BRIEFING PACKAGE
FOR
GAS-FIRED WATER HEATER IGNITION
OF
FLAMMABLE VAPORS

For Further Information Contact:

Donald W. Switzer
Directorate for Engineering Sciences
(301) 504-0508 ext.1303

Executive Summary

This memorandum provides updated information to the Commission to assist in choosing options to reduce the risk of death and injuries associated with gas-fired water heaters igniting flammable vapors. Traditionally designed gas-fired water heaters draw combustion air through the bottom of the appliance. In the event of a gasoline or other flammable liquid spill, vapors, which are heavier than air and tend to layer near the floor, are susceptible to being drawn into the water heater and ignited.

Gas-fired water heaters igniting flammable vapors cause an estimated 1,961 fires each year, resulting in an estimated 316 injuries, 17 deaths, and $26 million in property damage for a total societal cost which may be as high as $395 million. Typically, injuries occur when the victim is using flammable liquids (usually gasoline) for cleaning purposes, or when the liquid leaks or is accidentally spilled near the water heater.

On June 23, 1994, the Commission was briefed on this issue. Subsequent to the briefing, the Commission learned about additional industry activities to reduce the hazard and directed staff to reexamine completed industry research, to evaluate ongoing and planned industry activities to address the hazard, and to brief the Commission on its findings.

The material made available by industry has been reviewed. Industry is testing a new technology to eliminate the hazard. Preliminary results are promising, but additional testing is needed. An industry-sponsored standards development program to develop performance requirements to protect against ignition of flammable vapors has begun. The CPSC staff has reservations about the technical approach proposed and expressed its concerns to the Technical Advisory Group overseeing this project at its October 27, 1994, meeting. Industry is receptive to our concerns and is examining a "worst case" scenario as a basis for the test method.

A reexamination of completed industry research supports the staff's conclusion that raising water heaters 18" can significantly reduce the risk of vapor ignition.

CPSC staff's position is that the only adequate way to address the hazard is through a performance standard that leads to water heater design modification. Currently, industry estimates 39 months from the start of standards development to the effective date of a voluntary standard. Staff believes it may be possible to accelerate the voluntary standards process (particularly if ongoing research is successful).

Options available to the Commission to address this hazard include:

1. Issue an advance notice of proposed rulemaking to develop a performance standard to reduce or eliminate the risk of death or injury from ignition of flammable vapors.

2. Not issue an ANPR and work with industry to develop a voluntary standard.

Staff recommends option 2, that the Commission not issue an ANPR and work with industry to develop a voluntary standard. Industry has addressed the reasons for the previous recommendation to publish an advance notice of proposed rulemaking. At the November 22, 1994, industry meeting with Chairman Brown, industry stated that they are committed to developing a performance standard for new gas-fired water heaters to address the risk of death and injury from the ignition of flammable vapors. Industry is also is evaluating a new burner design to eliminate the ignition hazard.

If the Commission chooses this option, staff will alert the Commission immediately if progress on developing the performance standard is unsatisfactory and will brief the Commission on options to address the problem. This would include the option of issuing an ANPR, and initiation of the test method development work necessary to support rulemaking.

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

MEMORANDUM

DATE: NOV 29 1994

TO : The Commission
: Sadye E. Dunn, Secretary

Through : Eric A. Rubel, General Counsel EAR
: Bert Cottine, Executive Director

FROM : Ronald L. Medford, Assistant Executive Director RLM
for Hazard Identification and Reduction
: Donald W. Switzer, Project Manager for Fire/Gas Codes and Standards, ESEE (504-0508 ext. 1303) DWS

SUBJECT : Briefing Package for Gas-Fired Water Heater Ignition of Flammable Vapors

Purpose : To provide the Commission with the latest information on industry activities to address the hazard posed by gas-fired water heaters igniting flammable vapors

1 Background:

On June 23, 1994, the Commission was briefed on the Options Package for Gas-Fired Water Heaters and Ignition of Flammable Vapors (TAB A). At that time, as reported in the Options Paper, "The staff's greatest concern is an apparent unwillingness on the part of the water heater manufacturers to take a serious look at the potential deficiencies (of taking combustion air from near the floor) in the current design of water heaters." That concern was based primarily on:

1. Industry's insistence that the problem is not a water heater issue, but rather a consumer behavior issue that should be addressed solely through a consumer education program,

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2. Industry's lack of progress in developing a performance standard to address this issue, and

3. Test conditions and reported results from industry-sponsored research which appear, to CPSC staff, to minimize the effectiveness of elevating water heaters to address the flammable vapor ignition hazard.

On June 27, 1994, C. Reuben Autery, President of the Gas Appliance Manufacturers Association (GAMA), sent a letter to Chairman Ann Brown (TAB B) expressing concern about the June 23, 1994, briefing. In that letter, GAMA protested that the Options Paper and briefing did not provide the Commission with accurate information on the status of industry efforts to address the flammable vapor ignition hazard, and "shows an unreasonable bias on the part of the Commission staff." GAMA's primary concerns were that staff 1) disparaged the significance of industry-sponsored research into this area, and 2) did not provide information on ongoing standards development activities. The Commission staff responded to these concerns in a memo to Ronald L. Medford, Assistant Executive Director for Hazard Identification and Reduction (TAB C).

Based on the availability of additional information that GAMA identified in their letter, the Commission cancelled the decision meeting scheduled for June 30, 1994, and directed staff to:

1. Evaluate ongoing and planned industry efforts to address the flammable vapor ignition hazard,

2. Reexamine previously completed industry research, and

3. Brief the Commission on staff findings as soon as possible.

On July 7, 1994, staff requested industry to provide test protocols, schedules, and draft and final reports of studies and tests in order that staff could evaluate industry efforts to address vapor ignition (TAB D). GAMA provided preliminary information immediately, followed shortly by a more detailed response (TAB E and TAB F). Staff reviewed the material provided, requested additional information, and held a meeting to discuss the issues presented in the GAMA material (TAB G and TAB H). The material provided by GAMA and information provided at the subsequent meetings are the basis for the following discussion of the status of industry activities to address water heater ignition of flammable vapors. GAMA provided written response to our questions after the meeting (TAB I).

2 Evaluation of Recent Industry Activities:

Industry has initiated three activities to address the flammable vapor ignition issue. The first industry activity is testing of a new design that may reduce the potential for flammable vapor ignition. The second is a program to develop a test methodology to evaluate water heater designs for resistance to flammable vapor ignition. The third project is recently

completed "live fire" testing of the efficacy of a 14" sheet metal barrier in reducing flammable vapor ignition.

2.1 Design Testing:

Industry is currently testing prototypes of water heaters incorporating a new burner design to determine its potential to reduce the hazard of water heaters igniting flammable vapors. In traditionally designed water heaters, there are two sources of combustion air. Primary combustion air is mixed with the fuel before the fuel enters the burner. Primary combustion air can therefore be thought of as part of the fuel mixture. Secondary combustion air is drawn into the combustion chamber through holes in the bottom of the water heater combustion chamber. Secondary air then burns with the fuel after the fuel mixture is ignited. This means of providing secondary air is the path by which flammable vapors can enter the combustion chamber of traditionally designed water heaters. Flammable vapors in the vicinity of the appliance are drawn into the combustion chamber with the secondary air, are ignited by the main burner or pilot burner, and then flash back out of the holes in the bottom of the combustion chamber and ignite the vapors in the room. The resulting flash fire expands very quickly, and has resulted in a number of deaths and serious injuries.

The innovative burner design that industry is currently testing does not use secondary air. This allows the bottom of the combustion chamber to be sealed, precluding ignition of any flammable vapors that surround the water heater. Preliminary test results are favorable, but significant additional testing will be needed prior to commitment to production. Industry representatives have assured staff that they are committed to continuing the test program until the new burner design is proved to be either successful or ineffective in eliminating the vapor ignition problem, without introducing other unforeseen safety hazards. It is premature at this time to estimate if and when products using the new technology could be available.

