommend the proposed revisions to the parent Z21 Committee. However, if comments received on the review and comment text require the subcommittee to make further substantive revisions to the proposed text, such changes would have to be re-distributed for another review and comment period, followed by another subcommittee meeting to reconsider the modified proposals in light of comments received. This aspect could effectively drive this process into a 1 year time-frame, which is easy to assume given the nature and impact of such a proposal.

Task 16: Z21 Committee Approval

Once the above subcommittee recommends the proposal to the parent Z21 Committee, the approval process should take about 6 months to complete, depending on the Committee's next regularly scheduled meeting. However, if the Z21 Committee receives an objection that it feels is of a technical nature that was not completely addressed by the subcommittee, the issue will be referred back to the subcommittee for consideration. This aspect could effectively prolong the Z21 Committee approval process for another 6-12 months, depending on the next scheduled meeting of the subcommittee to address the comments referred by the Z21 Committee.

Task 17: Process Revisions for ANSI Submittal

Once Z21 Committee approval takes place, the Z21 Administrative Secretariat (A.G.A.) prepares the proposal for submittal to ANSI for its 60-day public review period. The ANSI submittal package includes copies of the final text of the Z21-approved standards revision, plus all documentation of the Z21 Committee's approval process. Preparation of the submittal may take about 4 months, since

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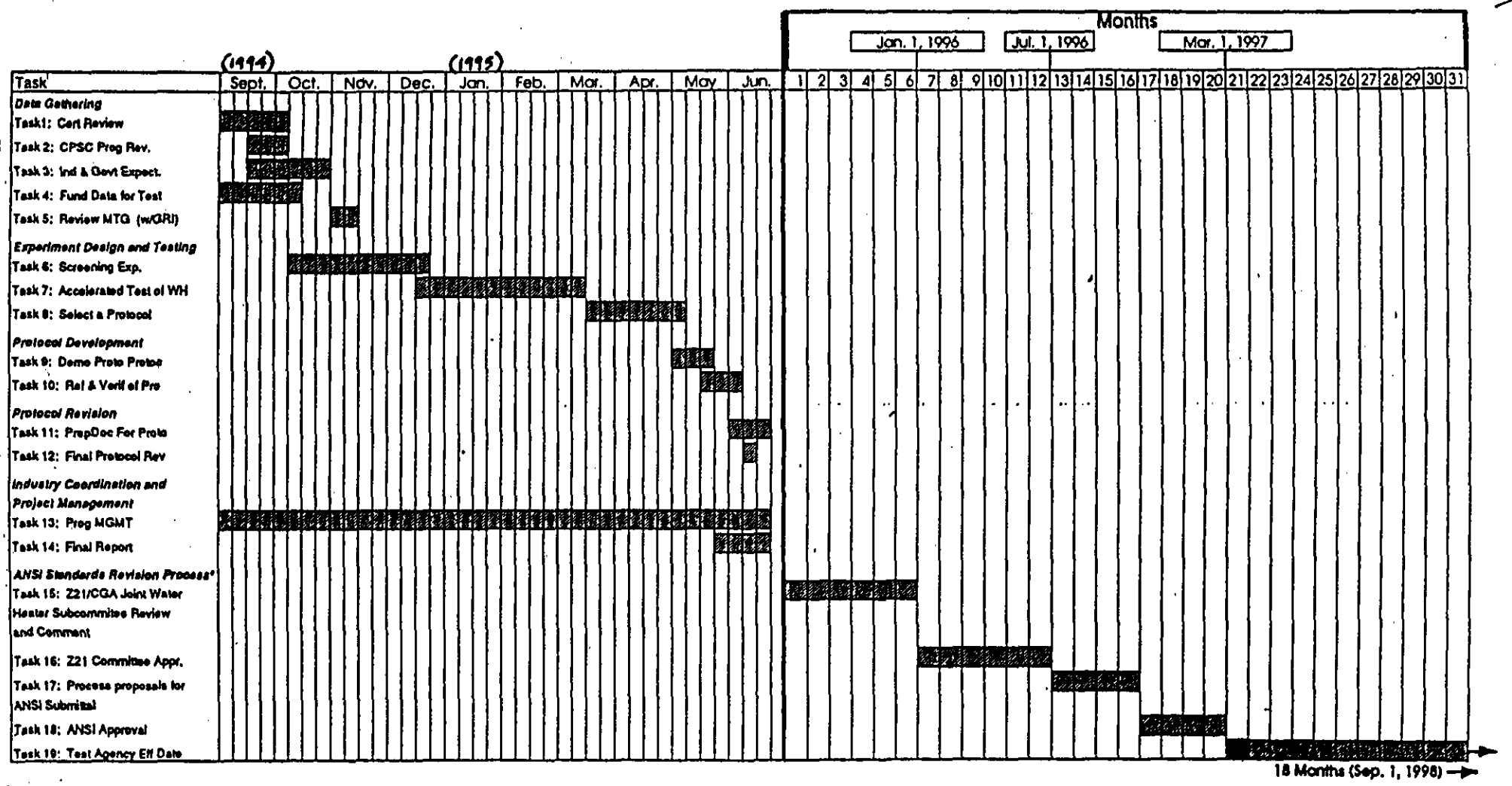
the Secretariat will be preparing many other Z21 standards revisions for ANSI submittal which were also approved by the Z21 Committee at its last meeting.

Task 18: ANSI Approval

Once the Z21 Secretariat submits the proposal to ANSI, it undergoes an ANSI 60-day public review period. If no appeals are made during this period, the Z21 Secretariat then formally submits the proposal to ANSI for approval by the ANSI Board of Standards Review (BSR), which meets periodically. This process should only take about 4 months (depending on the next BSR meeting). If an appeal to ANSI is received, the ANSI BSR approval process could be further extended another 4 months, due to the required BSR hearing process that must take place.

Task 19: Testing Agency Effective Date

The American Gas Association Laboratories usually assigns an 18 month effective date (from the time of ANSI approval) for Z21 standards revisions. This is to allow manufacturers the time to make the necessary design changes and to have their listed products certified by the testing agency to meet the revised standard. However, when standards revisions have greater design impacts on the industry as a whole, longer effective dates are usually considered and implemented.



*See Attached Notes

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U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

August 17, 1994

Mr. Frank A. Stanonik
Associate Director of Technical Services
Gas Appliance Manufacturers Association
1901 North Moore Street
Arlington, VA 22209

Re: Water Heater Ignition of Flammable Vapors

Dear Mr. Stanonik:

Thank you for promptly providing information about ongoing industry activities to address the hazard posed by water heater ignition of flammable vapors.

The CPSC staff has a number of questions about the information you have provided. Attached is a list of our questions and concerns about the ongoing industry activities. CPSC staff plans to discuss these issues with industry at the August 30, 1994 meeting. Staff requests that industry representatives provide a written response prior to or at the meeting. This material will be used to assist the Commission in reaching a decision as to the need for rulemakeing to address the hazard of water heater ignition of flammable vapors.

If you have any questions, or if I can be of assistance in any way, please call me on (301) 504-0508, ext. 1303.

Sincerely,

Donald W. Switzer
Project Manager, Fire/Gas
Voluntary Standards

Attachment

CPSC STAFF QUESTIONS AND CONCERNS
FOR DISCUSSION AT AUGUST 30, 1994 MEETING

GAMA Flammable Vapor Hazards Ignition Study: Bowin Burner Testing

1. How long will individual tests be run before the test is terminated? Will the only criteria for terminating the test be the vapor concentration falling below the LEL at the burner?

2. What will be the criteria for a successful test?

3. Which "critical ANSI Z21.10.1 tests" will be run?

4. Will the critical tests be run on all of the water heaters?

5. At what heights will the FID detectors sampling tube be located?

6. What is the rationale for the movement pattern chosen for the dummy?

7. How does the Bowin burner operate?

8. What changes must be made to a typical water heater to incorporate the Bowin burner? What are the major difficulties?

9. Approximately what cost will the Bowin burner add to gas-fired water heaters available to the consumer?

10. When will GAMA know if the Bowin burner design is manufacturable?

11. If the Bowin burner is manufacturable, when does GAMA expect products using the technology will be on the market?

12. What steps will a "typical" water heater manufacturer have to go through to redesign and manufacture an improved product using the Bowin burner?

13. What are the test conditions referred to in item 6 of the 5/20/94 agreement between GAMA and Bowin Designs Pty. Ltd.? The Confidential Disclosure Agreement, which was attached, does not contain the conditions.

Letter to Donald Switzer

1. What information in the Task 1 results led GAMA and ADL to believe that floor temperature played a part in accidents? It seems to staff that the floor temperature will be cooler than air temperature in almost all real-world instances.

2. It is not clear to staff how the room temperature can be higher than the floor temperature if heating the floor was how the room was heated.

3. What was the air exchange rate in the rooms where the testing was performed?

4. What steps would a typical water heater manufacturer have to go through in order to develop a water heater that incorporates the Bowin burner?

5. How long would each step take?

6. Please provide a listing of residential gas-fired water heaters that are currently marketed which draw combustion air from the top of the appliance. Please provide a similar listing of water heaters that take combustion air from outside the room in which the appliance is installed. Please provide the market share for each design.

8. Please provide assembly drawings depicting major components of the appliances and how they are assembled.

9. What is the estimated average life of water heaters that draw combustion air from the top of the appliance or from outside the installation room? Is it different from conventional water heaters?

10. How many of each of these appliances are currently produced?

11. What is the retail price of each model produced?

12. The graphic provided showing the steps and schedule of the standards test method development shows the method development portion of the program being completed in approximately 10 months. It also estimates that it will take approximately 31 months for the standard to become effective. How can this process be accelerated? Are there alternatives to the full ANSI consensus process? Could International Approval Services (IAS) require products meet the requirements as soon as the subcommittee approves the test method?

