Photo 10
Gas analyzer and power supply for water heater stack and stack speed gage.

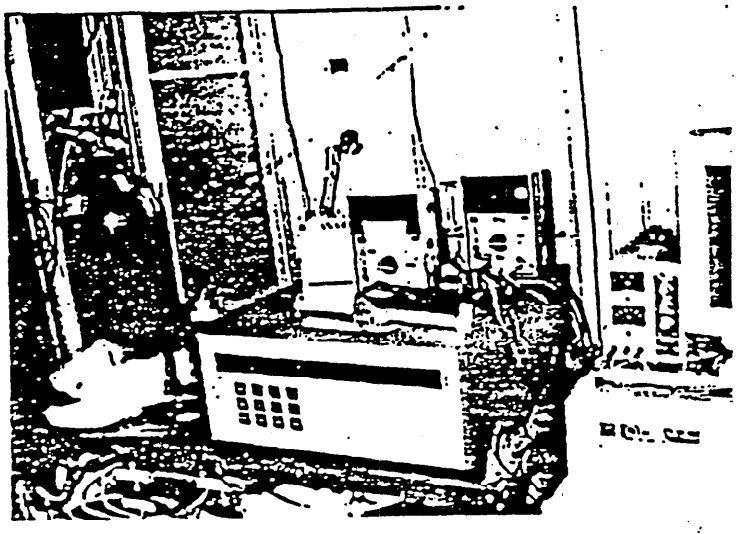

Photo 11
Sample/nitrogen and propane (half and full span) gas valves.

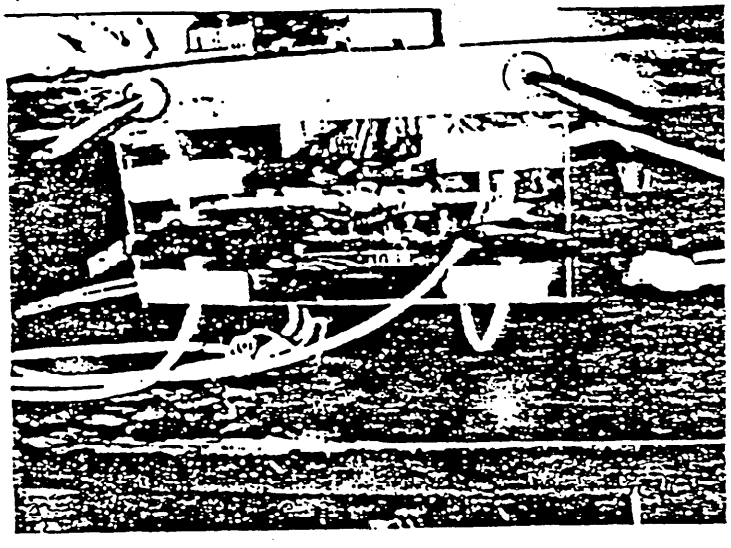

Photo 12
Pump

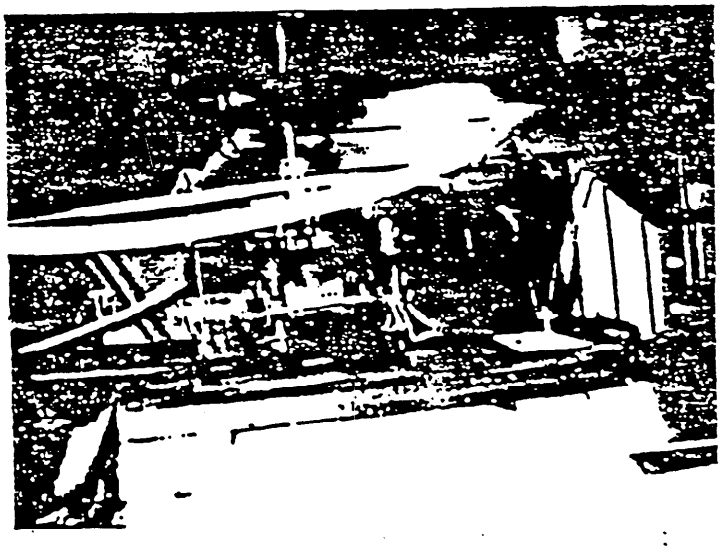

Photo 13
Solenoid valves.

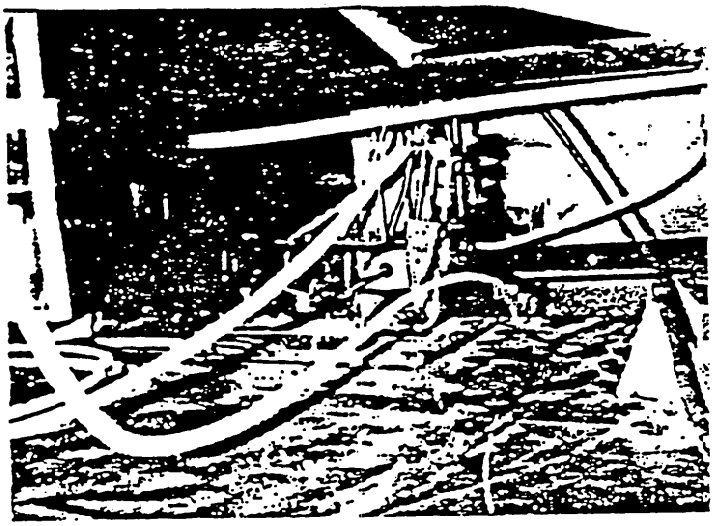

Photo 14
Nitrogen/propane gas bottles.