It must be emphasized that although the new burner design has been patented, it is an unproven technology. It was developed for another application and has not been used in water heaters. Before this technology can be accepted for this use, it must correct the vapor ignition problem and it must satisfy all current safety and efficiency requirements without causing other, currently unforeseen, hazards. This is the purpose of the ongoing industry test program.

2.2 Test Method Development Activities:

GAMA provided CPSC with a copy of a proposal made by Arthur D. Little, Inc., (ADL) to the Gas Research Institute (GRI) for development of a test methodology to screen water heater designs for resistance to flammable vapor ignition. The proposal is dated February 1994. Work began in October 1994. GAMA states that this delay is because of difficulties regarding liability. Staff understands that the work will result in a test method that

would be included in the American National Standards Institute (ANSI) Standard for Gas-Fired Water Heaters, ANSI Z21.10.1. This is the standard to which essentially all gas-fired water heaters are currently certified.

The standards development program described by the ADL proposal is a multi-task effort that intends to establish a standard set of test conditions to mimic conditions in the field and to test water heaters under those conditions. Those water heaters that cause ignition under the test conditions would fail the test and not receive design certification. GRI, which is providing funding for the method development, has established a Technical Advisory Group (TAG) to review the process and results of this project. The TAG consists of representatives from the gas industry, manufacturers, and industry trade associations, and CPSC staff. ADL estimates it will take 39 weeks from contract award (October 1, 1994) to complete development of the test method. GAMA estimates that it will take an additional 30 months from completion of the test method for an ANSI standard to become effective.

The CPSC engineering staff was concerned that ADL's originally proposed test method development program might not produce a test method to reliably evaluate water heaters' resistance to igniting flammable vapors when installed in the home. ADL intended to establish a "typical" accident scenario and develop their test method around a set of conditions that may or may not exist in an actual home. This could result in an appliance passing the test method, but being susceptible to igniting vapors in a home where the conditions do not match the test conditions.

What is needed is a quick way to ascertain whether a water heater will ignite flammable vapors when they are present. At the October 27, 1994, TAG meeting CPSC staff explained that it is examining a more direct way to measure water heater resistance to flammable vapor ignition. The staff's preliminary concept is to use a two-gas non-flammable tracer system to simulate the expected conditions. Two gases would be injected into the test room containing the operating water heater. One tracer gas, having a molecular weight close to that of air, would be used to measure the amount of room air drawn into the water heater. The other tracer gas, having a molecular weight similar to that of the flammable vapors, would be injected into the room in a manner simulating worst case generation and spread of gasoline vapors. The second tracer gas would be an indicator of the flammable vapors that have passed through the flame front. The tracer concentrations would be measured using electron capture gas chromatographic techniques. The room would be constructed so that the natural circulation as well as any other flows could be produced. The natural air flows could be accomplished by heating or cooling the ceiling or floor and by operating the water heater. Precision DC fans would be used for other required air flows that must be artificially generated. Criteria for vapor ignition would be established, and these criteria would be verified by "live fire" test to demonstrate the validity of the methodology. It is possible that a water heater could fail to meet the criteria of this proposed tracer gas test. In this case, it could be possible to qualify the design through rigorous live fire testing using the same test conditions as established with the tracer system.

CPSC staff met with GRI and ADL on November 15, 1994, to discuss our concerns in detail and explore ways to resolve them. In response to our concerns, GRI and ADL agreed

to explore a test method in which a water heater could not ignite vapors when installed in a chamber completely filled flammable vapors. This approach appears to meet all of the staff's concerns.

2.3 Barrier Effectiveness Tests:

In June 1994, the American Gas Association Laboratory (AGAL) in Cleveland, Ohio conducted two "live fire" experiments (TAB E) to determine the effectiveness of a sheet metal barrier in reducing gas-fired water heater ignition of flammable vapors. The testing was initiated in response to CPSC testing which showed that a sheet metal barrier may inhibit flammable vapors ignition by causing the appliance to draw combustion air from 14" above the floor.

Because of safety considerations, the testing by the CPSC Engineering Sciences Laboratories was not "live fire" testing. Staff simulated appliance operation and measured the concentration of gasoline vapors in the combustion chamber to determine if ignition would have occurred. As reported in the June 8, 1994, Options Paper, "The results were that the barrier provided significant protection against flammable vapor ignition."

The two AGAL experiments involved installing a typical gas-fired water heater in a room measuring 6'x10'x8'. A sheet metal barrier 14" tall was placed around the appliance about 2" from the water heater shell. In Test 1, the barrier was sealed to the floor with tape. In Test 2, the barrier was sealed to the floor with silicone caulking. A gasoline spill was created by tipping a full one-gallon gasoline can 20 " from the barrier. Approximately 0.75 gallon was spilled from the can toward the water heater. Movement in the room was to be initiated 1 minute after main burner ignition by moving a plywood mannequin at approximately 3 feet per second on a three-foot track toward the water heater and terminating about two feet from the appliance.

In Test 1, ignition occurred 27 seconds after the gas was spilled. The pilot burner ignited the spill before the main burner was lit. AGAL speculates that rapid ignition was the result of liquid gasoline passing through the tape and running under the water heater. There was no mannequin movement because vapor ignition occurred before main burner ignition.

In Test 2, the main burner lit 2 minutes and 25 seconds after the spill. Vapors ignited 3 minutes and 55 seconds after the spill. There were two movements of the mannequin prior to ignition. When staff reviewed the video tape of this test it appeared that ignition started at the top of the barrier at the rear of the water heater opposite from the spill.

The results of this very limited testing appear to contradict the results of the CPSC testing. However, since only two tests were performed, staff is very cautious in interpreting the results. As discussed in the June 23, 1994, briefing , live fire testing needs to be done to

confirm the utility of installing a barrier as a means to prevent flammable vapor ignitions. While there are a number of possible explanations for the variation between the two sets of results, it would be speculative to try to explain the cause of the different results based on the limited data on hand.

3 Evaluation of Previous Industry Research:

Arthur D. Little, Inc., under contract to GAMA, conducted research "to investigate and characterize hazards associated with the ignition of flammable vapors by residential gas water heaters in the United States." The investigation consisted of two tasks: Data Collection and Analysis (Task 1), and Analytical Modeling and Experimental Testing (Task 2). In Task 1, ADL examined incident data and attempted to develop accident scenarios to account for various types of accidents. In Task 2, ADL tested gas-fired water heaters under a variety of conditions. ADL states "The overall goal of the project is to develop a comprehensive understanding of the extent of the hazards identified and the effectiveness of current mitigating measures. " CPSC asked GAMA: "Is this work viewed by GAMA as suitable for development of a standard test method?" GAMA responded (TAB F), "...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."

3.1 Flammable Vapors Hazards Ignition Study, Task 1

As stated above, the purpose of ADL's Task 1 was to collect, review, and analyze data on fires involving water heater ignition of flammable vapors. The data were then grouped according to the conditions of the accident to generate accident scenarios that could form the basis of a subsequent test program (Task 2). ADL examined 142 reports (103 CPSC Epidemiological Investigation Reports, and 39 National Fire Protection Association reports) to generate seven accident scenarios.

