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 substantially reduce the unintentional ignition of gasoline vapors by gas-fueled residential water heater? 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*

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

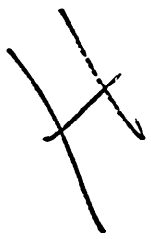
A.O. Smith
FPD-40 (40 gallon, gas, *Sealed Shot*)
FPD-50 (O gallon, gas, *Sealed Shot*)
PGCG-40 (40 gallon, gas, *Conservationist*)
PGCG-50 (50 gallon, gas, *Conservationist*)

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?



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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
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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*)
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FPD-50 (50 gallon, gas, *Sealed Shot*)
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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.

I

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

/Continued . . .

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.

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
Total In-Scope	90	63	61	51
Out-of-Scope	50 (+2 duplicates)	42 (+2 duplicates)	20	55
Total ADL Task 1	142	105	81	106

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

K

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.

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^2, 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.