Photo 15

APPENDIX B

UNITED STATES GOVERNMENT

MEMORANDUM

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

April 12, 1994

TO : Joe Fandy, ESEE

Through : Robert T. Garret, Acting Director - ESEL

FROM : Michael P. Smith, ESEL

SUBJECT : Water Heater Test Project

The attached report documents the final phase of the water heater test project. This along with prior reports concludes the testing for this project.

cc: Albert Martin, ESEL
George Sushinsky, ESEL
James Bradley, ES

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ESDOC 552908

INTRODUCTION

These tests determine the effects, on the heater's combustion characteristics, of placing a barrier(weir) around the base of a water heater. Previous tests performed at the National Institute for Standards and Technologies'(NIST) Fire Lab showed that with the water heater on the floor, a nearby gasoline spill can lead to vapor concentrations above the lower explosive level(LEL) at the pilot burner. The compiled data as well as test summaries from these tests were given to the project manager, Joe Fandy, in mid December 1993 at a meeting held in the Engineering Science's Engineering Laboratory's(ESEL) conference room. Further testing showed that this was prevented by placing a weir around the heater and sealing it to the floor.

APPARATUS AND PROCEDURES

The ESEL combustion hood lab was used to gather data on the combustion characteristics of the water heater. The heater tested is a methane gas fired water heater with a capacity of 40 U.S. gallons. The heater has a diameter of approximately 17.75 inches and the base is held 2 inches off the floor by the feet of the heater. The manifold pressure is regulated to 4 inches w.c. and the inlet pressure may range from 5-14 inches w.c.. The sample number of this heater is R-598-0709. It was referred to as heater ''C'' in previous testing. The weir used has a height of 14 inches and a diameter of approximately 23 inches. Figure 1 depicts the test setup with the weir in place.

Figure 1

Heater ''C'' was placed under the combustion hood and fitted with hoses for fresh water in and hot water out. Tests were made at various inlet fuel pressures. During each run the main

burner was cycled on and off manually using the heater's thermostat. Runs were made both with and without the weir in place. During one run the annular area between the heater and the weir was blocked with a rolled up cotton sheet to determine the effects of choking air to the fire.

RESULTS

Figure 2 compares the exhaust stack velocities of two runs. Both runs were with a fuel inlet pressure of 6 inches w.c.. One was performed with the weir and the other without. The graph shows that the weir had no notable effect on the exhaust flow. The difference in readings is within the accuracy of the instrumentation. On the run made with the weir a gradual