The Directorate for Epidemiology has reviewed the Task 1 report and points out some significant shortcomings in the scenarios developed in Task 1 (TAB J), in particular

1. The ADL scenarios are not representative of the National Fire Incident Reporting System (NFIRS) data.

2. The scenarios were more severe than indicated in the NFIRS data.

Since the scenarios formed the framework for ADL's Task 2 testing, the results of the testing may not be representative of what is occurring in the field. For example, in about half of the incidents, the source of gasoline is a leak, typically from either a lawn mower or a weed trimmer. The gas tanks on these appliances are smaller than the amount of gasoline spilled in many of the experiments in Task 2. Using more gasoline in the tests increased the likelihood of vapor ignition, and may explain why Task 2 results appear to conflict with field reports

indicating that elevating water heaters reduces the hazard of flammable vapor ignition.

3.2 Flammable Vapor Hazards Ignition Study, Task 2

The two stated primary goals of Task 2 were "to understand, through experiments, the dispersion of flammable vapor under controlled conditions and to determine the role of the water heater as an ignition source." Staff is concerned that many of the conditions chosen for the testing were not representative of field conditions. Also, staff disagrees with ADL's interpretation of the results.

ADL performed a total of 37 "live fire" tests to gain information on the role of water heaters as ignition sources for gasoline vapors. There were a total of seven primary variables in the test matrix; water heater height, room size, size of spill, room temperature, floor temperature, distance to spill, and movement in the room. A brief discussion of CPSC staff concerns with the test conditions follows.

3.2.1 Test Conditions

The staff has concerns that the test conditions chosen for ADL's Task 2 testing were more severe than typical home conditions, which may have caused more vapor ignitions under the test conditions than would be expected in the home. This could minimize the apparent effectiveness of elevating water heaters to prevent flammable vapor ignition. (For the purpose of increasing the safety of new water heaters, however, a test method with severe conditions is desirable.)

Room and Floor Temperature

ES disagrees with the floor and room temperatures chosen for the tests. When originally published (and provided to Commission staff), the Task 2 report showed a total of 13 experiments where the floor temperature in the test room exceeded the air temperature in the room. Subsequent to report distribution, numbers in the data tables were found to be transposed. In November, 1993, the data tables were corrected and the final number of cases where floor temperature exceeded room temperature was revised downward to 6. CPSC received copies of the revised tables with the submission of additional data requested from GAMA. We remain concerned that elevated floor temperatures increased the amount of vaporization of the gasoline spill on the floor, making vapor ignition more likely than may be the case in the typical accident scenario of which we are aware. ADL maintains the intent of those test conditions was not to increase vaporization, and that they were trying to mimic conditions in carports in the summer in the southwest, where many of the accidents occur. However, the tests were run in a tightly sealed room with an estimated air exchange rate much less than expected for a typical carport scenario, resulting in higher vapor concentrations and greater likelihood of ignition .

In subsequent conversations, industry personnel explained that the variation between room and floor temperature was also a product of the of the test facility (TAB H). The tests

were done in a room constructed outside on a cement slab during the winter. The slab was heated to above outdoor temperature of early spring in Cleveland, OH. The room itself was heated with an industrial space heater which had to be turned off prior to spilling the gasoline. This caused the room temperature to fall rapidly, resulting in average room temperatures below the floor temperature. This could result in an apparent decrease in effectiveness of raising the water heater.

Spill Size

As mentioned in the Task 1 discussion, we are concerned about the amount of gasoline used to produce the spills. When CPSC staff examined the accident reports, it determined that about half of the incidents involved gasoline leaking or spilled from the gas tanks of power tools such as lawn mowers and weed trimmers. Of the 32 spill tests performed by ADL, 18 tests were run with 1 gallon spilled, 7 with 2 gallons, 3 with 1.5 gallons, and 4 with a 0.5 gallon spill (4 tests were run with gasoline-soaked rags as the source of vapors). Staff believes that these spill sizes do not reflect field conditions and would tend to minimize the effectiveness of raising the water heater.

Motion in the Room

Motion is a critical variable, since gasoline vapors are heavier than air and tend to stay near the floor. Motion in the room effectively stirs the room air, lifting the vapors above the level they would achieve in a static room with no air currents. By controlling the amount of mixing, the likelihood of ignition can be influenced. ADL used a plywood cutout of a 3-foot tall figure in the shape of a person. Motion was generated by pushing and pulling the dummy back and forth a rate of approximately 2 feet per second over a distance of 2 feet. The dummy moved on tracks that were directed at the water heater. In both the 6'x10' and 8'x8' rooms the track was directed at the water heater and approached to 19" from the water heater. Staff believes that using a flat cutout and moving it at this rate may create excessive air movement in the room, thereby increasing likelihood of ignition.

3.2.2 Interpretation of Results

As a result of the Task 2 program, ADL offered general observations and insights into water heater ignition of flammable vapors:

- "Motion is an extremely important enhancement of ignition.... In an extremely quiescent environment with no temperature gradient, diffusion vertically will occur very slowly.....However, movement of some nature is almost always present.....This motion will elevate the vapor level and promote mixing. Ignition when mixture (sic) reaches an ignition source with a flammable vapor concentration above the flammable limit."

- "In comparison to floor mounted tests, elevation of the water heater delayed ignition in some cases but always resulted in a large volume of flammable vapor being present when ignition occurred. These events were characterized by

ignition more like explosions than pool fires."

- "Results of our tests were sensitive to spill volume and room size. The latter (sic) is perhaps obvious since greater spill volume gave larger spill areas, more surface for evaporation, and more liquid to evaporate. Room size is also important, particularly during our tests with minimal ventilation, introduced only near the ceiling. Natural vapor build-up and effect of motion are enhanced in smaller volume rooms."

- "....Our conclusion is that temperature is not as important as motion, room size, or spill volume."

As stated earlier, CPSC staff met with ADL staff on December 16-17, 1993, to review the Task 2 study (TAB K). At the time of the meeting, the results had been published for approximately 6 months, and amended tables had been supplied to GAMA. In the Task 2 report, ADL reached the following general conclusions:

"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 vapors, particularly in realistic situations where movement is present. The delayed ignition can produce significant pressure waves."

Based on a preliminary analysis of the published results, and the December, 1993, meeting, J.L. Mulligan of CPSC's Engineering Laboratories concluded, in part, that "...Raising the water heater 18 inches appears to significantly reduce the likelihood of ignition in case of a gasoline spill." (TAB K)

3.2.3 Analysis of Industry Data

A follow-up engineering analysis of the Task 2 results was done to determine the effects of raising the water heater and varying the test conditions (TAB L). Because of the small number of tests compared to the large number of variables, and because multiple variables were changed for many of the tests, a statistical analysis could not be performed. ES therefore took a "common sense" approach and grouped sets of tests of raised and unraised water heaters where few variables changed.

Analysis was done on data contained in tables 8-10, pages 20-22, of the Task 1 report. Tables 8-10 presented results of 32 "live-fire" gasoline spill tests. The effect that eight variable parameters had on ignition time of gasoline vapors by a water heater was examined. The eight parameters were: elevation, movement, floor temperature, room temperature, effect of

having floor temperature greater than room temperature, room size, amount of spill, and spill distance.

The method used to examine the data was simple and straightforward. By grouping together tests in which 7 of the 8 variables were held essentially constant it was possible to "isolate" the eighth variable such that its effects on ignition time could be better understood. The results are summarized as follows:

- Elevating a water heater 18 inches generally increased the time to ignition and prevented ignition when similar elevated and unelevated cases are compared.
- Movement in the room reduced the time to ignition.
- Increasing floor temperature slightly reduced the time to ignition.
- Increasing the room temperature slightly reduced the time to ignition.
- Having the floor temperature greater than the room temperature slightly reduced the time to ignition.
- Increasing the room size increased the time to ignition.
- The greater the amount of the spill, the greater the reduction in the time to ignition.
- Increasing spill distance increased time to ignition.

4 Economic Considerations

There are several possible approaches to reduce this hazard by modifying the design of water heaters currently on the market without the cost of designing entirely new water heaters. Direct vent water heaters and appliances currently on the market that take combustion air from above floor level may hold promise as solutions.