13. GAMA has suggested that CPSC staff be appointed to the GRI Technical Advisory Group (TAG) for this project. Will GAMA allow CPSC staff to be present on site during critical phases of the testing?

14. Once the project is underway, how do the test staff communicate with the TAG, and how are TAG recommendations developed and communicated to the testers without slowing down the test program?

15. Does the TAG regularly review data and results from the testing? How often would that occur?

16. What assurances does GAMA provide that CPSC comments on the test program will be incorporated into the testing?

17. What organizations will be represented on the TAG?

18. GAMA states that there are 579 models of water heaters on the market. How is this number broken down? How many residential gas water heaters models are there? Of these models, how many are essentially duplicates? For example, Rheem sells what are essentially the same models under the names Rheem, Ruud, Marathon, and Sears. Are these being counted as one model or four models?

DEVELOPMENT OF A FLAMMABLE VAPORS SCREENING PROTOCOL FOR GAS-FIRED WATER HEATERS

1. On page 1-2, ADL states "However, this protocol is not intended to be a standard nor to address situations where the water heater has been misused, or has not been installed in accordance with manufacturer's recommendation or local building codes."

   If this is not intended to be a standard, then how does GAMA expect to have the water heater subcommittee accept it as a proposed test method?

2. Task 3, "Establish industry and Government Expectations" - On page 4-3,under "Approach," ADL states that they are "particularly interested in learning how well the proposed program and the resulting protocol accommodates the possible solutions being evaluated and developed by the manufacturers and those solutions proposed by others. Information on possible solutions will be used to enhance the flexibility of the protocol, and where appropriate will be kept confidential."

   Staff is concerned that ADL not tailor the test procedure to possible fixes. It is the staff's view that the test protocol must be absolutely technology blind. The incident data determine conditions that result in accidents. Pass/fail criteria should be developed based solely on the incident data. If any technological information is used to "enhance the flexibility" of the test method; it may hinder the ability of the method to fairly judge the suitability of other designs.

3. Task 4, Preliminary Testing" - On page 4-4, the fourth bullet is "Flammable limit characteristics of various flammable vapors with the intent of identifying a substitute, non-flammable liquid."

   Staff suggests that the test program be limited to gasoline vapors.

4. Task 6: Design and Conduct a Screening Experiment - If the test method is based on statistically designed case, consideration must be given to what portion of the accidents ADL is willing to accept. A different approach may be to establish a test condition certain to cause ignition. Staff is concerned that the proposed approach will unnecessarily delay the test program, and possibly leave a significant portion of the population unprotected.

5. Task 6: Design and Conduct a Screening Experiment - Why is water heater elevation included in Table 1: "Experimental Testing Tasks - Variables to be Considered?" The test method is being developed to certify the water heater design. The installation practices do not need to be considered.

   If industry decides to include water heater elevation as a test variable, the height will need to be determined. There is bound to be a strong height effect that will need to be quantified. Furthermore, the relevant variable is the height from which combustion air is taken, not the height of the water heater.

   CPSC staff believes that it is inappropriate to include water heater elevation in any of the test matrixes. The purpose of the test method is to design certify products, and not to depend upon elevated installation if the product is such that it is likely to be floor-mounted.

6. Task 7: Design and Conduct an Accelerated Test - Is modeling of time-to-ignition necessary? Please clarify how the data produced in this task will be used. If an acceptable time for resistance to vapor ignition is established based on incident data, then this task is not needed. In other words, if it is specified that a water heater must operate for one hour, for example, in an explosive atmosphere without igniting the vapor, then many of the variables will disappear. Size of spill, distance of spill, size of room, would all become irrelevant if the performance is specified based on accident data. Eliminating this Task would shorten the test period by 11 weeks.

7. CPSC engineering staff believes that there is a more direct and economical approach to design certify gas-fired water heaters' resistance to igniting flammable vapors. Staff believes that trying to model or mimic conditions in the field and adapting those standard conditions into a performance standard is overly expensive and time-consuming. With this approach, acceptable performance is based not on the product's design, but on "modeled" conditions that may or may not exist in the field.

   What is needed is a quick way to ascertain whether a water heater will ignite vapors when vapors are present. One direct way to accomplish this is to generate a flammable

mixture and determine if the water heater will cause ignition. A researcher would determine the height of the vapor cloud when a standard amount of gasoline is spilled (two gallons for instance) in a still small room (worst case conditions) to establish "test height." Then a water heater would be installed in a horizontally partitioned chamber to limit vapor height to the "test height." Establish a flammable vapor mixture in the lower portions, and determine if the water heater ignites the vapors in a specified period of time. ES staff is certain that ignition will occur quickly if it is to occur at all because ignition will be initiated by vapor leakage into the combustion chamber from the ambient environment. Considering the negative pressure in the combustion chamber, if there are any leaks in the chamber, the vapors will quickly migrate into the chamber. If the leaks are large enough to achieve a flammable mixture in the chamber, the product fails the test.

8. Would GAMA or IAS suggest ways of making the flow of fuel air mixtures into water heaters visible? Would a smoke source be useful to demonstrate what is happening?

9. Would GAMA consider a more specific goal useful at this time? If so, would an acceptable goal be to <u>substantially reduce the unintentional ignition of gasoline vapors by gas-fueled residential water heater</u>? Flammable vapors could be considered to mean everything from natural gas to liquids with flash points over 200°F.

"EVALUATION OF A 14" BARRIER PROPOSED AS A MEANS TO PREVENT ACCIDENTAL IGNITION OF FLAMMABLE VAPORS BY A GAS-FIRED WATER HEATER"

1. What vapor concentrations were measured at the "different distances above the floor?"

2. Have additional tests been performed subsequent to the work described in this white paper?

FLAMMABLE VAPORS IGNITION HAZARDS STUDY

1. The following materials were reviewed in ADL Task 1, and are listed in Appendix A. Staff request full citations on the following documents or copies.

Doc #	Title
60	Proposal for a Homeowner Water Heater Safety Awareness Program, Loran Nordgen & Company 6/22/92
64	Tech. Comm. Rpts., Log # 20, NFPA 54-A92TCR
65	Tech. Comm. Rpts., Log # 27, NFPA 54-A92TC
67	County of LA Fire Dept., w/attachments re garage fires
68	So. Cal. Gas Co.: Re: Hearing on fuel Burning Appliances in Private Garages

69 County of LA: Synopsis of Minutes of Public Hearing on Fuel Burning Appliances in Private Garages
71 Calspan Tech Rpt: Investigation of Safety Stds for Flame Fired Furnaces, Hot Water Heaters, Clothes Dryers, and Ranges
98 Calspan Report: "Identification and Classification of Potential Hazards Associated with the use of Residential Flame Fired Furnaces, Hot Water Heaters, Clothes Dryers, and Ranges"
140 LA city data
141 Sacramento city data

2. Please list which scenario was assigned to each Detailed Report listed in Appendix C of Task 1.

3. Were there supplemental sources used with the Detailed Reports? For example, Document #28 is CPSC investigation 88018CCC0228. The Appendix C narrative summary says "Hot and humid." One might expect an August 20 at 1:30 PM in Kentucky to be hot and humid; however, I do not find that statement in CPSC report or the attached civil action. The defendant or its insurance company may have had additional information.

4. In the Task 1 report, page 9, part of the discussion of the Oregon data has been changed, per R.F. Topping's letter of 11/24/93. The original report contains the statement, "However taking these violations into account, the average incident rate is still above the national average." Is that statement retained in the current text, or does the paragraph end with, "...in violation of the state building code?"

GENERAL COMMENTS AND REQUESTS

1. There is some information that may help us to get started on a more thorough economic analysis of the issues involved. This information may be obtainable through industry sources. Your help in obtaining this information would be much appreciated. On the models, or equivalents listed below, I would like to have the best information available on 1) the estimated useful life of the product, 2) the wholesale and retail prices, 3) the estimated annual energy cost, and 4) possible restriction on product use because of conflicts with local codes.

Bradford White Corporation
M-I-40S10LN (40 gallon, gas, Energy Saver)
M-I-50310LN (50 gallon, gas, *Energy Saver*)
M-I-40S10DS (40 gallon, electric, *Energy Saver*)
M-I-50T10DS (50 gallon, electric, *Energy Saver*)
M-II-504S10CN (50 gallon, gas, *Deluxe Extra Recovery*)
DV-II-40S10LN (40 gallon, gas, *Direct Vent Deluxe Energy*

H

Saver)
DV-II-50S10LN (50 gallon, gas, *Direct Vent Deluxe Energy Saver)*

A.O. Smith
FPD-40 (40 gallon, gas, *Sealed Shot)*
FPD-50 (O gallon, gas, *Sealed Shot)*
PGCG-40 (40 gallon, gas, *Conservationist)*
PGCG-50 (50 gallon, gas, *Conservationist)*

Ruud Water Heater Division
WL40 (40 gallon, gas, *Performer)*
WL50 (50 gallon, gas, *Performer)*

State Industries
SEX-40-NXRT (40 gallon, gas, *Turbo Super-Saver)*
SEX-50-NXRT (50 gallon, gas, *Turbo Super-Saver)*
SR8-40-NADS (40 gallon, gas, *Turbo Super-Saver Direct-Vent)*
SR8-50-NADS (50 gallon, gas, *Turbo Super-Saver Direct-Vent)*
TCL-40-2LRT (40 gallon, electric, *Lifetime)*

It would also be helpful to obtain any available information concerning the proportion of new water heater shipments that are higher priced models and the proportion that are lower priced models.

2. If the Commission directs publication of an Advance Notice of Proposed Rulemaking, what effect will that action have on ongoing industry activities to address the issue of water heater ignition of flammable vapors?

described in this white paper?

A1&2 Two tests were conducted [CPSC has video tapes.] The data on vapor concentrations and height are available from AGA Labs and were requested. One sampling device was used to test different heights successively, so there may not be very much data from the first test.