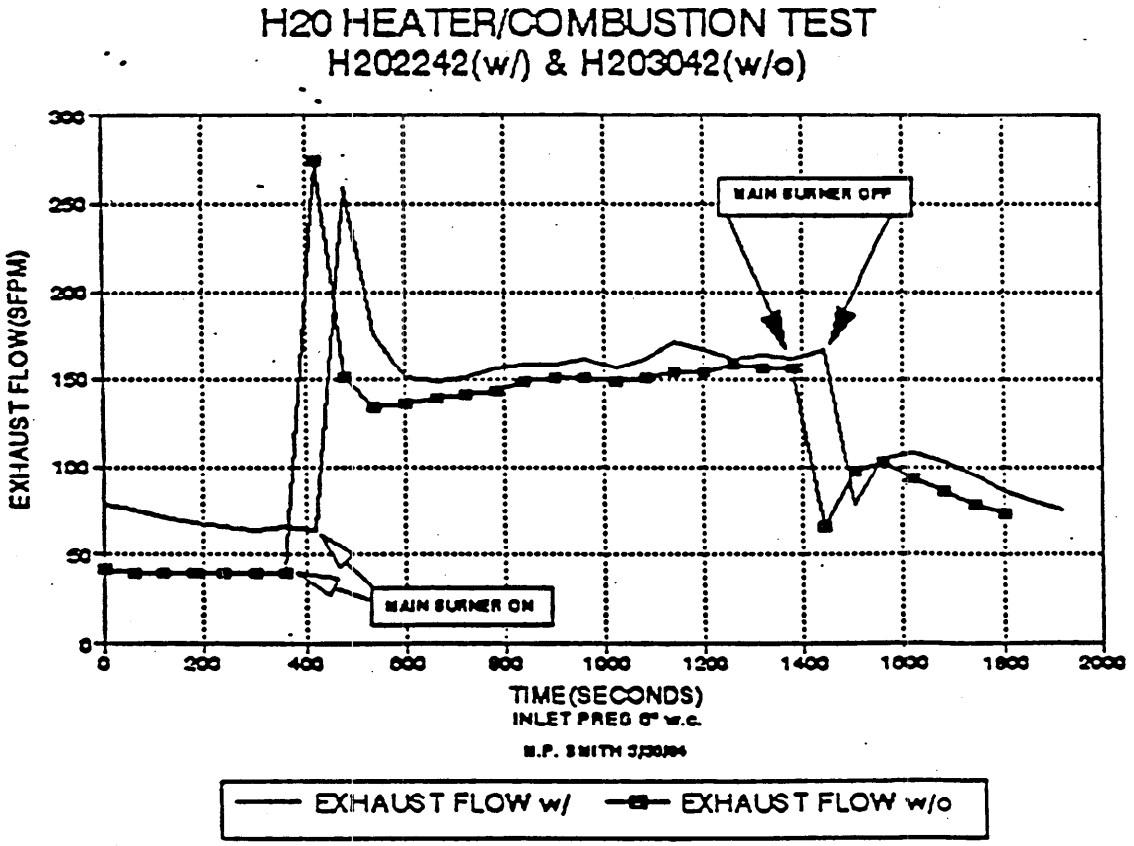

Figure 2

decrease is seen in the flow before the main burner was ignited. This was caused by residual heat in the exhaust stack from the previous run. Because of this the flow gradually decreased, as the stack cooled, to the level created by the pilot burner. The spikes just after the main burner was either ignited or extinguished are caused by the transient characteristics of the hot-wire anemometer.

Figures 3 and 4 show data from the same run. This run was performed with an inlet pressure of 6 inches w.c.. The weir was not set in place until approximately 900 seconds into the test. By 1150 seconds the weir had been sealed, and at 2100 seconds it was removed. Throughout this test there were no changes in the CO or CO2 produced by the heater. The gradual decrease in fuel flow was the result of the heating of the burner's components.

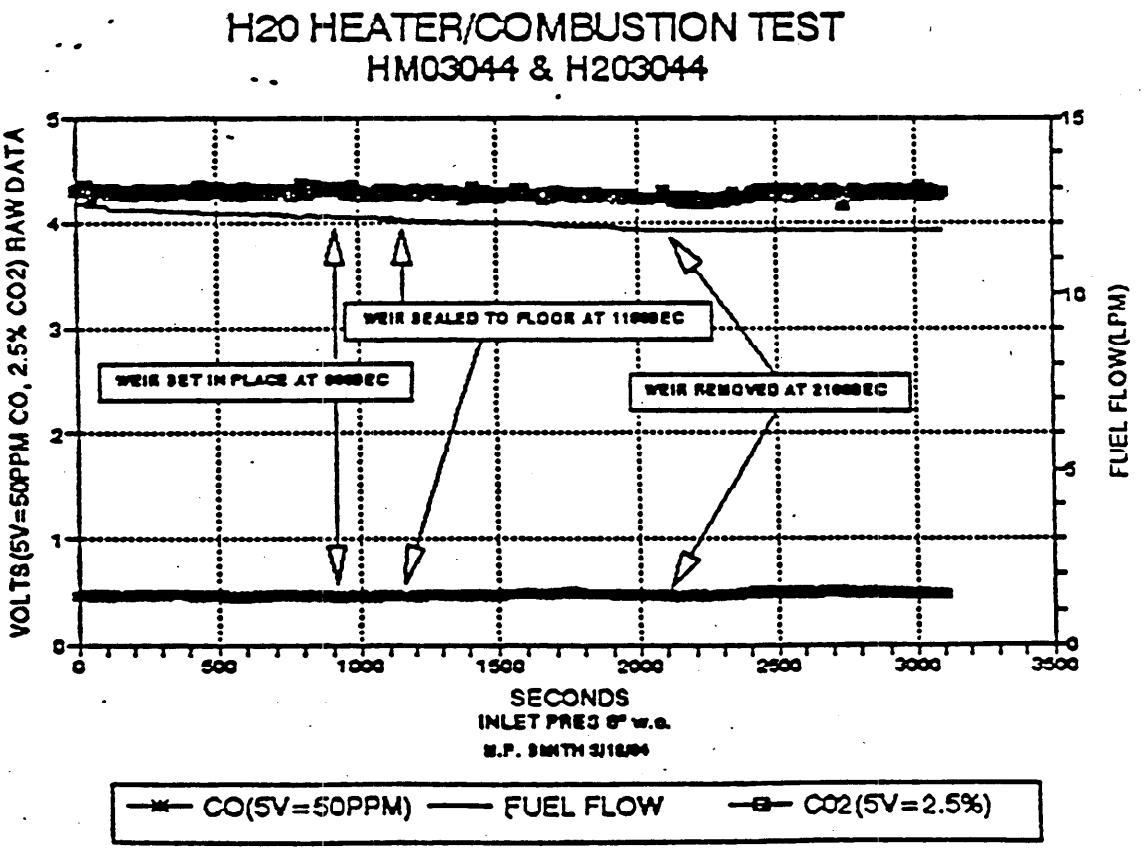

Figure 3

The exhaust flow also failed to show any notable changes with the weir in use.