Direct vent water heaters use an annular vent pipe to both exhaust the flue products and bring combustion air from outside the dwelling where the appliance is installed. Combustion air is brought in through the outer portion of the annulus, and combustion products exit through the inner portion. The success of this approach depends on keeping the flammable vapors out of the appliance combustion chamber. This requires that the combustion chamber and the air intakes be sufficiently tight to prevent the vapor concentration from reaching the LEL in the combustion chamber when a flammable mixture exists in the vicinity of the appliance. As this is not currently required, staff believes that current designs may need to be modified for this application. A direct vent water heater normally is vented horizontally thorough the wall to the outside. This design holds promise only for installations where a direct vent appliance can be installed. In those installations where it is not possible to vent the product horizontally, the air intake portion of the vent annulus could be opened above the water heater. This would result in combustion air being taken from above the water heater, greatly reducing, but not absolutely eliminating, the potential for flammable vapor ignition. At the current time direct vent water heaters are significantly more expensive than typical residential water heaters. The Directorate for Economics Analysis reports that the cost differential is about $200.

At least one manufacturer lists a water heater in their catalogue that takes combustion air from above the floor by perforating the outer appliance jacket, and ducting the combustion air down between the inner tank and the outer jacket. It may be possible to modify this design by raising the intake holes and sealing the combustion chamber. If this approach is taken, the risk would be reduced but not eliminated. This model now lists for $420, about $245 more than a base model.

Although these water heaters cost more than the standard or basic models, the higher prices are not due solely to the methods by which combustion air is drawn into the appliance. Theses higher-priced models also include features such as higher energy efficiency, longer warranties, and sediment prevention features that are not provided with the basic models. Based on the most recent information from the Directorate for Economic Analysis, the societal cost of these accidents, including, deaths, injuries, and property damage, may reach $395 million annually (TAB M). There are an estimated 40 to 50 million residential water heaters in use in the United States. Assuming a discount rate of 5 percent and an average useful life of 11 years, we estimate that a modification that eliminates nearly all of the incidents would be cost effective at $68 to $85 per unit.

5 Conclusions:

Based on this review of current and planned industry activities to address the hazard posed by gas-fired water heater ignition of flammable vapors, it appears that industry is now attempting to resolve this problem. A standards development project has begun, and industry is testing a new burner design to address the hazard. However, staff has concerns about the details and timely completion of these activities.

Although industry has orally briefed Commission staff on the design testing currently underway, they have not provided enough information to allow an independent assessment of the technology and its potential to resolve the vapor ignition problem. While industry representatives report that preliminary test results are favorable, additional testing must be performed to assure that the new technology does not cause other, currently unforeseen, hazards. No schedule is available for the completion of this work. Industry claims the testing will be completed soon and that as soon as the results of the additional testing have been reviewed by industry and a decision has been reached as to the design's viability, this information will be provided to CPSC staff.

The proposal for the standards development test activity being conducted under contract to the Gas Research Institute has been reviewed. Staff expressed reservations about the technical approach being taken to develop the test conditions for the test method. GRI and ADL responded by proposing a new test approach based on a "worst case" scenario. Staff believes that this approach, which presumes that the water heater will be exposed to a flammable vapor atmosphere and must be designed so that it does not produce ignition, is an adequate basis for a test method.

The current schedule for the test method development calls for the contract testing to be completed 9 months from contract award. GAMA estimates an additional 30 months to the effective date for the resulting ANSI standard provision. While CPSC staff will explore ways to accelerate the ANSI approval process, this may not be possible because of the major impact of a substantial change in design certification requirements. Also, schedules for test development can be delayed significantly because of technical difficulties in developing a method that produces consistent results.

Further testing needs to be done to validate the effectiveness of raising a water heater to eliminate or reduce ignition of flammable vapors if it is to be a solution to the vapor ignition problem. CPSC analysis of industry research shows that raising the water heater will greatly reduce the likelihood of vapor ignition in a room without air mixing. Further live fire testing must be conducted to ascertain the effects of room air mixing. Also, while it appears that temperature effects are minimal, the number of tests run is small, and additional testing would be necessary to quantify temperature effects. While industry states that the completed tests do not represent a "standards development activity," if industry were to use the results to define future standard test conditions, any bias in the test method may be reflected in the final test method.

The two ongoing industry activities, design testing and test method development, are independent. If the new technology proves effective in reducing the hazard, industry assures CPSC that it will be incorporated into all water heaters as quickly as possible. It is possible that products could be brought to market before the effective date of a voluntary standard. However, this does not obviate the need for a voluntary standard because other technologies may be developed as well, and a standard would be needed to evaluate them for acceptability.

Staff is convinced that gas-fired water heaters will continue to cause flammable vapor ignitions so long as the current "typical" water heater design is used. There are, however, several possible approaches to reduce this hazard by modifying the design of water heaters currently on the market. As discussed above, direct vent and water heaters with elevated combustion air intakes may hold promise as solutions.

Staff emphasizes that these are not proven solutions. They are approaches that may hold promise. Once modifications are completed, and if the modifications are successful in reducing the vapor ignition hazard, the appliances must still pass all other performance requirements currently required. Additionally, durability, service, and installation considerations must figure into the final acceptance of any design. Due to condensation during normal operation, water may accumulate in the combustion chamber. If this leads to corrosion and perforation of the combustion chamber, the vapor ignition protection could be lost. Also, water heaters need to be field serviced to re-light pilots or replace thermocouples. This means that the combustion chamber must be accessible to service personnel, but be able to be resealed to prevent vapors from entering. Clearly, significant changes will need to be made to assure long-term safe operation of any modified products.

Staff recommends that the Commission not issue an ANPR and work with industry to develop a voluntary standard. Industry has addressed the reasons for the previous recommendation to publish an advance notice of proposed rulemaking. At the November 22, 1994, industry meeting with Chairman Brown, industry stated that they are committed to developing a performance standard for new gas-fired water heaters to address the risk of death and injury from the ignition of flammable vapors. Industry is also is evaluating a new burner design to eliminate the ignition hazard. Industry has acknowledged by these actions that the solution to this problem is not solely a consumer education issue, but a water heater design issue as well.

If the Commission chooses this option, staff will alert the Commission immediately if progress on developing the performance standard is unsatisfactory and will brief the Commission on options to address the problem. This would include the option of issuing an ANPR, and initiation of the test method development work necessary to support rulemaking.

In view of the uncertainties in the content, timing and ultimate adoption of any industry voluntary standard, the staff believes very close participation with the industry is *critical to judge the progress of standard development.*

If the Commission directs the staff to publish an ANPR, it may not be possible to publish a proposed rule in one year. There are a number of difficult technical issues involved, and a test method can not, in all likelihood, be developed quickly. Because of the time required to develop the test method for a proposed rule, respond to issues raised by an ANPR, and support the preliminary findings required by the CPSA to propose a rule, the staff estimates that it may take as long as 18 months from publication of an ANPR to publication of a proposed rule.

If directed to publish an ANPR, the staff will try to accomplish the necessary work to support a proposed rule sooner than 18 months. However, any period for publication of a proposed rule that is longer than 12 months after ANPR publication, will require that the Commission, for good cause, extend the 12-month period for publishing a proposal as provided in section 9(c) of the CPSA.

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CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

VOTE SHEET

DATE: JUN 8 1994

TO : The Commission
Sadye E. Dunn, Secretary

FROM : Eric A. Rubel, General Counsel
Stephen Lemberg, Asst. General Counsel
Harleigh Ewell, Attorney, GCRA (Ext. 2217)

SUBJECT: Options for Gas-Fired Water Heaters Concerning Ignition of Flammable Vapors

This vote sheet concerns the staff's briefing package on options for Commission action to address the risk that gas-fired water heaters will ignite vapors from flammable liquids that are present in the home. Please indicate your vote on the following options.