FLAMMABLE VAPORS IGNITION HAZARDS STUDY

ADL TASK 1

Q1. The following materials were reviewed in ADL Task 1, and are listed in Appendix A. Staff request full citations on the following documents or copies.

Doc #	Title
60	Proposal for a Homeowner Water Heater Safety Awareness Program, Loran Nordgen & Company 6/22/92
64	Tech. Comm. Rpts., Log # 20, NFPA 54-A92TCR
65	Tech. Comm. Rpts., Log # 27, NFPA 54-A92TC
67	County of LA Fire Dept., w/attachments re garage fires
68	So. Cal. Gas Co.: Re: Hearing on fuel Burning Appliances in Private Garages
69	County of LA: Synopsis of Minutes of Public Hearing on Fuel Burning Appliances in Private Garages
71	Calspan Tech Rpt.: Investigation of Safety Stds for Flame Fired Furnaces, Hot Water Heaters, Clothes Dryers, and Ranges
98	Calspan Report: "Identification and Classification of Potential Hazards Associated with the use of Residential Flame Fired Furnaces, Hot Water Heaters, Clothes Dryers, and Ranges"
140	LA city data
141	Sacramento city data

A1. The requested documents or their complete citations will be provided, less the Calspan reports, which CPSC has.

Q2. Please list which scenario was assigned to each Detailed Report listed in Appendix C of Task 1.

A2. Mr. Topping didn't know if the assignment of the reports to scenarios was readily available. He supervised Dale Larson who developed the scenarios. The reports exist in a data base. We can have the distribution if it is available. The complete files will cost approximately $1000 for coping. CPSC may not want the complete set of files. The scenarios do not have a simple correlation to the Task 2 tests. The scenarios were used to suggest the direction of

the tests and are a framework for the tests. The tests may be within or outside of the scenario framework. ADL justified full scale testing by saying the unresolved complexity of the actual incidents could not be resolved by other approaches. They said the full scale testing did not follow the scenarios, and we did not try to discuss any relationship between the scenarios and the incident reports or the National Fire Incident Reporting System (NFIRS) data.

Q3. Were there supplemental sources used with the Detailed Reports? For example, Document #28 is CPSC investigation 88018CCC0228. The Appendix C narrative summary says "Hot and humid." One might expect August 20 at 1:30 PM in Kentucky to be hot and humid; however, I do not find that statement in CPSC report or the attached civil action. The defendant or its insurance company may have had additional information.

A3. It was unclear if supplemental information had been used.

Q4. In the Task 1 report, page 9, part of the discussion of the Oregon data has been changed, per R.F. Topping's letter of 11/24/93. The original report contains the statement, "However taking these violations into account, the average incident rate is still above the national average." Is that statement retained in the current text, or does the paragraph end with, "...in violation of the state building code?"

A4. The intent of revising the discussion of the Oregon data was to back off from making conclusions. Topping will check with Larson on the exact complete statement.

ADL TASK 2

Q1. What information in the Task 1 results led GAMA and ADL to believe that floor temperature played a part in accidents? It seems to staff that the floor temperature will be cooler than air temperature in almost all real-world instances.

A1. The intent was not to vaporize the fuel more quickly. ADL feels seasonality and geographic location are factors in the data. The room chamber was heated to simulate "... the South baking at 100°F for days on end."

At this point staff asked what the purpose of the fire tests was: whether to try to recreate injury scenarios to see if ignition occurred, or to create a variety of conditions to see what would cause a fire. Mr. Topping replied it was more like the latter.

Q2. It is not clear to staff how the room temperature can be

higher than the floor temperature if heating the floor was how the room was heated.

A2. The tests were conducted in a chamber within a wood and plastic "green house" outside of the AGA Labs test building. The chamber ceiling and walls were drywall (unpainted?) and the floor was metal. Under the metal floor were water coils, to control temperature, on top of a 4 inch concrete slab. The chamber was heated by heating the floor and blowing hot air from a construction heater into the room. The floor was sometime hotter than the room because the room air cooled more quickly than the floor after the construction heater was removed. The tests were conducted in Cleveland, OH, in February through May.

Q3. What was the air exchange rate in the rooms where the testing was performed?

A3. The air exchange rate was not measured. It was loosely estimated at 0.1 volume exchanges per hour. During this discussion Mr. Topping stressed the apparent complexity of the problem to explain why ADL felt full scale tests were necessary. CPSC noted this statement explained why CPSC had to understand the Task 1 scenarios.

Q4. The Task 2 report indicates that measurements were taken to ascertain the concentration of gasoline vapors during the testing. Please provide the maximum height the vapor cloud achieved while the concentration remained above the lower explosive limit (LEL).

A4. The duration of the tests depended upon the vapor concentration. The LEL was measured, and when dispersion overcame vaporization, and the vapor concentration fell below the LEL, the test was stopped. The maximum height was not measured, but was stated as, 'over 18" for 1 gallon."

Q5 Was ADL able to ascertain where ignition initiated? Did ADL staff record where ignition actually took place?

A5. The location of the ignition was not determined. There is additional information in the complete files.

Q6. Why was the floor heated?

A6. See A2.

Q7. What were the maximum temperatures achieved during each test, counting from the time the gasoline container was first places in the test room?

Q7. Question not asked.

Q8. Were preliminary tests run that are not reported in the final report? What were the results of those tests?

A8. There were no preliminary runs. One run, #5, was not recorded.

Q9. What was the basis for the floor and air temperatures chosen in the tests?

A9. The floor temperatures used were an attempt to duplicate climate. The question of developing temperature data from Task 1 was not raised.

Q10. How did the empirical results for the location of the vapor cloud compare with the profiles predicted by the dispersion models?

A10. The tests results are consistent with the profiles predicted by the dispersion model, but "verify" is too strong to describe the relationship between the two.

Q11. Please rank the relative importance of the following parameters, as determined by the dispersion models; spill surface, floor temperature, room temperature, room boundaries, liquid composition, and ventilation. Was there an effort to ascertain the relative importance of agitation, as provided by the dummy?

A11. Factor rank was based on observations, not the model. Ordinal data were not provided. See Task 2 3.4.5 Additional Observations, p.26.

Q12. Question Intentionally blank (misnumbered).

Q13. Were tests run using a three dimensional dummy? If so, what were the results?

A13. A 3-D dummy was not tested. They were not trying duplicate a particular situation.

Q14. What is the distribution pattern of air introduced into a operating water heater for combustion? Was the velocity profile depicted in Figure 3 of the Task 2 report symmetrical in all directions?

A14. The combustion air velocity profiles were simulated at ADL using a blower in a water heater and were symmetrical. In the discussion of ignition Mr. Dewerth observed that 1/2 gallon of gasoline "wetted the whole corner of the room." The amount of gasoline used was discussed at this point. The Task 1 Basement/Garage Scenario specifies the amount of gasoline as "leak" this was described as the "Volkswagen scenario." Test(s)were not conducted on this scenario.

Q15. Staff presumes that the profile depicted in Figure 3 is with the water heater installed on the floor. Were any tests run to ascertain the velocity profiles when the water heater was installed on a stand?

A15. Velocity profiles were developed for elevated water heaters, and they were consistent with the floor level heater. On the floor the air velocity is 1.5 inch/sec measured 1 inch from the heater.

Q16. Was test 16 the only test run where the can was spilled away from the water heater?

A16. This was the only test where the can was spilled away from the heater. In test 16, two cans were tipped, one toward and one away from the water heater. The answer is not completely clear.

Four items relevant to the test conditions were discussed at this point. 1) There was concern that a spill on a metal floor would spread further that a similar spill on a concrete floor. ADL conducted a spill test, and the spill on the concrete floor seemed about the same size or a little larger. 2) The air opening to the test chamber was in accordance with the National Fuel Gas Code. 3) The gasoline was stored outside prior to the tests. 4) ADL felt that mass transport of gasoline vapor was more important in these incidents than vapor diffusion.

GENERAL COMMENTS AND REQUESTS

Q1. There is some information that may help us to get started on a more thorough economic analysis of the issues involved. This information may be obtainable through industry sources. Your help in obtaining this information would be much appreciated. On the models, or equivalents listed below, I would like to have the best information available on 1) the estimated useful life of the product, 2) the wholesale and retail prices, 3) the estimated annual energy cost, and 4) possible restriction on product use because of conflicts with local codes.

Bradford White Corporation
M-I-40S10LN (40 gallon, gas, *Energy Saver*)
M-I-50310LN (50 gallon, gas, *Energy Saver*)
M-I-40S10DS (40 gallon, electric, *Energy Saver*)
M-I-50T10DS (50 gallon, electric, *Energy Saver*)
M-II-504S10CN (50 gallon, gas, *Deluxe Extra Recovery*)
DV-II-40S10LN (40 gallon, gas, *Direct Vent Deluxe Energy Saver*)
DV-II-50S10LN (50 gallon, gas, *Direct Vent Deluxe Energy Saver*)

A.O. Smith
FPD-40 (40 gallon, gas, *Sealed Shot*)
FPD-50 (50 gallon, gas, *Sealed Shot*)
PGCG-40 (40 gallon, gas, *Conservationist*)
PGCG-50 (50 gallon, gas, *Conservationist*)

Ruud Water Heater Division
WL40 (40 gallon, gas, *Performer*)
WL50 (50 gallon, gas, *Performer*)

State Industries
SEX-40-NXRT (40 gallon, gas, *Turbo Super-Saver*)
SEX-50-NXRT (50 gallon, gas, *Turbo Super-Saver*)
SR8-40-NADS (40 gallon, gas, *Turbo Super-Saver Direct-Vent*)
SR8-50-NADS (50 gallon, gas, *Turbo Super-Saver Direct-Vent*)
TCL-40-2LRT (40 gallon, electric, *Lifetime*)

It would also be helpful to obtain any available information concerning the proportion of new water heater shipments that are higher priced models and the proportion that are lower priced models.