Figure 5 shows the CO, fuel flow, and exhaust flow for a test where a rolled up cotton sheet was used around the top of the weir to block the air passage way between the weir and the heater.

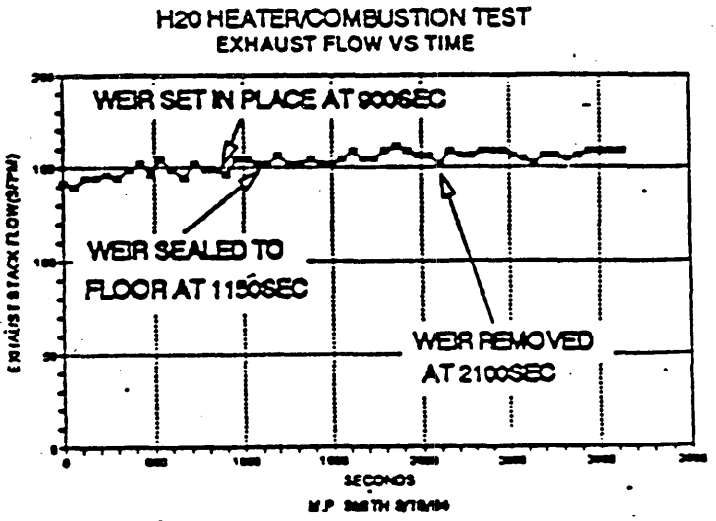

Figure 4

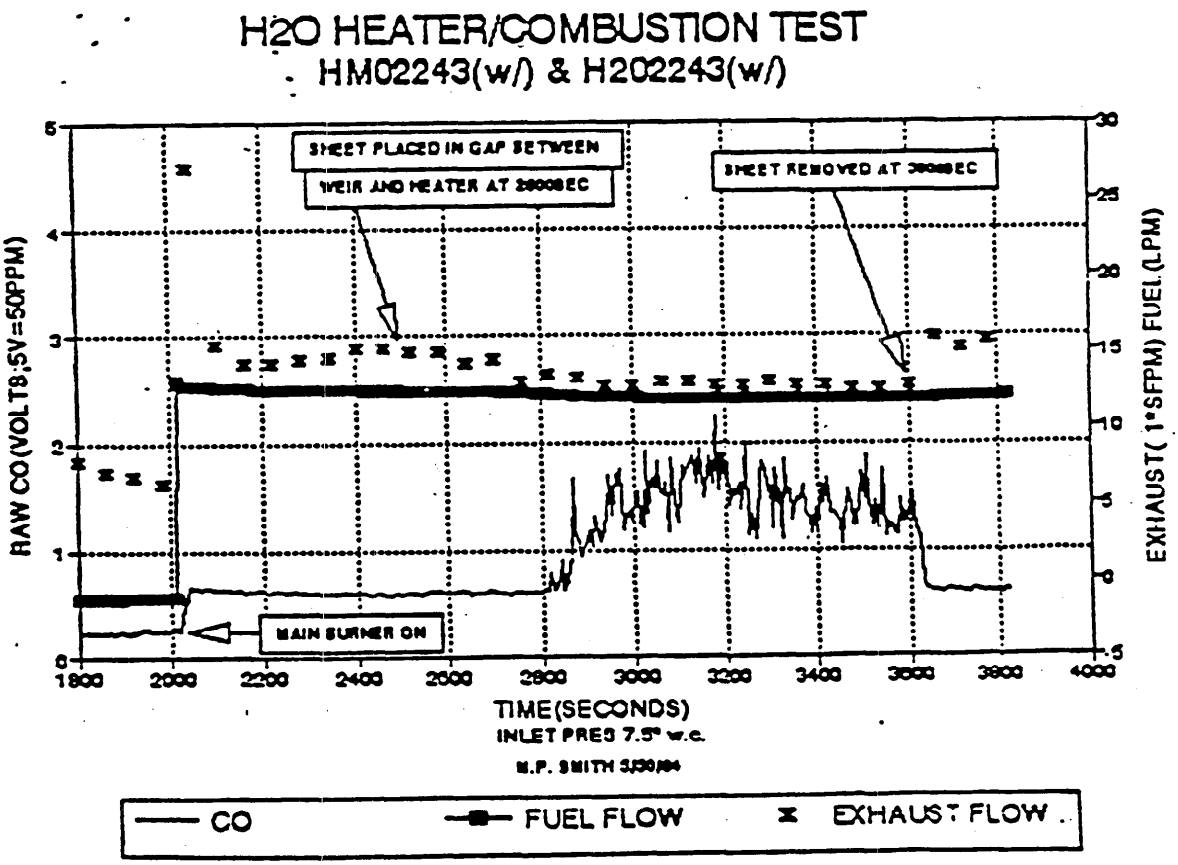

Figure 5

The inlet pressure for this run was 7.5 inches w.c.. Only the pilot burner was on until 2000 seconds when the main burner was ignited. As with previous tests the spikes present in the exhaust flow were caused by the transient characteristics of the hot-wire anemometer. This test demonstrates what happens when a fire is choked. The exhaust flow decreased soon after the sheet was in place. About 300 seconds after the air supply was cut off the fire exhausted most of its oxygen and began to burn below stoichiometric conditions which resulted in high amounts of CO being produced. The reduction of fuel flow was the result of normal heating as explained earlier. Once the sheet was removed the fire quickly returned to its normal state of dynamic equilibrium.