I. ISSUE AN ADVANCE NOTICE OF PROPOSED RULEMAKING ("ANPR") (a draft ANPR is at Tab H of the briefing package). Please check the relevant option below.

____ 1. APPROVE THE DRAFT *FEDERAL REGISTER* NOTICE WITHOUT CHANGE.

____ 2. PUBLISH THE DRAFT *FEDERAL REGISTER* NOTICE WITH CHANGES (please specify).

____ 3. OTHER (please specify).

(Signature) (Date)

II. DEFER TO THE VOLUNTARY STANDARDS PROCESS (staff will encourage ANSI and GAMA to develop adequate voluntary standards).

(Signature) (Date)

NOTE: This document has not been reviewed or accepted by the Commission.
Initial: SD Date: 6/8/94

OS Closed
6/9/94

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III. THE OFFICE OF COMPLIANCE AND ENFORCEMENT IS DIRECTED TO ANALYZE THE FEASIBILITY OF ACTION UNDER SECTION 15 OF THE CONSUMER PRODUCT SAFETY ACT.

_____ _____
(Signature) (Date)

IV. TAKE OTHER ACTION (please specify).

_____ _____
(Signature) (Date)

Comments/Instructions:

Executive Summary

This memorandum presents options to address the risk of death and injury associated with gas-fired water heaters igniting flammable vapors. Gas water heaters, of traditional design, draw the air necessary for combustion from the bottom. When they are mounted on the floor that means that they draw their air from near the floor. When gasoline or other heavier-than-air flammable vapors are present, the vapors tend to layer near or on the floor and can be pulled into the flame, be ignited and cause fires.

Each year an estimated 1,961 such fires occur causing an estimated 316 injuries, 17 deaths and $26 million in property damage, representing an annual estimated societal cost of $344 million. The typical injury happens when a person is using gasoline for cleaning purposes or when gasoline is accidentally spilled in an area close to a gas water heater.

Two years ago, staff requested the American National Standards Institute (ANSI) Accredited Z-21 sub-committee on water heaters to begin development of a performance standard to reduce the risk of death and injury presented by water heaters igniting flammable vapors. Since that time the water heater industry, through their trade organization, the Gas Appliance Manufacturers Association (GAMA), has funded two studies and a consumer information program but has not moved toward developing a standard. The voluntary standards process has been delayed while these studies were in process and no progress is known to staff towards developing an adequate standard.

Staff has demonstrated that the flammable-vapor-ignition fires associated with water heaters can be virtually eliminated using simple engineering principles about relative vapor densities of air and gasoline and the ability of mechanical barriers to change fluid flow patterns. Staff believes that these principles can be applied to new water heaters with little difficulty or cost.

Options available to the Commission to address this hazard include:

1. Issue an advance notice of proposed rulemaking to develop a performance standard to reduce or eliminate the risk of death or injury from the ignition of flammable vapors.
2. Defer to the voluntary standards process.
3. Pursue action under section 15 of the CPSA.

Staff recommends option 1, that the Commission publish an advance notice of proposed rulemaking to develop performance requirements for new gas-fired water heaters to address the risk of death and injury from the ignition of flammable vapors.

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05#5595

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

MEMORANDUM **DATE:** JUN 8 1994

TO : The Commission
: Sadye E. Dunn, Secretary

THROUGH : Eric A. Rubel, General Counsel Office EAR
: Bert Cottine, Executive Director

FROM : Ronald L. Medford, Acting Assistant Executive Director for Hazard Identification and Reduction RLM
: Joseph Fandey, Project Manager for Fire and Gas Voluntary Standards, ESEE (504-0508 ext. 1293)

SUBJECT : Options Paper re: Hazards associated with gas-fired water heaters igniting flammable vapors.

Purpose: To present options for the reduction of flammable vapor ignition hazards and resulting injuries and deaths.

Background:

Staff has been concerned with gas-fired water heaters igniting flammable vapors for several years. Deaths and injuries occur when flammable vapors, most often from spilled gasoline, are pulled into the water heater flame. Water heaters, of traditional design, draw air necessary for combustion from the bottom. When gasoline or other heavier-than-air flammable vapors are present they tend to layer near or on the floor and can be pulled into the flame where they can be ignited and cause fires.

Until the spring of 1991 staff had considered that the solution was one of changing consumer behavior to cause consumers to not use or store gasoline or other flammable vapors in the house.

In the spring of 1991 this approach changed when the staff realized that a mechanical fix (bringing combustion air into the appliance from 18 inches above the floor) could reduce or eliminate the risk of injury associated with water heater ignition of flammable vapors. The

NOTE: This document has not been reviewed or accepted by the Commission.
Initial SJ Date 6/8/94

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SC memo removed;

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information that changed the staff's approach was presented to the American National Standards Institute (ANSI) Z-21 Accredited Water Heater Subcommittee in November 1991. In March of 1992, staff formally requested that the ANSI subcommittee develop a performance standard designed to protect against flammable vapor ignition. (Tab A) The industry did not respond by undertaking standard development. Instead the Gas Appliance Manufacturers Association (GAMA) began to study the problem, ostensibly to determine whether there were geographic differences in injury rates. A study was also funded by GAMA to determine whether an 18 inch stand would prevent all ignitions of flammable vapors. When some fires were started, albeit in extreme conditions, the industry concluded that not all fires would be prevented and thereafter declined to consider elevating water heaters.

Instead of developing a product standard, as staff had requested, GAMA developed a consumer education program. The program is of excellent quality and the Commission has acknowledged this effort and voted to allow the use of the CPSC name and logo on certain publications and video tapes contained therein. However, the education program is not a "fix" for the problem, it is merely a means of informing consumers of the potential hazard.

Death and Injury Data:

CPSC Data:

The Directorate for Epidemiology presents 5-year fire, death, injury, and property damage averages for the period 1986-1991. (TAB B) Gas-fueled water heaters igniting flammable liquids are identified annually in only 20% of the 1,961 estimated annual fires associated with water heaters, but they account for 54% of the injuries (316), 44% of the of the deaths (17) and 30% of the property losses ($26,339,000).

Typical injury scenarios fell into three categories; children playing with or near gasoline, gasoline being used as a solvent, or other gasoline spill or leak.

Other Data:

GAMA sponsored work done by A.D. Little Laboratories (included in the supplemental materials available in the Office of the Secretary) examined several data bases including CPSC's and identified scenarios related to the bathroom, utility room, and a combination garage and

basement.

No current building code allows water heaters to be installed in bathrooms; nevertheless, many such installations exist. The two scenarios identified included people becoming "soaked" during activity such as cleaning parts, car repair or fueling operations. When such a person enters the bathroom where a water heater is installed, the vapors fall like water from the clothing and an ignition occurs. The other bathroom scenario involved children becoming covered in paint or a petroleum product and being brought into the bathroom and placed in the bathtub to have the material removed using gasoline as a solvent.

The utility room was associated with two scenarios. One, with a spill outside the room containing the water heater such as in an adjoining garage. The other scenario involved a spill within the room. In these accidents, some activity such as playing, fueling, or other use is often involved.

The garage and basement accidents again involve storage and associated spills, use of gasoline as a solvent, refueling and activities of children. The A.D. Little report indicates that of a data base of 135 incidents involving ignition of flammable vapors by residential gas water heaters, only 27 were known to have occurred in a garage. While 31 of the incidents did not specify the room location, the report's analysis showed that, in incidents where the room location was specified, the garage was involved in 10 of 27 deaths, 5 of 33 injuries and 2 of 11 incidents in which there were both deaths and injuries.