A1. GAMA can provide energy used items, but they do not collect product life, wholesale or retail pricing, or building code conflict information.

Q2. Please provide a listing of residential gas-fired water heaters that are currently marketed which draw combustion air from the top of the appliance. Please provide a similar listing of water heaters that take combustion air from outside the room in which the appliance is installed. Please provide the market share for each design.

A2. AGA Labs suggested we look at the AGA listings for water heater drawing their combustion air from the top and from outside. It was suggested we look at Appliance magazine for market data.

Q3. Please provide assembly drawings depicting major components of the appliances and how they are assembled.

A3. GAMA will try to get typical useful drawings.

Q4. What is the estimated average life of water heaters that draw combustion air from the top of the appliance or from outside the installation room? Is it different from conventional water heaters?

Q5. How many of each of these appliances are currently produced?

A4&5 Suggest we look at the September issue of Appliance magazine for product sales and life data.

Q6. What is the retail price of each model produced?

A6. GAMA does not collect price data.

Q7. GAMA states that there are 579 models of water heaters on the market. How is this number broken down? How many residential gas water heaters models are there? Of these models, how many are essentially duplicates? For example, Rheem sells what are essentially the same models under the names Rheem, Ruud, Marathon, and Sears. Are these being counted as one model or four models?

A7. AGA Labs will look at how the same design is certified under different listings and provide relevant information.

Q8. If the Commission directs publication of an Advance Notice of Proposed Rulemaking, what effect will that action have on ongoing industry activities to address the issue of water heater ignition of flammable vapors?

A8. Mr. Mattingly thought that rule making could delay product innovations. He said the need to address the hazard is recognized, and research will be funded by manufacturers. They might delay that funding if CPSC was going to direct the solution so as to avoid research in a direction that would not fit with CPSC's regulatory plans.

New Technology Development and Evaluation

Q1. Are new technologies being evaluated to address the hazard of water heater ignition of flammable vapors?

Q2. What is the status on the new technology development and testing?

A1&2 New Technology and Test Method Development will be discussed after evaluating work in progress.

Test Method Development

Q1. Are industry efforts planned to develop performance requirements for gas-fired water heaters to address the issue of water heater ignition of flammable vapors?

Q2. What is the status of standard development efforts?

A1&2 New Technology and Test Method Development will be discussed after evaluating work in progress.

GAMA agreed to answer the written questions from the CPSC staff contained in the CPSC letter to Frank Stanonik, dated August 17, 1994.

Gama

1901 North Moore Street · P.O. Box 9245 · Arlington, Virginia 22209 · 703/525-9565

October 3, 1994

Mr. Donald W. Switzer
Project Manager
Fire/Gas Voluntary Standards
U.S. Consumer Product Safety Commission
Washington, D.C. 20207

Re: Water Heater Ignition of Flammable Vapors (Your August 17, 1994 letter)

Dear Mr. Switzer:

This is in response to your August 17, 1994, letter requesting additional information from GAMA relating to water heater industry and gas industry activities to address ignition of flammable vapors by gas water heaters. GAMA has previously provided information to CPSC staff about water heater industry activities in this area in letters dated June 14, July 28 and August 1, 1994. GAMA has also arranged for CPSC staff to be briefed by Arthur D. Little, Inc. (ADL) on its work for the water heater industry in this area. On August 30, 1994, Dick Topping of ADL responded to CPSC staff's questions about ADL's Flammable Vapor Hazards Ignition Study Task 1 and Task 2 reports. Also at that meeting, Doug DeWirth of International Approval Services (IAS) (A.G.A. Laboratories in the United States) responded to CPSC staff questions about IAS testing of the ability of a collar sealed to the floor around a gas water heater to prevent flammable vapors ignition. On October 5, 1994, Dick Topping will brief CPSC staff on the results to date of ADL testing of a prototype burner designed to prevent ignition of flammable vapors.

In your August 17 letter, you ask a number of questions about the data collection and analysis and testing of water heaters done by ADL in preparing its Task 1 and Task 2 reports. These questions were covered during the August 30 meeting. CPSC staff agreed at that meeting to identify any particular materials in ADL's Task 1 and Task 2 project files it wishes to have copied at CPSC expense and produced to CPSC.

Your letter also asks a number of questions and raises several issues concerning the development, under the auspices of the Gas Research Institute (GRI), of a "flammable vapors screening protocol for gas-fired water heaters." As you know,

/Continued . .

GRI is forming a Technical Advisory Group (TAG) to guide this effort. CPSC staff has been invited to be on the TAG, and you have already discussed CPSC staff participation with Bob Hemphill, the GRI project director. As a member of the TAG, you should have ample opportunity to participate fully in the process of developing a suitable screening protocol and to provide desired input into the final product of that effort. We anticipate that GRI will follow its standard practices concerning the role of the TAG. However, you should recognize that GAMA and GRI are distinct entities and that GAMA will not be in a position to dictate what happens in this process. Nevertheless, you can be assured that GAMA will continue to support full CPSC staff participation in the process.

In your letter, you also ask numerous questions about the operation, testing and commercial feasibility of the previously mentioned burner that ADL has been testing. ADL testing of this burner has not yet been completed. On October 5, ADL will report to you on the results to date of its testing of this burner. ADL will respond at that time to your questions regarding the scope, methodology and results of the testing. ADL may not be able to answer many of your questions about the operation of the burner because ADL, GAMA and water heater manufacturers are parties to confidentiality agreements with the owner of the burner prohibiting disclosure to third parties of the operating details of the burner.

Your questions about the commercial feasibility of the burner and the added cost of water heaters employing the burner cannot be answered at this time. GAMA does not know the process by which individual water heater manufacturers evaluate new technology and design new products. We do know that at present this particular burner is not being produced on a commercial scale, and that the owner of the burner appears not to have the manufacturing capacity to supply the burner to U.S. water heater manufacturers on a commercial scale. The owner of the burner could choose to license water heater manufacturers to manufacture and use the burner and charge them a royalty, which presumably would be reflected in the cost of the water heater. GAMA does not know what royalty the owner of the burner would charge, and we do not know that any licensing negotiations for the manufacture or use of the burner have begun.

In your letter, you also ask for information about residential gas-fired water heaters "which draw combustion air from the top of the appliance," or "take combustion air from outside the room in which the appliance is installed." We read both of these descriptions as referring to direct vent water heaters. GAMA does not collect statistics on direct vent water heaters; therefore, we are unable to answer your questions concerning

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annual shipments, prices, market share, and average life of these products. We do know that all gas-fired mobile home water heaters are direct vent. In response to your request for a listing of direct vent water heaters now available in the marketplace, we refer you to the July 1, 1994, edition of the A.G.A. Laboratories' Directory of Certified Appliances and Accessories.

You have also asked how many different models of residential gas water heaters there are. We previously said that there are 579 models of water heaters on the market; this figure included gas, electric and oil water heaters. There are about half as many gas water heater models. For a full listing of residential gas water heater models available in the marketplace, we again refer you to the July 1, 1994, edition of the A.G.A. Laboratories' Directory of Certified Appliances and Accessories. GAMA is unable to distinguish whether particular models are essentially duplicates of other listed models. Individual water heater manufacturers have their own proprietary technical and marketing reasons for distinguishing one model from another. Energy source, input rate, storage capacity and energy efficiency clearly are among the main factors that may distinguish one model from another.

In your letter, under "General Comments and Requests," you ask for information on specific water heater models, i.e. estimated product life; wholesale and retail prices; estimated annual energy cost; and possible local code restrictions. GAMA has no data on estimated or average lifetimes of any specific water heater model, nor do we have any data on wholesale or retail prices of specific models. GAMA has never collected this kind of information for any purpose. We also do not know of any local code restrictions on use of any of the listed models, which is not to say that such restrictions do not exist.

GAMA is able to estimate the average annual energy cost of operation of the listed models based on the Energy Factors listed for these models in GAMA's Consumers' Directory of Certified Efficiency Ratings and the latest average national energy costs published by the U.S. Department of Energy. This information is provided in the attachment to this letter.

Finally, you have asked in your letter GAMA's opinion as to the likely effect CPSC initiation of a rulemaking proceeding would have on ongoing industry activities to address the issue of water heater ignition of flammable vapors. GAMA believes that the water heater industry and individual water heater manufacturers are committed to finding a technical solution to this problem if one exists. We believe they are working diligently toward that goal, exploring a variety of potential "fixes". At the moment, based on credible testing, we know that

/Continued . . .

the 18-inch elevation of water heaters proposed by Ed Downing is not the answer; neither is the collar or barrier proposed by Joe Fandey. Very shortly, you will know more about the tested performance of water heaters equipped with the previously discussed burner. You and your colleagues on the CPSC staff will also have the opportunity to influence the development of the test protocol to be used to evaluate all proposed solutions to this problem.

Given the degree to which we have tried to involve CPSC staff in the industry's efforts to address this issue, we do not think that a rulemaking proceeding is necessary to insure that CPSC staff is kept informed of industry activities in this area. More importantly, we do not see how a rulemaking proceeding would accelerate the process of finding an effective solution. The industry is not going to be forced by the CPSC into adopting an unreliable solution such as the 18-inch elevation of water heaters proposed by Mr. Downing. The result of CPSC mandating 18-inch elevation of water heaters is sure to be litigation challenging the CPSC's support for its rule.

Moreover, there is a risk that a CPSC rulemaking proceeding would cause at least some water heater manufacturers to become more passive about finding a technical solution to the problem. Manufacturers might let the CPSC try to solve the problem rather than try to solve it themselves. A manufacturer might be reluctant to devote substantial resources to the development and evaluation of new technology for fear that the CPSC might mandate a wholly different solution to the problem.