DISCUSSION

These tests have demonstrated that placing a weir around the base of a water heater has no notable effect on the heater's combustion characteristics. These were the expected results. The area around the outside of the heater between the base and the floor was approximately 104.5 square inches. The annular area between the weir and the heater was approximately 171 square inches. As long as the weir provides an area for the heater to breath through which is equal to, or larger than, the area the furnace would otherwise breath through there should be no adverse effects on combustion. Previous testing at NIST showed the weir's effectiveness in preventing gasoline vapors from reaching the heater's burner. Current data along with data from previous testing demonstrate that the placement of a weir around the base of a water heater is an acceptable way to keep combustible vapors away from the heater's burner.

CONCLUSIONS

While previous testing has shown that using a weir is an effective way of preventing vapors from gasoline spills from being ignited by a water heater's burner, there was a question as to the effects it could have on the heater's air supply. These

tests show that the use of a weir has no adverse effects on the combustion performance of the water heater.

UNITED STATES GOVERNMENT
MEMORANDUM

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

January 19, 1994

TO: The Commission

THROUGH: Sadye E. Dunn, Secretary
THROUGH: Jerry G. Thorn, General Counsel
THROUGH: Eric C. Peterson, Executive Director
THROUGH: Bert G. Simson, Assistant Executive Director, EXHR
THROUGH: James E. Bradley, Acting Associate Executive Director, ES
William S. West, Director, ESEE

FROM: Joseph Z. Fandey, ESEE, Project Manager (504-0508 ext.1293)

SUBJECT: Request for Commission endorsement of an information campaign for the dangers of flammable vapors

I. **Issue:** Whether the Commission should endorse the campaign, for grades kindergarten through eight, and allow the use of the Commission's name and/or logo in the consumer education materials developed by the Gas Appliance Manufacturers Association (GAMA).

II. **Background:** For several years, staff has been concerned with the problem of gas appliances, especially water heaters, igniting flammable vapors. Two years ago, staff requested that the voluntary standards organization, American National Standards Institute (ANSI) Z-21 subcommittee on water heaters, set up a special working group to study these ignitions in an attempt to develop a strategy to reduce or eliminate them. Shortly after the working group first met, the GAMA Consumer Information and Education Committee, Water Heater Division, sponsored two phases of an initial response. One was scientific and one was informational. Staff has received final reports on the first two phases of scientific study and will report separately.

At a GAMA reported cost of several million dollars, the GAMA consumer education program takes a multiple approach with video segments for television, a program for children in kindergarten through eighth grade including a comic book and other print products, and communications to the plumbing trade. Once the program was developed, GAMA representatives came to CPSC and made a presentation of the materials to two Commissioners and staff. This presentation showed the entire program in context. A similar presentation is included on the video tape in the package

CPSA § 6(b)(1) cleared

previously distributed to the Commissioners (a copy is available for viewing in the Office of the Secretary). The video portion has been shown on television this past summer, most notably during the NBA basketball championship play-offs.

When GAMA announced their plans for the informational program, staff discussed with GAMA the possibility of working together in the development of a cooperative educational program; however, GAMA felt that it did not have enough time to ask for CPSC participation or prior endorsement before showing the pieces during the period of highest risk (the summer). Now that the time pressure is over, GAMA is taking this opportunity to request CPSC participation through endorsement, (Tab A).

III. **Discussion:** The Commission is being requested to endorse the information campaign that GAMA developed advising consumers about the hazards of flammable liquids. Staff notes that the National Fire Protection Association (NFPA) allowed the use of its trademarked "Sparky"® the Fire Dog. The CPSC General Counsel reviewed the materials and reports he sees no legal impediments to supporting the campaign (TAB B). Subsequent to the General Counsel's opinion, staff made contact with GAMA about the specific language which GAMA would like, should an endorsement be granted by the Commission. The specific language discussed was "...developed (or sponsored) by GAMA in cooperation with the Consumer Product Safety Commission" or other words to that effect which the Commission determines to be preferable. The Commission could decide whether to allow use of such words with or without the CPSC logo.

The GAMA made a studied attempt to get useful information to the attention of a broad cross-section of "at risk" consumers. To the extent that it convinces consumers to avoid having gasoline and other flammable vapors present in the home or around gas appliances, it will reduce the risk of injury. Staff considers that this is an important and significant contribution to reducing the death and injury incidents which involve flammable vapors around the home. However, staff believes that the program will be only partially effective unless combined with technical solutions.