Applicable Codes and Standards:

Staff is aware of two standards which impact ignition of flammable vapors:

- The National Fuel Gas Code, NFPA 54/ANSI Z-223.1 which requires that water heaters installed in residential garages have all burners and burner ignition devices located not less than 18 inches above the floor. §5.1.9. In addition at §5.1.8 there is a requirement that "gas appliances shall not be installed in any location where flammable vapors are likely to be present, unless the design, operation, and installation are such to eliminate the probable ignition of the flammable vapors."

- The ANSI Gas Water Heater Standard, ANSI Z21.10.1 requires a label warning of the risk of injury associated with ignition of flammable vapors.

Staff has noted that the NFPA 54 requirements for garage installations have recently been incorporated into all model building codes. Staff notes that adoption by the model building codes does not guarantee that the provisions will be incorporated into local building ordinances, where compliance is enforced. Even if local jurisdictions adopt these provisions, garages apparently represent only a portion of the problem. Staff also notes that even if all new construction of houses and commercial replacements of existing residential water heaters followed the practice of elevating water heaters in the garage, there is a large portion of the incidents that would not be addressed. Staff believes that there has been very poor adherence over the years (since 1959) that the requirement has been in the National Fuel Gas Code. Moreover, staff believes that the provisions for other than garage installations are virtually never enforced for residential installations.

Additionally, the Division of Human Factors notes that the label is likely to have limited effectiveness and is unlikely to be thought about during activities unrelated to the water heater like lawn mower filling, or other gasoline usages such as for cleaning purposes, even if the label has been read.

Engineering:

Feasibility of a Performance Standard: Work at the Engineering Sciences Laboratory (ESEL) and at the American Gas Association Laboratory, by A.D. Little, demonstrated that when a gas water heater is installed on the floor, one half gallon of spilled gasoline caused dangerous levels of vapor in the area of the water heater burner. Engineering Laboratory work demonstrated that even minor elevation of the water heater (6 inches) significantly reduced the vapor levels reached. At the full 18 inch elevation, good protection was observed. The A.D. Little work also demonstrated greatly improved performance by elevation, but the work was extended to demonstrate that two gallons spilled with a lot of air turbulence forcing the vapors into the water heater could result in conditions where fires were possible.

Not every installation provides enough space above the water heater to allow elevation and proper venting for standard water heaters. To

address this problem, ESEL tested the water heaters on the floor with a 14 inch high sheet-metal barrier sealed to the floor. Even a one gallon spill 18 inches from the center-line of the water heater (so close that without the barrier, the gasoline ran under it) resulted in levels of flammable vapors below those considered unsafe. When these results were shared with the industry, the most important questions raised were about the effect of the barrier on the combustion characteristics of the water heater (to see whether unsafe levels of CO would be released). To answer this question, ESEL tested the water heater with and without the barrier. The results in combustion characteristics were indistinguishable. Staff believes that the combined work by CPSC and A.D. Little demonstrate that new water heaters can be made much safer. The effect of a barrier such as that used by ESEL can be built into a new water heater.

Feasibility of a Retrofit Method: Engineering has demonstrated the feasibility of developing a method to retrofit water heaters already installed in residences. (Tab C) The method used by Engineering was very simple, a piece of sheet metal (roof flashing) 14 inches by 6 feet was taped together using duct tape to form a circle slightly larger than the water heater's circumference and was then taped to the floor. This action forced all air for combustion to be drawn over the 14 inch barrier created. As a result, very little air was drawn from near the floor. This performance can also be incorporated into new water heaters without restricting design options. In order to assist in the retrofit work staff was undertaking, GAMA supplied water heaters which had been tested by the Department of Energy for fuel efficiency. Five water heaters were received at the ESEL and were properly fueled and run to determine the normal exhaust gas velocities that were produced at the top of each water heater. (Tab C) A "typical" water heater was then fitted with a small fan, which was adjusted to produce the same exhaust gas velocity and thereby safely simulate the gas flow which is produced by the burner's fire in normal operation. Using the fan instead of a burning unit allowed the tests to be conducted with gasoline while minimizing potential risk to laboratory personnel. The unit was transported to the National Institute of Science and Technology (NIST), where it was installed in a fire test facility with the fan used to simulate normal operation. Several experiments were conducted where gasoline was spilled on the floor near the water heater (18 inches from its center). Gasoline vapor concentrations in the air were measured at several locations,

most importantly at the burner. The results were that the barrier provided significant protection against flammable vapor ignition.

Industry Activities:

The staff's greatest concern is an apparent unwillingness on the part of the water heater manufacturers to take a serious look at the potential deficiencies (of taking combustion air from near the floor) in the current design of water heaters.

As noted above, the water heater manufacturers, through GAMA, have elected to emphasize consumer education over product improvements which could reduce or eliminate the risk of flammable vapor ignition. While staff believes that GAMA's efforts in the consumer education area are commendable, staff has repeatedly noted that it is not a complete solution. In the January 19, 1994 briefing package in which staff recommended that the Commission grant permission to GAMA to use the CPSC name and logo on certain consumer information materials, staff stated that "Staff considers that this [consumer information campaign] 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*" [emphasis added]. (Tab D) The Division of Human Factors had voiced a similar concern regarding labeling. Human Factors stressed that prominent warning labels are necessary, but also noted that "A warning label is not an acceptable substitute..." (Tab E). The Chairman of the ANSI Z-21 Committee received a letter from Factory Mutual Research, and shared that letter with CPSC staff. (Tab F). Therein, Factory Mutual expressed the same concerns about the industry approach of only initiating a consumer information campaign. "If it is easy to handle the flammable liquid indoors, it will be done by some individuals, no matter how many warning labels or education programs to which they are exposed . . . Thus, the hazard [vapors in the home] cannot be eliminated. Therefore, it must be mitigated." Factory Mutual describes the approach taken by the industry as ". . . 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."

Economic Analysis:

Market Information: Based on Department of Energy data, the

Directorate for Economic Analysis (EC) indicates (Tab G) that there are between 40 and 50 million homes in the U.S. that have gas water heaters. Current sales are about 3.5 million units annually, according to the American Gas Association, and replacement rates (between the 4th and 18th year of use, according to *Appliance Magazine*) suggest that an additional 10 million units may be in use by the end of this decade. The five manufacturers that dominate the gas water heater market account for an estimated 99% of production.

Cost/Benefit Data: The total estimated societal costs associated with incidents involving gas water heaters and the ignition of flammable vapors are $344 million. These costs include deaths, injuries, and property damage. EC estimates that it would be cost-effective to spend from $59 to $74 per water heater for modifications that would eliminate virtually all incidents involving the ignition of flammable vapors.

Options:

1. Issue an advance notice of proposed rulemaking to develop a performance standard to reduce or eliminate the risk of death or injury from the ignition of flammable vapors.
2. Defer to the voluntary standards process and encourage ANSI and GAMA to proceed with developing adequate provisions for reducing or eliminating the risk of injury associated with gas water heaters igniting flammable vapors.
3. Pursue action under section 15 of the CPSA.

Recommendation:

There are significant numbers of severe injuries and deaths occurring from gas water heaters igniting flammable vapors that could be cost-effectively prevented by establishing a performance standard which would be adhered to in the manufacture and certification of gas water heaters. Staff notes that even though a request was made 2 years ago, no standard development work has been undertaken by the committee charged with such development. Therefore, staff recommends that the Commission exercise option 1 for new water heaters. Available information indicates that it is technically feasible to develop performance requirements to address this hazard. A draft ANPR appears at Tab H for Commission consideration.