Sincerely,

C. Reuben Autery
President

CRA:dml

Attachment

WATER HEATER MODEL	ESTIMATED ANNUAL COST OF OPERATION (NATIONAL AVERAGE)
Bradford White Corporation	
M-I-40S10LN	$159
M-I-50310LN	$167
M-I-40S10DS	$419
M-I-50T10DS	$429
M-II-504S10CN	$159
DV-II-40S10LN	$151
DV-II-50S10LN	$156
A.O. Smith	
FPD-40	$153
FPD-50	$151
PGCG-40	$151
PGCG-50	$151
Ruud Water Heater Divsion	
WL40	Discontinued Model
WL50	Discontinued Model
State Industries	
SEX-40-NXRT	$148
SEX-50-NXRT	$151
SR8-40-NADS	$153
SR8-50-NADS	$151
TCL-40-2LRT	$410

J

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: SEP 16 1994

TO : Donald W. Switzer
Manager, Fire/Gas Codes Standards Project
Directorate for Engineering Sciences

Through: Robert E. Frye, Director
Division of Hazard Analysis

FROM : William Rowe (504-0470-1271)
Division of Hazard Analysis

SUBJECT: Review of the Scenarios from Arthur D. Little's Flammable Vapor Hazards Ignition Study, Task 1 Report

Arthur D. Little Inc. of Cambridge, MA (ADL), was employed by the Water Heater Division of the Gas Appliance Manufacturers Association (GAMA) to study gas water heater ignition of flammable vapors. Gasoline vapor was emphasized. In the Task 1 Report scenarios were developed which became the basis for full scale fire tests in Task 2 at International Approval Services (IAS), however these full scale tests were not attempts to duplicate the Task 1 scenarios.

ADL used seven scenarios, shown in Attachment 1. The scenarios were based on 142 reports listed in Appendix C, Detailed Reports, of Task 1. These incidents were 103 CPSC Epidemiological Investigation Reports (EIR), and 39 National Fire Protection Association (NFPA) reports, not found in the EIRs. In this review, incidents were assigned by CPSC staff to the seven ADL scenarios or an "out-of-scope"category based upon the information in each report and the parameters of each scenario in the ADL Task 1 Report. A report was categorized "out-of-scope" if it was not an unintentional residential fire due to ignition of gasoline vapors by a gas water heater. Some reports seemingly could be categorized two ways. For example; a power tool that leaked gasoline in a utility room, could be categorized by ADL as "Utility Room Spill Inside," which involves one gallon of gasoline, or as "Garage/Basement Leak," which uses a room twice as large as the utility room. The distribution of the 142 reports in Appendix C by CPSC together with the number of deaths, injuries, and incidents with casualties associated with each is shown on Table 1. The ADL Task 1 Report does not say which scenario each report was allotted to, or what was the distribution of the reports between the seven scenarios, so a direct comparison of CPSC's analysis with ADL's is not possible. The allocation of reports to the scenarios was requested at the August 30 meeting between CPSC and GAMA. GAMA said they would provide this distribution later, if it is readily available.

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The scenarios developed by ADL, and later used as the framework for full scale tests, have the following variables:

Location includes room size, either 10x7x8 FT, 10x10x8 FT, or 10x20x8 FT and whether the spill occurred inside or outside the room (the liquid gasoline or its' vapors can go under a door). Only one scenario of the seven had the gasoline source outside the room.

Features refers to the room's contents. The only operating equipment in the room was a 40 gallon water heater. All seven scenarios appear to have used the same type of water heater.

Quantity is the amount of gasoline spilled in the test. It is not the amount of gasoline vaporized. Four of the scenarios used 1 gallon of gasoline, two used 1 to 5 gallons, and one was a slow leak with the total amount leaked unspecified.

Source refers to whether the gasoline was initially spilled or otherwise evaporated, and whether it was inside or outside the room, repeating some information found under the location variable.

Activity means movement of potential victims, and in one scenario also describes the water heater operation. Five of the scenarios involved movement of people represented by a manikin and two did not.

If the Task 2 tests had been attempts to duplicate all the conditions used in the seven scenarios they would have had to consider that there are three room sizes, three quantities, three sources, and three activities. This could result in 81 different experiments, but this was not done. No attempt was made in Task 2 to duplicate the Garage/Basement Leak scenario.

When enough flammable liquid is vaporized, it will ignite if there is an ignition source; the vapor is said to have reached the Lower Explosive Limit (LEL). The concept of a LEL provides a convenient way to look at various combinations of room size and the amount of vapor present. Gasoline that has not vaporized is not a factor in ignition, though it may be involved in the subsequent fire after it vaporizes. Thus, if one were to consider modeling a gasoline fire ignited by a gas water heater they could combine the Location, Quantity, and Source from the ADL Task 1 Report by considering the LEL. The smallest quantity specified is 1 gallon. and at the LEL a flammable mixture of 1 gallon of gasoline and air has a volume of about 2,100 $Ft.^3$ (Handbook of Industrial Loss Prevention) The largest room in the seven scenarios has a volume of 1,600 $Ft.^3$, so all the scenarios related to the full scale tests had enough gasoline to fill the entire room with an explosive mixture.

Ideally, one would know how much gasoline had vaporized just before the vapor ignited; and this is not available from any sample of incident data we know of. Next best would be knowing the amount spilled or leaked. In some CPSC EIRs the amount is described as "small", a "jar", etc. Sometimes there is information about the container. About half of the incidents, where the amount of gasoline involved is implied, appear to have involved leaks. However all the gasoline in the Task 2 tests came from spills. The fires involving leaks from power lawn mowers and weed trimmers are limited by the size of the fuel tanks,

and thus provide useful information. Mower fuel tanks are typically 2 quart and trimmers 1 quart. If ADL has assumed the tanks were half full and made the typical spill 1 quart or less, their scenarios might have been more representative. This would have produced a vapor cloud over 3 feet. high in the largest room. The injuries in some of the incidents suggest less gasoline, because just the legs of the victims were burned. This would be consistent with the fire data from Oregon, where all new water heaters have been elevated since 1976, and California, where some building codes require that water heaters be elevated. These data suggest elevating the water heaters in garages reduced the risk of flammable vapor fires.

Table 1: CPSC Allocation of Incidents, Deaths, and Injuries from Appendix C of the ADL Task 1 Report

Scenario	Number of Reports	Number of Reports with Death or Injuries	Number of Death s	Number of Injuries
Bathroom	10	10	6	14
Utility Room Spill Outside	5	3	12	5
Utility Room Spill Inside	11	6	2	4
Garage/Basement Use	8	5	3	3
Garage/Basement Refuel	12	9	13	4
Garage/Basement Leak	21	9	10	8
Garage/Basement Playing	23	21	15	13
Out-of-Scope	50 (+2 duplicates)	42 (+2 duplicates)	20	55

Source: CPSC/EPHA and Arthur D. Little, Inc. 1993 "Flammable Vapor Hazards Ignition Study, Task 1 Report

Table 1 shows 61 deaths and 51 injuries from the 90 in-scope form the ADL Task 1 report. These deaths and injuries occurred in 63 of 90 incidents. In Table II-3/4 of Appendix

report. These deaths and injuries occurred in 63 of 90 incidents. In Table II-3/4 of Appendix D, the ratio of reports with casualties to total incidents is referred to as a Severity Ratio. The severity ratio for gas water heaters and gasoline is given as 18.2 percent. The severity ratio of in-scope incidents, as calculated by CPSC, after Garage/Basement Leak scenario is subtracted is 78 percent. Therefore the reports used in ADL Task to develop typical scenarios may be about four times as severe as the national data presented in the TASK 1 Report.

The ADL Task 1 Report states the scenarios, in which the only flammable liquid was gasoline, represent 80 to 90 percent of the flammable vapor incidents involving gas water heaters. Appendix D National Fire Incident Report System (NFIRS) Analysis: Data Tables, Table II-1/2, 1988-90 FIRE INCIDENTS BY EQUIPMENT INVOLVED IN IGNITION shows 75 percent of the gas water heater fires associated with flammable vapors are associated with gasoline. The 75 percent figure agrees with CPSC estimates from the National Fire Incident Reporting System (NFIRS) data.

Conclusions

> The scenarios developed by ADL do not represent the National Fire Incident Reporting System (NFIRS) data provided to ADL.
> The scenarios are limited to relatively large amounts of gasoline.
> The test conditions developed by ADL in Task 2 did not include leaks. The incident data in Task 1 showed leaks were important.
> The Task 2 tests were a poor model for the epidemiological data available to ADL and CPSC.

Attachment(s)

cc:
Dr. Robert D. Verhalen

Attachment 1

Scenarios used in ADL Flammable Vapor Hazards Ignition Study

Scenario	Location	Features	Quantity	Source	Activity
Bathroom	Inside 10x7x8FT room	40 gallon Heater Window 4x3FT	1 gallon Gasoline in container	Evaporation from clothing in center of room.	1-3 persons moving Heater firing
Utility Room, spill outside	Outside door of 10x10x8FT room	40 gallon Heater Furnace etc.	1 gallon Gasoline in container	Evaporation from outside room.	No activity
Utility Room, Spill inside	Inside 10x10x8FT room	40 gallon Heater Furnace etc.	1-5 gallon Gasoline in container	Spill in room	Movement in vicinity of heater
Garage/ Basement Use	Inside 20x10x8FT room	40 gallon Heater Furnace etc.	1 gallon Gasoline in container	Evaporation from use	Movement in vicinity of heater
Garage/ Basement Refuel	Inside 20x10x8FT room	40 gallon Heater Furnace etc.	1 gallon Gasoline spill	Spill and evaporation	Movement in vicinity of heater
Garage/ Basement Playing	Inside 20x10x8FT room	40 gallon Heater Furnace etc.	1-5 gallon Gasoline in container	Spill and evaporation	Movement in vicinity of heater
Garage/ Basement Leak	Inside 20x10x8FT room	40 gallon Heater Vehicle	Slow leak	Evaporation	None

Source: Arthur D. Little, Inc. 1993 "Flammable Vapor Hazards Ignition Study, Task 1 Report

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United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: March 10, 1994

TO: Joseph Z. Fandey, ESEE

Through: Robert T. Garrett, Acting Director ESEL

FROM: J. L. Mulligan, ESEL

SUBJECT: Comments on the A.D. Little Study of Gasoline Vapor Ignition.