When the request from GAMA was received, this writer responded that the Commission would be requested to consider the matter (Tab C). During the review of the materials received in order to develop this package, staff found a number of points of emphasis, error or variation from what has been consistent staff position on warnings. Staff, therefore, could not then recommend that the Commission endorse the program. However, staff has had several meetings and telephone conversations with GAMA, after which significant improvements in the printed materials were made (TAB D). In addition, one label which was included in the ANSI standard without incorporating staff comments will be removed from the program. Therefore, staff feels that, as revised, and not including the label from the ANSI standard, staff can recommend that the Commission favorably consider allowing the program to include the use of the CPSC logo with the requested statement.

Staff believes that CPSC endorsement would make the program more attractive to TV and other potential outlets as a public service.

IV. Options:

1. Grant the request to use CPSC's name with the phrase "...developed (or sponsored) by GAMA in cooperation with the Consumer Product Safety Commission." This granting could apply to each program component remaining after the removal of the label.
2. Extend option one by allowing the CPSC logo in conjunction with the phrase from option one.
3. Deny the request.

V. Recommendations: Staff recognizes the contribution which GAMA is making to product safety with this program. Staff recommends that the Commission commend the GAMA effort, grant the request and allow the use of the CPSC name and/or logo on the materials presented (except the label) with the statement "developed by GAMA in cooperation with the Consumer Product Safety Commission.

UNITED STATES GOVERNMENT

MEMORANDUM

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

NOV 21 1991

TO : Joseph Z. Fandey, Project Manager, ESEE

B for EW

Through: Dr. Robert D. Verhalen, Associate Executive Director
Directorate for Epidemiology
Jacqueline Elder, Acting Director, EPHF

FROM : George Sweet, EPHF, 492-6468

SUBJECT: Gas Water Heaters

Human Factors was asked to comment on the recommendation that air intake openings on gas water heaters be raised above the floor. Human Factors was also asked to provide input on the use of warning labels on gas water heaters to address the potential for ignition of flammable vapors.

Background

Fires have been started by flammable vapors coming into contact with the pilot light of gas water heaters. In most cases, the air intake openings on gas water heaters are at floor level. Flammable vapors are usually denser than air and therefore, stay near the floor. The vapors can travel significant distances across a floor. Flammable vapors enter the water heaters at the air intake openings which delivers the air flow to the burners. If the vapors reach the air intake openings and come into contact with the pilot light, they are ignited. Recommendations have been made to raise air intake openings above the floor as a means of preventing flammable vapor fires.

Discussion

Raising the air intake openings on gas water heaters appears to promote fire prevention. Logically, it follows that raising the air intake openings would reduce fires occurring from the ignition of flammable vapors because it would be less likely that the dense vapors would rise a sufficient height to enter the water heater through the air intake openings. However, it is not a complete solution, and additional research is required to determine the height that best reduces the potential of vapors being ignited.

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A warning label is not an acceptable substitute for raising air intake openings off the floor. It is important that a warning label be placed on the product, however, the warning label is not the solution to the problem, it is an identification of the problem to the consumer. Even though raising the air intake opening should decrease the potential of fires, it will not eliminate the potential for fires. It is conceivable that consumers will perceive the change of height as a complete solution to the problem, resulting in a false sense of security. The consumer must still be warned of the dangerous combination of gas water heaters and substances with flammable vapors. The warning label must be noticeable, easily understandable, and provide complete information in order to be effective. The warning label should be conspicuous, not blending in with the instructions.

Conclusion

Human Factors supports raising the air intake openings of gas water heaters to decrease the potential for fires caused by the ignition of flammable vapors. Even with the adjusted height, it is essential that warning labels be conspicuously placed on gas water heaters to inform consumers of the potential fire hazard when products with flammable vapors are kept in proximity to a gas water heater. Additional research is required to determine the ideal height for the air intake openings in order to enhance fire prevention.

bcc:
Verhalen
Official
EPHF:SWEET:phg:11/21/91

Factory Mutual Research

1151 Boston-Providence Turnpike
P.O. Box 9102
Norwood, Massachusetts 02062
Telephone (617) 762-4300
Fax (617) 762-9375

15 April 1994

Attention: Dr. Howard I. Forman, Chairman
ANSI Z21 Accredited Standards Committee
Post Office Box Number 66
Huntigdon Valley, Pennsylvania 19006

Subject: GAMA Consumer Safety Awareness Campaign

Dear Dr. Forman:

I just received your letter of 8 April 1994. Like you, I am impressed with Jack Langmead's abilities and sincerity, but I cannot share your apparent unreserved endorsement of this campaign as a solution to the flammable vapor-ignition hazard problem.

This is a public relations response to a technical hazard. Or, as the computer-oriented would say, we are trying to solve a hardware problem with a software solution.