U.S. CONSUMER PRODUCT SAFETY COMMISSION

WASHINGTON, D.C. 20207

March 6, 1992

Allan J. Callahan
Manager, Standards Department
American Gas Association Laboratories
8501 E. Pleasant Valley Road
Cleveland, OH 44131

Dear Mr. Callahan:

Enclosed, for use by you and the Water Heater Subcommittee's working group on flammable vapor ignition, is a position paper from the staff of the CPSC on the subject of the need for standards for preventing such ignition from water heaters.

It is the position of the staff that ignition performance equal to or exceeding that achieved when a "standard" water heater is tested in an essentially draft free room at an elevation of approximately 18 inches (or another value which testing demonstrates to be needed) is a desirable goal. We would suggest that any standard developed be expressed in performance terms to eliminate any unessential design restriction.

The staff recognizes that the committee must consider only safety when making its decisions; nevertheless, the staff examined the benefits of preventing the deaths and injuries associated with the ignition of flammable vapors by water heaters. Staff estimates that net benefits would accrue to the consumer if the cost to implement any design changes was less than about $40 to $60.

Staff plans to participate fully with the working group and subcommittee in the examination of these issues and the development of test requirements and standards.

The views expressed in this letter (with enclosures) are those of the technical staff and not necessarily the official position of the Commission.

Sincerely,

Joseph Z. Fandey
Project Manager,
Gas Voluntary Standards

Enclosure

CPSC Working Group on Gas Voluntary Standards

Position Paper On A Standard for Gas Water Heaters To Prevent Ignition of Flammable Vapors

FEBRUARY 1992

FLAMMABLE VAPOR IGNITION BY GAS WATER HEATERS

BACKGROUND:

On April 4th, 1991, CPSC staff met with Edward Downing, an attorney practicing in Louisiana. At that meeting Mr. Downing presented injury information indicating that about 360 injuries, 20 deaths and $16,000,000 in property loss were occurring annually from the ignition of flammable vapors by gas water heaters. These estimates mirrored CPSC's own data and were consistent with a 1975 study done for CPSC by Calspan. While staff was concerned with this problem over the years it accepted the position of the industry (as the industry recently reiterated in a meeting with staff) that the problem was not amenable to design fixes but was a result of a lack of consumer awareness of the hazard and knowledge of proper storage and handling of flammable vapors. Mr. Downing's presentation also included videotaped demonstrations of two design fixes which, under the conditions of the test, eliminated the ignition hazard. As a result of that presentation and a subsequent staff review of all available data, CPSC staff revised its plan to include encouraging the ANSI Z-21 subcommittee on Water Heaters to develop performance standards to reduce or eliminate the degree of hazard associated with currently produced (non-sealed combustion) water heaters installed at floor level.

On November 13th, 1991, Mr. Downing made a similar presentation before the ANSI Z-21 Water Heater subcommittee. In subsequent discussions the subcommittee made a commitment to form a working group to study the issue and work toward a performance standard. In support of that effort CPSC staff is providing the following information.

DISCUSSION:

Injury Update - The most recent information available from the U.S. Fire Administration reports that there were an estimated 380 injuries, 30 deaths, and $50.6 million in property loss associated with gas-fired water heaters in 1989. Twelve of the 30 deaths were associated with flammable vapors as were 75 percent of the injuries. A more complete discussion of this information is provided at Tab A.

Benefits Associated with the Prevention of Deaths, Injuries, and Property Damage - Using the annual average numbers of deaths and injuries associated with flammable vapor ignition by water heaters, the Directorate for Economic Analysis estimated the benefit which could

be achieved by eliminating this hazard (Tab B).

The estimation of the benefits considered the severity of burns the most frequently seen injury associated with this scenario. It also considered that three-fourths of current annual water heater production, estimated at 3.9 million units, is for replacement and one-fourth for new construction. Finally, the estimates considered that, if the entire production of gas water heater installations could be affected, and if the changes were fully effective injury reduction could accumulate at the rate of up to two deaths, 30 injuries and $1.2 million in property damage each year. The estimated benefit expected per household could total $40-$60 over the expected 11-year life of the gas-fired water heater.

Effectiveness of labeling - The Human Factors Division has examined the possible effectiveness of labeling for preventing these injuries and concludes, at Tab C, that a warning label is not the solution to the hazard and should not be used as a substitute for a design change. However, because raising the water heaters will not eliminate the potential for the ignition of flammable vapors, consumers are still at risk and need to be warned of the potential hazard.

CONCLUSION:

CPSC staff believes that it is technically feasible to reduce the hazards associated with flammable vapor ignition by water heaters. Mr. Downing suggested that an appropriate height is already in the NFPA standard for installation of water heaters in garages, 18 inches. However, whether an 18 inch height or its equivalent is necessary or even sufficient has not yet been determined. The CPSC staff therefore recommends that the subcommittee's working group examine various heights and make a determination of the actual performance requirement necessary to reduce or eliminate the existing hazard. Subsequently, it will be necessary to devise a test method whereby non-height related fixes can be evaluated and certified.

UNITED STATES GOVERNMENT

MEMORANDUM

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

DEC 18 1991

TO : Joseph Z. Fandey, Manager, Gas Voluntary Standards Project

Through: Robert D. Verhalen, Associate Executive Director
Directorate for Epidemiology
Robert E. Frye, Director, EPHA

FROM : William Rowe, EPHA, 492-6470

SUBJECT: Fires from Gasoline Ignited by Gas Water Heaters

An estimated three-fourths of the reported deaths and injuries, and over half of the property losses from flammable vapor fires ignited by water heaters involve gasoline vapor and gas water heaters (see the attached table). The data included in this table are for 1989, the most recent year that is available from the U.S. Fire Administration's National Fire Incident Reporting System(NFIRS). In 1989, there were an estimated 30 deaths, 380 injuries, and $50.6 million in property loss due to gas fired water heaters. The attached table shows an estimated 12 of the 30 deaths were due to flammable vapors (nine gasoline and three other vapors). About 75 percent of the injuries were related to gasoline vapors.

From October 1975 to November 1991 the Consumer Product Safety Commission (CPSC) conducted 41 in-depth investigations (IDI) involving the ignition of flammable vapors by gas water heaters. Only four of the 41 cases contain information on the height of the air intake. Among them, the highest air intake was estimated as 12 inches above the floor.

Discussion:

The hazard of gasoline vapor ignition by water heaters has often been seen as addressable through increasing consumer awareness of fire hazards associated with gasoline and improving gasoline storage containers. Raising the gas water heater air intake 18 inches above the floor through a voluntary standards effort should be encouraged to prevent gasoline vapor ignition by

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gas water heaters. The pilot light and burner assembly of gas water heaters are at the bottom, and heaters are usually installed on or very close to the floor. Heavy flammable vapors, typically gasoline, stay close to the floor. If gasoline is spilled in the same room as a gas water heater the vapors can easily be drawn into the water heater and ignited. The hazard is very well demonstrated in a video tape shown to the staff in April 1991.