Ref: Memo, Fandey to Bradley, "Request for Engineering Services", 25 August 1993.
Report, Arthur D. Little, Inc., "Flammable Vapor Hazards Ignition Study; Task 2: Analytical Modeling and Experimental Testing", Reference 42238, 15 July 1993
Report, Melhem, G.A. & P.A. Croce. Arthur D. Little, Inc., "Advanced Consequence Modeling: Emission, Dispersion, Fires and Explosions", Second Draft July 1993
Meetings, J.L. Mulligan, CPSC, with Richard Topping, Nelson Macken and George Melhem, A.D. Little Inc., 16-17 December 1993

Introduction and Purpose

The purpose of this memo is to present an engineering review of the Task 2 study by A. D. Little. The stated overall goal of the GAMMA/A.D. Little project was "to develop a comprehensive understanding of the extent of the hazards and the effectiveness of current mitigating measures." However, while the previous statement may have been the overall goal of the project; the goal of the Task 2 effort as stated at the December meeting was more limited:

> The objective of the analytical modeling and experiential testing task was to determine if gasoline spills in the vicinity of gas fired water heater represented a fire and explosion hazard potential. We [A.D. Little] make a distinct difference between potential and likelihood. While hazard potential depends on spill characteristics, the likelihood of ignition has probabilistic aspects associated with it. The scope of this task did not attempt to quantify in any way the probabilistics of ignition, but focused on assessing potential.

This memo will discuss the information from the report and the topics discussed during the meetings in December.

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Testing

From the meeting in December it was evident that the major A.D. Little emphasis during this Task 2 was on testing. While A.D. Little felt that the testing reflected the scenarios developed in the Task 1 effort, the purpose was, as stated, "to show the hazard potential." Based on this criterion, the emphasis was on the conditions that would produce fires. It appears that some test decisions were made primarily to create fire conditions. However, even with these explanations, there are several questionable areas in the tests:

- The use of two one-gallon gas cans in the two-gallon spill.
- The manner in which air movement was generated with the dummy.
- The use of high floor temperatures with low air exchanges.

While one unknown in the incidents is the actual amount of gasoline spilled, the concurrent spill of two one-gallon cans would seem to be unusual. The method and frequency of air movement is another area where, admittedly, the experimental procedure was implemented without scientific data for justification. The implementation seems unusual and the relationship of this demonstration to the real world needs further thought. The whole subject of air movement and the effect on ignition of gasoline vapors may need further study unless the mitigation method overcomes the effect. The high floor temperatures were rationalized by A.D. Little to represent carports in the summer heated by the sun. However, the air exchange rate (really the gas vapor removal rate) in the carport would be much higher than that used in any of the tests.

Even with these limitations the tests had some very interesting implications when comparing the safety of floor mounted water heaters to ones mounted 18 inches above the floor.

Floor Mounted

According to the report, when the water heater is floor-mounted:

1. A one-gallon spill always resulted in a fire when the water heater was operating.
2. Fires will occur even when only the pilot light is on.
3. Induced movement of the air and vapors is not necessary for ignition.
4. Fires will occur even with air exchanges as high as two air changes per hour.

The stated conclusions in the report were:

> "... a floor mounted water heater will ignite flammable vapor from a one gallon spill or larger in a room the size of a one-car garage. For a smaller room of about 60 ft^3, the same hazard is present with a spill as small as .5 gallons."

These tests show what well could be an unnecessary risk of injury in an accident situation where, based on the accident reports, the hazard is not apparent to the consumer and where mitigation methods, that could reduce the risk, are known.

Mounted on 18 Inch Stand

While the data in the report for the floor mounted heaters is fairly straight forward, the data for a heater mounted on an 18 inch stand needs to be carefully examined to learn what information it contains. Three room configurations were used for the tests, a large room (10 feet x 20 feet x 8 feet) and two smaller rooms (8 feet x 8 feet x 8 feet and 6 feet x 10 feet x 8 feet). The data for the rooms are:

The large room:

1.	Without movement[1]-	two gallon spill	two fires in five tests
2.	With movement -	two gallon spill	resulted in fires
		1.5 gallon spill	two fires in three tests
		one gallon spill	one fire in five tests.

The small rooms:

1.	Without movement-	one gallon spills	no ignition.
2.	With movement -	half-gallon spills	ignition.

The "conclusion" in the data section of the report is stated as:

> The conclusion to the tests with gasoline spills in small rooms (about 60 ft^2) with the elevated water heater is that ignition is likely with one gallon spills with no motion and with spills as small as .5 gallons with motion.

[1] In one test, in which there was a fire, considerable air movement was observed. The A.D. Little experimenter attributed this air movement to external factors.

This "conclusion" in the report was discussed at the December meeting. The experimenter's explanation was that this statement was probably the result of poor proofreading of the report. The test data presented in the report clearly indicates that no ignition will occurs for a one gallon spill with no motion of the dummy when the heater is elevated 18 inches. The data also indicates that the probability of ignition is definitely decreased in the other cases when the heater is elevated 18 inches. From discussions at the meeting in December, it appears that the conclusion A.D. Little wanted to make was that raising the water heater 18 inches, as a mitigation method, would not prevent ignition in all cases.

Analytical Modeling

The report stated the objective of the Analytical Modeling Task was to provide insight into the selection of key parameters for experimental testing. This effort was to include identification and verification of incident scenario patterns and an assessment of parameter sensitivity for experimental testing. From the December meetings, it was evident that the experiential task took precedence over the analytical and that only very cursory analytical modeling was undertaken for this task.

The "SuperChems™" Program.

"SuperChems™", "Super Charged Hazard Evaluation MethodS for Integrated Design Safety™", is a multifarious implementation of mathematical consequence modeling. This type modeling is used for risk quantification, emergency response planning, loss prevention, safe design, and environmental planning. One definition of this modeling is "*the use of solutions of mathematical representations of conservation and physical laws to analyze and quantify potential damaging effects of hazardous events.*"[2]

The modeling in the SuperChems™ program, follows this definition. It begins by determining source terms and then, dependent on the problem to be addressed, can quantify dispersion, fire and explosion hazards. There is no claim that this program "accurately predicts" all these hazards for all cases. The program has been validated for certain type "spills" against large scale tests and showed good agreement.

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[2] Melhem, G.A. & P.A. Croce, "Advanced Consequence Modeling: Emission, Dispersion, Fires and Explosions" Second Draft, July 1993, A.D. Little, Inc.

CPSC has a "Beta test" version of the SuperChems™ program, Version 1.21. The program, although complete in some aspects, is still in development. One of the extensions that A.D. Little appears to be looking at is the application of this tool to areas of more interest to CPSC. These extensions include the potential hazards associated with "small scale" problems, e.g., small gasoline spills ignited by gas water heaters. One possible difficulty in these extensions is that many parameters, used in the current modeling, are based on experimentation and empirical data from large scale spills. The applicability of the approximations, the theory and the program to small spills still has to be shown. As an example for some large spills an accuracy of 100 feet may be more than adequate, where for the small gasoline spills accuracies less than one inch (1") might be needed.

Conclusions:

A.D. Little reached the following conclusions in the report:

> As a result of these tests, we [A.D. Little] have several general conclusions:
>
> - A gasoline spill near a floor mounted water heater is likely to result in ignition of flammable vapor.
> - Rags soaked in gasoline in small rooms can present ignition sources.
> - Repeated tests are required to validate conclusions due to the variability and uncertainty associated with tests of this nature.
> - An 18-inch stand will delay but not eliminate ignition of flammable vapor, particularly in realistic situations where movement is present. The delayed ignition can produce significant pressure waves."

Based on the critical engineering review of the test, analysis and report, and the meetings with A.D. Little, the ES staff conclusions are:

- Raising a water heater 18 inches appears to significantly reduce the likelihood of ignition in the case of a gasoline spill.
- The A.D. Little analysis and test for Task 2 had a much narrower purpose than the overall project purpose stated in the report. That is, rather than "to develop a comprehensive understanding of the extent of the hazards and the effectiveness of current mitigating measures.", the purpose of the Task 2 effort was to show that gasoline spills in the vicinity of gas fired water heater represented a fire and explosion hazard potential.
- The SuperChems™ computer program may have applicability not only to the gasoline vapor / water heater analysis but to many other interests of the Commission, e.g., IAQ. However, the program may need to be verified by experiments depending upon the application.

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Recommendations

Since CPSC's efforts in this area are ongoing, it is probably premature to make definitive recommendations as to the direction CPSC should take. However, the efforts, to date, do allow some general comments and recommendations:

- The efforts by CPSC, as well as the tests conducted in the GAMMA/A.D. Little study, show that the risk of injury from the ignition of flammable vapors by gas water heaters can be significantly reduced. This effort to determine the "best" method(s) of mitigation/reduction should be continued.

- A.D. Little is pursuing further studies of this problem and, more importantly, of mitigation methods. Based on the discussions at the December meeting, A.D. Little has shown great interest in conducting design reviews for their future efforts. The design review process is dependent on the desires and agreement of their customer. They have expressed an interest in CPSC's participation in this design review.

- The evaluation of the SuperChems™ program's applicability to this problem should continue, with perhaps testing of the prediction ability based on CPSC tests. In addition the applicability of the program to other CPSC efforts should be investigated.

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: September 22, 1994

TO: Don Switzer, ESEE

Through: William H. King, Division Director ESEE

FROM: Tim Johnson, ESEE T. J.