In my industry, we refer to "human element" problems as contributing factors to losses, but have long recognized that, no matter how thorough our educational efforts, inherrent hazards cannot be eliminated or even adequately mitigated through such efforts.

Flammable vapors exposed to sources of ignition are an inherrent hazard. They can only be prevented by removing one or the other. We would say that flammable liquid operations cannot be conducted within a building without putting that building (and its occupants) at inherrent risk. If its easy or convenient to handle the flammable liquid indoors, it will be done by some individuals, no matter how many warning labels or educational programs to which they are exposed. Similarly, the ignition sources cannot all be removed (hot surfaces, static discharge, sparks from dropped tools, et cetera) without bulldozing everyone's home and starting over. Thus, the hazard cannot be eliminated. Therefore, it must be mitigated.

Mitigation involves isolating all obvious controllable sources of ignition from exposure to the vapors, as much as is possible. Clearly, elevating the pilot on a water heater is a very doable mitigation strategy. To argue that it is not 100 percent effective as justification for doing something with a much lower probability of success is indefensible. I realize that elevating the pilot will cost money and create market resistance, but that cannot be a concern of the committee. We do not exist to promote an industry. We are intended to be one of the countervailing forces to resist industry's natural self-serving tendencies.

While I applaud GAMA's educational efforts, I cannot accept them as grounds for our delaying or deferring requiring hardware changes to minimize the likelihood of a gas appliance's pilot or burner becoming an ignition source for flammable vapors.

Very truly yours,

Armand V. Brandao, P.E.
Manager
Fuels Section
Approvals Division

Direct Telephone: (617) 255-4860

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

MEMORANDUM

DATE: April 18, 1994

TO : Joseph Z. Fandey
Project Manager for Fire and Gas Voluntary Standards

Through: Warren Prunella, AED, Economic Analysis WP

FROM : Robert Franklin, Economist, ECSS (504-0962)

SUBJECT: Economic Issues Concerning Modifying Water Heaters to Prevent the Accidental Ignition of Gasoline Vapors.

Information provided to the staff of the Consumer Product Safety Commission (CPSC) by an attorney indicates that the risk of accidental ignition of gasoline vapors by gas water heaters can be substantially reduced by modifying the design or installation of water heaters. Further investigation by the staff of the CPSC seems to substantiate this conclusion. This memorandum discusses some economic issues that need to be considered in developing the Commission's options for reducing the incidents of gasoline vapors being ignited by gas water heaters.

Number in Use and Annual Sales of Gas Water Heaters

According to the Department of Energy's Residential Energy Consumption Survey of 1990, 40 million to 50 million U.S. households have gas water heaters. All other things being equal, the number of gas water heaters in use will likely increase over the foreseeable future as the number of households in the United States increases. Based upon current sales trends and the replacement rate for gas water heaters, there may be an additional 10 million units in use by the end of this decade.

Annual sales of residential, gas water heaters have been increasing. From 1960 through 1965, an average of just under 2.5 million gas water heaters were shipped annually. Since 1987, over 3.5 million units have been shipped annually (American Gas Association). The number of shipments in any particular year is influenced by the volume of new housing starts in particular and overall economic conditions in general. Shipments of water

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heaters will also be affected by changes in the retail price of natural gas relative to the retail price of electricity and by energy-related regulations that favor the use of natural gas over electricity.

Structure of the Industry

The water heater manufacturing industry is highly concentrated. According to *Appliance Magazine*, the five largest water heater manufacturers have a combined market share of 99 percent. The high degree of concentration in the water heater industry should facilitate standards development and enforcement. It is a much less onerous task to coordinate standards development and enforcement in a market dominated by a small number of large manufacturers than it is in a market in which there are many small and medium size manufacturers. This applies to both voluntary and mandatory standards.

Number and Cost of Incidents

The number of incidents involving the ignition of flammable vapors by gas water heaters varies from year to year. A study prepared for a law firm in Louisiana showed that from 1980 to 1984, there were an average of over 2,000 fires involving gas water heaters and flammable vapors annually (Gauthier, Murphy, and Downing). These fires resulted in an average of 361 injuries, 21 deaths, and over $15 million in property damages annually. The Directorate for Epidemiology reports that in 1991 there were a total of 1,211 fires involving gas water heaters and flammable vapors. Of these fires, 845 involved gasoline. The fires involving gasoline resulted in 165 injuries and 21 deaths. In 1991, the average property damage resulting from fires involving gas water heaters was $17,500 (CPSC, 1993). Using this figure, the property damage in 1991 assoicated with gas water heaters igniting gasoline vapors can be estimated at $15 million.