SUBJECT: Analysis Of Data Contained In Tables 8-10, pages 20-22, Of The A.D. Little Task 2 Flammable Vapor Hazards Ignition Study.

Ref: A.D. Little Flammable Vapor Hazard Ignition Study, Task 2: Modeling and Experimental Testing, Reference 42238, 15 July 1993

Introduction and Purpose:

The purpose of this memo is to present a CPSC analysis of the data supplied in tables 8-10, pages 20-22, of the A.D. Little Task 2 study. These tables list the results of 32 "live-fire" tests performed by A.D. Little (ADL) and are included in Appendix 1 of this memo. Eight parameters were varied throughout the 32 "live-fire" tests outlined in Appendix 1. The effect that these eight parameters had on ignition time of gasoline vapors by a water heater were looked at by staff. Ignition time is defined as the time from when gasoline is spilled to the time the vapors are ignited by the water heater.

The eight parameters consisted of:
1) ELEVATION
2) MOVEMENT - Effect of room movement on ignition time.
3) FLOOR TEMPERATURE.
4) ROOM TEMPERATURE.
5) FLOOR TEMPERATURE GREATER THAN ROOM TEMPERATURE.
6) ROOM SIZE.
7) AMOUNT of gasoline spilled.
8) SPILL DISTANCE of gasoline with respect to the water heater.

Note that staff does NOT claim that the following is a rigorous statistical analysis. There were very few tests run that consisted of similar parameter values. Due to the small number

of tests run in relation to the number of variable parameters (8), it is nearly impossible to do a "high level" statistical analysis on the A.D. Little data such that firm conclusions can be drawn. Instead, staff has grouped together tests in which 7 of the 8 parameters are essentially the same in order to compare results of similar experiments (tests) where measured variables were held constant. As a result, it is possible to "isolate" a particular parameter such that its effects on gasoline vapor ignition time can be more clearly understood.

Analysis Criteria:

In analyzing the eight parameters outlined above staff grouped together two sets of tests for each parameter. The criteria for a test set was that for all tests in the set 7 out of the 8 parameters needed to be essentially the same for all tests in the set. Often this constraint resulted in small sets of 2 or 3 tests. The goal of each test set was to have only 1 parameter changing significantly for each test in the set. The ultimate goal of the analysis is to ascertain the effect that each parameter has on gasoline vapor ignition time by a water heater.

Analysis:

Attached tables 1a,1b,2a,2b,3a,3b,4a,4b,5a,5b,6a,6b,7a,7b,8a,8b, form the basis for staff's analysis and were created by Engineering Science (ES) staff from the ADL data contained in Appendix 1. Each table represents one of the test sets grouped together by staff. Note that the result of many of the tests included in these tables was "NO FIRE". Tests that resulted in NO FIRE were stopped when it was determined that a fire was never going to occur. This is determined by a measuring device in the room that can measure when the gasoline vapor has dispersed to a point below the Lower Explosive Limit (LEL). If the concentration of gasoline vapors is below the LEL it is impossible for the gasoline vapor to ignite.

1) ELEVATION - Effect of elevating a water heater on ignition time of gasoline vapors.

Table 1a (note attached tables) shows that in tests 2 and 29 the ignition hazard is eliminated, i.e. no ignition, when the water heater is elevated 18" and there is no air movement in the room. This is a dramatic change from test 1 in which, under similar circumstances, ignition occurred in 15 sec. Note that tests 2 and 29 were run for about 2 hours before they were stopped. They were stopped when it was determined that the concentration of gasoline vapors was below the Lower Explosive Limit (LEL).

Table 1b shows that in test 8 the ignition hazard is eliminated, i.e. no ignition of gasoline vapors, when gasoline is spilled 8 feet from the water heater and there is movement in the room. This is a dramatic change from tests 7 and 11 in which, under similar circumstances, ignition of gasoline vapors occurred in approximately 1 minute. Note that in tests 7 and 11 there was no movement in the room.

2) MOVEMENT - Effect of movement in the room on ignition time.

Tables 2a and 2b show that movement in the room can greatly reduce the ignition time of gasoline vapors by a water heater. Note that in test 13, of table 2b, an unbaffled vent was used on a windy day, suggesting that there was movement of the air (air turbulence) in the room. This could explain why ignition occurred in this test as opposed to tests 14 and 19.

3) FLOOR TEMPERATURE - Effect of floor temperature on ignition time.

Tables 3a and 3b show that increasing the floor temperature decreased the ignition time of gasoline vapors by a water heater. However, the extent to which ignition time can be controlled by increasing or decreasing the floor temperature is unclear. It appears from the limited data sets shown in tables 3a and 3b that floor temperature is not a primary factor in determining ignition time.

4) ROOM TEMPERATURE - Effect of room temperature on ignition time.

Tables 4a and 4b show that increasing the room temperature decreased the ignition time of gasoline vapors by a water heater. However, the extent to which ignition time can be controlled by increasing or decreasing the room temperature is unclear. It appears from the limited data sets shown in tables 4a and 4b that room temperature is not a primary factor in determining ignition time.

5) FLOOR TEMPERATURE GREATER THAN ROOM TEMPERATURE - Effect of having the floor temperature greater (higher) than the room temperature on ignition time of gasoline vapors.

Tables 5a and 5b show that when the floor temperature is higher than the room temperature ignition time is decreased. However, the extent to which ignition time can be controlled by having the floor temperature greater than the room temperature is unclear. It appears from the limited data sets shown in tables 5a and 5b that having the floor temperature greater than the room temperature does not significantly decrease the time to ignition and thus is not a primary factor in determining ignition time.

6) ROOM SIZE - Effect of room size on ignition time of gasoline vapors by a water heater.

Tables 6a and 6b show that increasing the room size increased the ignition time of gasoline vapors by a water heater. Note in table 6b, tests 12,15 and 27 no ignition occurred (test duration of approximately 1 hour) when these tests were run in the larger room as opposed to fairly quick ignition times of about 4 minutes for tests 33,28,and 35, run in the smaller room. In table 6a, a less dramatic change occurs between test 35 (small room test) and test 26 (larger room test) as far as ignition time is concerned. Thus, as we would expect, a larger room will increase the time to ignition, however, the extent to which it will be increased

cannot be ascertained from the A.D. Little data.

7) AMOUNT OF SPILL - Effect of the amount of gasoline spilled on ignition time of gasoline vapors by a water heater.

Table 7a shows that increasing the amount of gasoline spilled from 1 to 2 gallons slightly decreased gasoline vapor ignition time. Table 7b shows that increasing the amount of gasoline spilled from 0.5 to 1 gallon did not significantly change the ignition time.

8) SPILL DISTANCE - Effect of gasoline spill distance on ignition time of gasoline vapors by a water heater.

Tables 8a and 8b show that increasing the spill distance increased the ignition time for gasoline vapors by a water heater.

Conclusion:

Using data obtained from the A.D. Little Task 2 Study, staff analyzed the effect of eight variable parameters on gasoline vapor ignition time. The eight parameters were: water heater elevation, movement, floor temperature, room temperature, effect of having floor temp greater than room temp, room size, amount of gasoline spilled, and gasoline spill distance. Of these eight parameters, three had a significant effect on the ignition time of gasoline vapors - elevation, movement, and room size.

ELEVATION of a water heater can, in some situations, significantly reduce and/or eliminate the gasoline vapor ignition hazard. Note, however, that the only test results included in the ADL study for which direct comparisons can be made between elevated and non-elevated tests were those in which there was either no movement present or the spill distance was 8 feet. Most tests run by A.D. Little, where the water heater was elevated 18", used a spill distance of 2.5 feet. As other tests in the A.D. Little study showed, ignition can occur in as little as 3-7 minutes if a combination of 2 or more of the following conditions is present: a) the room size is small (500 cubic feet), b) there is a significant amount of movement in the room, c) a large amount of gasoline is spilled (1.5 - 2 gallons), and d) the spill distance is relatively small (2.5 feet).

MOVEMENT in the room is another key factor in determining when ignition will occur. Movement can greatly reduce the ignition time of gasoline vapors by a water heater. Movement in a room causes air turbulence which usually causes gasoline vapors, emanating from a spill, to reach the burner portion of the water heater much faster. Obviously, this will decrease the time to ignition.

ROOM SIZE is yet another key factor. As expected, it will take longer for a water heater to ignite gasoline fumes when installed in a large room. In some of the ADL tests conducted in a "large" room (1600 cubic ft) no ignition occurred.

The other five parameters appeared to play a somewhat less significant role in determining if and when gasoline vapor ignition occurred. Their effects on ignition time were:

- FLOOR TEMPERATURE. Increasing floor temperature will decrease the ignition time of gasoline vapors by a water heater.

- ROOM TEMPERATURE. Increasing room temperature will decrease the ignition time of gasoline vapors by a water heater.

- FLOOR TEMPERATURE GREATER THAN ROOM TEMPERATURE. Having a situation in which the floor temperature is greater than the room temperature appears to decrease the ignition time of gasoline vapors by a water heater.

- AMOUNT OF SPILL. Increasing the amount of gasoline spilled from 1 to 2 gallons slightly decreased gasoline vapor ignition time. Increasing the amount of gasoline spilled from 0.5 to 1 gallon did not significantly change the ignition time.

- SPILL DISTANCE. Increasing the spill distance generally increased the ignition time for gasoline vapors by a water heater.

Finally, staff emphasizes that, in the A.D. Little Flammable Vapor Ignition Study - Task 2, there were not enough tests run, in relation to the large number (8) of variable parameters, to perform an in-depth, high level type of statistical analysis. Thus, no firm conclusions can be drawn from the above analysis. However, by grouping "like" tests and using a common sense approach, it is possible to gain a better understanding of the effects of certain key variables on ignition time of gasoline vapors.

1) ELEVATION - Effect of elevating a water heater on ignition time.

Table 1a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
1	approx 500 ft^3	0	No	1	88	57	2 ft 5 in	15 sec	Fire	Vented Room
2	approx 500 ft^3	18	No	1	85	69	2 ft 4 in	2 hr 36 min	No Fire	Cold Floor
29	approx 500 ft^3	18	No	1	84	59	2 ft 6 in	2 hr	No Fire	Warm Floor, Room

* Tests were run in either an 8'x8'x8' room or a 6'x10'x8' room = approx 500 ft^3 (*cubic feet*)

Table 1b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
7	10'x20'x8' (1600 ft^3)	0	No	1	91	68	8 ft	51 sec	Fire	Pilot Only
11	10'x20'x8' (1600 ft^3)	0	No	1	85	69	8 ft	68 sec	Fire	Ventilation - approx. 2 Air Changes
8	10'x20'x8' (1600 ft^3)	18	Yes	1	84	59	8 ft	1 hr 57 min	No Fire	Continuous Movement, 30 sec. intervals

Conclusion - In some situations the gasoline vapor ignition hazard was eliminated by elevating a water heater.

2) MOVEMENT - Effect of movement within a room on ignition time.

Table 2a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
2	approx 500^3 ft	18	No	1	71	52	2 ft 4 in	2 hr 36 mins	No Fire	Cold Floor
4	approx 500^3 ft	18	Yes	1	79	45	2 ft 4 in	15 min	Fire	Movement every 5 min

* Tests were run in either an 8'x8'x8' room or a 6'x10'x8' room = approx 500 ft^3 (cubic feet)

Table 2b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
13	10'x20'x8' (1600 ft^3)	18	No	2	92	114	2 ft 6 in	1 hr 13 min	Fire	Windy Day, Unbaffled Vent
14	10'x20'x8' (1600 ft^3)	18	No	2	80	94	2 ft 6 in	2 hr 11 min	No Fire	
19	10'x20'x8' (1600 ft^3)	18	No	2	96	83	2 ft 6 in	1 hr 28 min	No Fire	
21	10'x20'x8' (1600 ft^3)	18	Yes	2	84	77	2 ft 6 in	7 min	Fire	Continuous Movement 30 sec Intervals

Conclusion - room movement greatly reduces the ignition time of gasoline vapors by a water heater.

3) FLOOR TEMPERATURE - Effect of floor temperature on ignition time.

Table 3a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
4	approx 500^3 ft	18	Yes	1	79	45	2 ft 4 in	15 min	Fire	Movement every 5 min
35	approx 500^3 ft	18	Yes	1	84	86	2 ft 6 in	4 min 15 sec	Fire	Continuous Movement, 30 sec intervals

* Tests were run in either an 8'x8'x8' room or an 6'x10'x8' room = approx 500 ft^3 (cubic feet)

Table 3b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
23	10'x20'x8' (1600 ft^3)	18	No	2	87	78	2 ft 6 in	1 hr 49 min	Fire	FID showed output fluctuation
13	10'x20'x8' (1600 ft^3)	18	No	2	92	114	2 ft 6 in	1 hr 13 min	Fire	Windy Day, Unbaffled Vent

Conclusion - increasing the floor temperature decreased the ignition time of gasoline vapors by a water heater.

4) ROOM TEMPERATURE - Effect of room temperature on ignition time.

Table 4a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
37	approx 500 ft^3	18	Yes	0.5	76	68	2 ft 6 in	4 min 40 sec	Fire	Continuous movement, 30 sec intervals
30	approx 500 ft^3	18	Yes	0.5	99	87	2 ft 6 in	3 min	Fire	Continuous movement, 30 sec intervals

*. Tests were run in either an 8'x8'x8' ft room or a 6'x10'x8' room = approx 500 ft^3 (cubic feet)

Table 4b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
11	10'x20'x8' (1600 ft^3)	0	No	1	85	69	8	68 sec	Fire	Ventilation - approx. 2 air exchanges
10	10'x20'x8' (1600 ft^3)	0	No	1	105	72	8	40 sec	Fire	Ventilation - approx. 2 air exchanges

Conclusion - increasing the room temperature decreased the ignition time of gasoline vapors by a water heater.

5) FLOOR TEMPERATURE GREATER THAN ROOM TEMPERATURE.

Effect of having floor temperature greater than room temperature on ignition time of gasoline vapors by a water heater.

Table 5a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
28	approx 500 ft^3	18	Yes	1	88	77	2 ft 6 in	4 min	Fire	Continuous Movement, 30 sec intervals
33	approx 500 ft^3	18	Yes	1	78	84	2 ft 6 in	3 min	Fire	Continuous Movement, 30 sec intervals

* Tests were run in either an 8'x8'x8' room or a 6'x10'x8' room = approx 500 ft^3 (cubic feet)

Table 5b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
23	10'x20'x8' (1600 ft^3)	18	No	2	87	78	2 ft 6 in	1 hr 49 min	Fire	FID showed output fluctuation
13	10'x20'x8' (1600 ft^3)	18	No	2	92	114	2 ft 6 in	1 hr 13 min	Fire	Windy Day, Unbaffled Vent

Conclusion - Having floor temperature greater than room temperature decreased the ignition time of gasoline vapors by a water heater.

6) ROOM SIZE - Effect of room size on ignition time.

Table 6a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
35	approx 500 ft^3	18	Yes	1	84	86	2 ft 6 in	4 min 15 sec	Fire	Continuous Movement, 30 sec intervals
26	10'x20'x8' (1600 ft^3)	18	Yes	1	87	89	2 ft 6 in	15 min	Fire	Continuous Movement, 30 sec intervals

Table 6b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
33	approx 500 ft^3	18	Yes	1	78	84	2 ft 6 in	3 min	Fire	Continuous Movement, 30 sec intervals
28	approx 500 ft^3	18	Yes	1	88	77	2 ft 6 in	4 min	Fire	Continuous Movement, 30 sec intervals
35	approx 500 ft^3	18	Yes	1	84	86	2 ft 6 in	4 min 15 sec	Fire	Continuous Movement, 30 sec intervals
12	10'x20'x8' (1600 ft^3)	18	Yes	1	99	99	2 ft 6 in	45 min	No Fire	Continuous Movement, 30 sec intervals
15	10'x20'x8' (1600 ft^3)	18	Yes	1	84	94	2 ft 6 in	1 hr 17 min	No Fire	Continuous Movement, 30 sec intervals
26	10'x20'x8' (1600 ft^3)	18	Yes	1	87	89	2 ft 6 in	15 min	Fire	Continuous Movement, 30 sec intervals
27	10'x20'x8' (1600 ft^3)	18	Yes	1	87	88	2 ft 6 in	1 hr 35 min	No Fire	Continuous Movement, 30 sec intervals

Conclusion - Increasing the room size increased the ignition time of gasoline vapors by a water heater.

7) AMOUNT OF SPILL - Effect of amount of gasoline spilled on ignition time.

Table 7a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
26	10x20'x8' (1600 ft^3)	18	Yes	1	87	89	2 ft 6 in	15 min	Fire	Continuous Movement, 30 sec intervals
21	10x20'x8' (1600 ft^3)	18	Yes	2	84	77	2 ft 6 in	7 min	Fire	Continuous Movement, 30 sec intervals

Table 7b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
30	approx 500^3 ft	18	Yes	0.5	99	87	2 ft 6 in	3 min	Fire	Continuous Movement, 30 sec intervals
34	approx 500^3 ft	18	Yes	0.5	80	77	2 ft 6 in	3 min	Fire	Continuous Movement, 30 sec intervals
37	approx 500^3 ft	18	Yes	0.5	76	68	2 ft 6 in	4 min 40 sec	Fire	Continuous Movement, 30 sec intervals
33	approx 500^3 ft	18	Yes	1	78	84	2 ft 6 in	3 min	Fire	Continuous Movement, 30 sec intervals
28	approx 500^3 ft	18	Yes	1	88	77	2 ft 6 in	4 min	Fire	Continuous Movement, 30 sec intervals
35	approx 500^3 ft	18	Yes	1	84	86	2 ft 6 in	4 min 15 sec	Fire	Continuous Movement, 30 sec intervals

* Tests were run in either an 8'x8'x8' room or a 6'x10'x8' room = approx. 500^ft

Conclusion - Increasing the amount of gasoline spilled from 1 to 2 gallons slightly decreased gasoline vapor ignition time by a water heater.
Increasing the amount of gasoline spilled from 0.5 to 1 gallon did not significantly change the ignition time of gasoline vapors by a water heater.

8) SPILL DISTANCE - Effect of gasoline spill distance on ignition time.

Table 8a

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Distance	Test Duration	Result	Comments
11	10x20'x8' (1600 ft^3)	0	No	1	85	69	8 ft	1 min 8 sec	Fire	Ventilation - approx 2 air exchanges
16	10x20'x8' (1600 ft^3)	0	No	1	83	68	13 ft	2 min 3 sec	Fire	Spill Towards Back Wall

Table 8b

Test No.	Room Size	Elevation (in)	Movement	Amount (gal)	Room Temp (F)	Floor Temp (F)	Spill Dist	Test Duration	Result	Comments
21	10'x20'x8'	18	Yes	2	84	77	2 ft 6 in	7 min	Fire	Continuous Movement, 30 sec intervals
9	10'x20'x8'	18	Yes	2	87	63	approx 7 ft	19 min	Fire	Continuous Movement, 1 min intervals

Conclusion - increased spill distance increased the ignition time for gasoline vapors by a water heater.

APPENDIX 1

Tables 8-10, from A.D. Little Flammable Vapor Hazard Ignition Study, Task 2: *Modeling and Experimental Testing*, Reference 42238, 15 July 1993.

** Note **

Tables 8-10 have been updated by A. D. Little to correct errors in the tables originally published in the A.D. Little report of 15 July 1993. A.D. Little supplied the corrected tables in a letter dated 11/24/93 to GAMA (forwarded to CPSC).