Although the nature and severity of all the injuries is not known, it is known that at least some of the injuries involve second and third degree burns. Severe burns are among the most costly personal injuries that can be suffered in terms of direct medical expense, loss of income, physical pain, emotional trauma, and damage to interpersonal relationships. Elizabeth Leland reported in a 1992 memorandum that in 1988, 22 percent of the jury awards for burn injuries ranged from $100,000 to $299,000 and 35 percent of the awards exceeded one million dollars (CPSC, 1992). A CPSC sponsored study estimated that the average societal cost of a hospitalized fire burn was $900,000. The largest component of this cost was "pain and suffering," which was estimated to be $785,000 per case. The other components of the costs included medical costs, lost productivity, and

administrative and legal costs (Miller, p. 74). Therefore, if one assumes that all of the 165 injuries in 1991 were burns requiring hospitalization, the total social costs of these injuries may be as high as $150 million.

Using these estimates, the total cost to society of fires involving the ignition of gasoline vapors by gas water heaters in 1991, may be over $200 million. This estimate includes $150 million in cost of injuries, $15 million in property damage, and $42 million for the social cost of the 21 fatal injuries.

Reducing the Costs

The evidence available strongly suggests that raising the combustion air intakes 12 to 18 inches from the floor will substantially reduce, if not eliminate, the risk of a gas water heater igniting gasoline vapors. The risk of gas water heaters igniting other flammable vapors may also be reduced. If no action is taken to reduce the risk the incidents will continue to occur. And since the number of gas water heaters in use are expected to increase, all other things equal, the number of incidents occurring annually will likely increase. However, if modifications are made that substantially reduce or eliminate the risk, the number of incidents occurring each year will be reduced as the existing water heaters are replaced with the safer models.

According to *Appliance Magazine*, the average useful life of a water heater is 11 years, with most being replaced between the 4th and 18th year. If a standard eliminated the risk of new water heaters igniting gasoline vapors, by the 10th year after such a standard became effective fewer than 50 percent of the gas water heaters in use when the standard became effective should still be in use. The number of incidents occurring annually should likewise be reduced. By the 25th year, fewer than 10 percent of the old units should remain in use and the number of incidents occurring should be similarly reduced. Assuming that 1991 was a typical year, within 10 years of a standard becoming effective, the annual social costs can be expected to have fallen from $200 million a year to under $100 million a year. Within 25 years the annual social costs can be expected to be close to zero.

On a per unit basis, the expected social costs related to incidents involving gas water heaters and the ignition of gasoline vapors is $4 to $5 per year ($200 million in social costs divided by the 40 million to 50 million units in use in 1991). Assuming an average useful life of 11 years and a discount rate of 5 percent, a design modification that eliminates this risk would on average be worth $35 to $45 over the life of the unit. If the a design modification also reduces the risk incidents involving gas water heaters and flammable vapors other than gasoline, the value of the modification would be greater.

At the present time, a new gas water heater with a 50 gallon capacity can be expected to cost at least $200 and another $150 to install.

References

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_____, April 1993, p. 53.

CPSC (1992), "Benefits of Preventing Accidents Associated with Flammable Vapor Ignition by Gas-Fired Water Heaters," memorandum from Elizabeth W. Leland (EC) to Joseph Z. Fandey (ESSE) (January 8, 1992).

CPSC (1993), "1991 Residential Fire Loss Estimates," CPSC Memorandum from Linda Smith (EPHA) to the Commission (September 16, 1993).

Gauthier, Wendell H., Robert M. Murphy, and Edward F. Downing, III, Water Heaters and Flammable Vapors, Gauthier & Murphy (law firm), Metaire, Louisiana.

Miller, Ted R., et al., Estimating the Costs to Society of Cigarette Fire Injuries: Final Report, (July 1993).

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

MEMORANDUM

DATE: April 21, 1994

TO : Joseph Z. Fandey
Project Manager for Fire and Gas Voluntary Standards

Through: Warren Prunella, AED, Economic Analysis WP

FROM : Robert Franklin, RF Economist, ECSS (504-0962)

SUBJECT: Updated Estimates of the Societal Costs of Fires Associated with Gas Water Heaters and Flammable Vapors

On April 18, the Directorate for Economic Analysis provided you with estimates of the societal costs associated with gas water heaters and the ignition of gasoline vapors (CPSC, 1994a). These estimates were based solely on the number of incidents in one year, 1991. Since that memorandum was written, the Directorate for Epidemiology has provided estimates of the annual average number of fires, injuries, deaths, and property damages associated with gas water heaters over the six year period from 1986 to 1991 (CPSC, 1994b). Because these estimates cover more years, we have revised our estimates of the average annual societal costs of these incidents.

The estimates provided in our original memorandum of April 18 were based only upon the incidents involving gasoline vapors. The estimates were limited to incidents involving gasoline because most of the experiments conducted on the problem have involved gasoline. However, we understand that modifications to water heaters that reduce the risk of gasoline vapors being ignited will also reduce the risk of other flammable vapors being ignited. Therefore, this memorandum provides estimates of the societal costs of incidents involving gas water heaters and all flammable vapors as well as estimates of the societal costs of incidents involving gasoline vapors only.

Societal Costs of Injuries

There were an average of 316 people injured each year between 1986 and 1991 in incidents involving gas water heaters and flammable vapors (CPSC, 1994b). Of these, 239 involved

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