Attachment:

Estimated Fire Deaths, Injuries, and Property Loss from Flammable Vapors Ignited by Water Heaters, 1989

Estimated Fire Deaths

Type of Water Heater	Total		Type of Flammable Vapor: Gasoline		Other	
	No	%	No	%	No	%
Total	12	100	9	75	3	25
Gas Fuel	12	100	9	75	3	25
Other Fuel	0	-	0	-	0	-

Estimated Fire Injuries

Type of Water Heater	Total		Type of Flammable Vapor: Gasoline		Other	
	No	%	No	%	No	%
Total	374	100	281	75	93	25
Gas Fuel	349	93	272	73	77	20
Other Fuel	26	7	9	2	16	4

Estimated Property Loss (in Thousands)

Type of Water Heater	Total		Type of Flammable Vapor: Gasoline		Other	
	No	%	No	%	No	%
Total	$19,400	100	$14,300	73	$5,170	27
Gas Fuel	$15,700	81	$12,500	64	$3,200	17
Other Fuel	$3,700	19	$1,800	9	$1,900	10

Source: U.S. Consumer Product Safety Commission/EPHA from data obtained from the National Fire Protection Association and the U.S. Fire Administration

UNITED STATES GOVERNMENT

MEMORANDUM

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

8 JAN 1992

TO: Joseph Z. Fandey, ESEE, Project Manager, Gas Voluntary Standards
Through: William W. Walton, AED, ES
Through: Warren J. Prunella, AED, EC
FROM: Elizabeth W. Leland, ECPA, 504-0962

SUBJECT: Benefits of Preventing Accidents Associated with Flammable Vapor Ignition by Gas-Fired Water Heaters

Every year, an estimated 20 deaths, 360 injuries, and $15 million in property damage are associated with fires that start when flammable vapors are ignited by gas water heaters. The burn injuries from these fires are severe and require major long-term medical treatment.

A proposal to the building codes and standards to change the design or location of water heaters potentially could eliminate the risk of these accidents, and up to two deaths, 30 injuries, and $1.2 million in property damage could be avoided each year. The estimated expected benefits per household over the life of the product could total from about $40 to about $60.

I. Introduction

This memorandum provides information about the benefits of preventing accidents associated with the ignition of flammable vapors by gas-fired water heaters. The injury and property damage information is based on data from the National Fire Protection Association (NFPA) and the U.S. Fire Administration (USFA). Industry sources provided information about the severity of the injuries, the costs associated with hospitalization, medical treatment, and lost wages, and the dollar amounts of related jury verdicts and legal settlements. Information about the market for water heaters was obtained from the trade press.

II. Background

In some homes, flammable liquids, such as gasoline, household solvents, and paint thinners, are stored in the same location as the household's gas-fired water heater. Gas-fired water heaters operate by taking in room air about two inches from the floor and passing it over a pilot flame; it is possible that

vapors from flammable liquids can be taken in with the room air, especially when the flammable liquid has been spilled or left exposed to the air. When this happens, the vapors can be ignited and a fire or explosion can occur.

In 1980, the American National Standards Institute (ANSI) adopted into its Z223.1 standard a requirement that gas utilization equipment, including water heaters, should not be installed in any location where flammable vapors likely would be present unless the design, operation, and installation of the water heater was such that the probable ignition of the vapors would be eliminated. The National Fuel Gas Code similarly states that the burners and burner ignition devices of gas utilization equipment that is installed in residential garages should be at least 18 inches above the floor. The CPSC staff is considering submitting to the National Fuel Gas Code a proposal to extend this requirement to the entire residence and a proposal to ANSI to change the voluntary standard for water heaters to provide similar protection.

III. Number and Severity of Injuries

There are two readily-available sources of information concerning the number of injuries and deaths associated with the ignition of flammable vapors by gas-fired water heaters. A report prepared by the NFPA in 1987 for a law firm in Metairie, Louisiana, discussed the origin during 1980-1984 of residential structural fires involving flammable and combustible liquids.(1) According to this report, 2,034 fires, 21 deaths, 361 injuries, and $16 million in direct property damage occurred each year during that period as a result of ignition of flammable vapors by gas-fired water heaters.(2)

The other source of information is an estimate provided by the CPSC Directorate for Epidemiology based on data from the NFPA and the USFA. According to the Directorate for Epidemiology, 12 deaths, 374 injuries, and $19 million in property damage occurred in 1989, the most recent year for which data are available.(3) This estimate includes deaths, injuries, and property damage associated with the ignition of flammable vapors by gas-fired water heaters.

The predominant injury associated with these fires is a burn. Information about the severity of the burns resulting from these types of accidents consists of documents from 15 legal cases in which the Metairie, Louisiana law firm represented plaintiffs.(4) Correspondence from the law firm indicates that in those 15 cases the burns were mostly second-and third-degree and covered from 17 to 100 percent of the body.

Of the 15 people who were injured, one suffered burns to 17 percent of his body, four suffered burns to 30 to 50 percent of their bodies, five suffered burns to 50 to 90 percent of their bodies, and four suffered burns to 90 percent or more of their

bodies. The ages of the injured ranged from 14 months to 37 years old. Eleven of the 15 victims were children under the age of five years, one was a seven-year-old child, and three were persons over 30 years old.

IV. Cost of Injuries

According to a report prepared for Congress,

> "a severe burn is considered by many to be the most devastating injury a person can survive. Numerous studies of severely burned patients point to the deep and complicated emotional reactions that accompany burns. Facial disfigurement caused by a severe burn potentially alters consciousness more drastically and creates more serious emotional problems than other forms of disability because the face represents oneself, one's essential being, more than any other part of the body. (6)

Burn victims must confront not only medical costs, but also lost wages as a result of time away from work and emotional costs associated with changes in personal relationships. Information concerning the total dollar value of the costs for burns resulting from accidents involving the ignition of flammable vapors by gas-fired water heaters is not readily available; however, there is some information from three cases litigated by the Metairie, Louisiana, law firm which indicates that the present value of lost wages alone approximated $700,000. (7)

Additional information from Personal Injury Valuation Handbooks about three other cases involving the types of burns suffered by the individuals involved in these accidents indicates that the jury verdicts in each case were $2 million, $3 million, and $10 million.(8) In addition, a 1988 study of burn injuries and verdicts for a five-year period indicated that 22 percent of the awards ranged from $100,000 to $299,000 and 35 percent of the awards were $1 million or more. (9) Information from the cases litigated by the Louisiana law firm indicate that one settlement totalled $7.2 million; all other settlements were at least $1 million. (10)

V. Product Market Information

According to Appliance magazine, the average product life of a gas-fired water heater is 11 years. In 1990, about 48 million, or 53 percent of United States households had gas-fired water heaters. Sales in 1990 totalled 3.9 million; of these, it is estimated that 2.9 million were sold for replacement and that 1.0 million were sold for new homes. (11)

VI. Benefits Associated with the Prevention of Deaths, Injuries, and Property Damage

The dollar value of the benefits associated with the prevention of deaths, injuries, and property damage will depend on how any change made to the installation and building codes is implemented. Reportedly, there are several methods available to prevent deaths, injuries, and property damage from these types of accidents, including changing the physical design and location of the air inlet on the water heater, adding a flame break, or placing the water heater on a stand so that the air inlet is higher off the floor.

Installation and building codes generally apply to new construction; however, if manufacturers were to change the physical design or location of the water heater, then it is likely that all new water heaters on the market would be changed, whether intended for the replacement market or for the new housing market. In this case, then, nearly four million households purchasing new water heaters potentially could be affected by the change to the building and installation codes. If the changes were fully effective, then about two deaths, 30 injuries, and $1.2 million in property damage would be avoided each year.

If the change to the building and installation codes were implemented to apply to only those water heaters being installed in new homes, then potentially one million households could be affected. If the changes were fully effective, then about one death, eight injuries, and $315,000 in property damage would be avoided each year.

VII. Dollar Value of the Benefits of Preventing Deaths, Injuries, and Property Damage

The dollar value of the benefits accruing from the prevention of deaths, injuries, and property damage can be estimated using the information described above about injury costs, jury verdicts, and awards. The estimated dollar value of total benefits from the elimination of all deaths, injuries, and property loss associated with these types of accidents ranges from about $160 million to about $180 million. These estimates are based on the following: a consensus statistical value of life of $2 million, discount rates of 5 percent and 10 percent, an estimated average injury cost of $600,000, (12) the assumption that changes are made to the design of water heaters so that about 4.0 million households are affected, and the assumption that the changes made to the water heaters are fully effective in reducing deaths, injuries, and property damage. The estimated expected benefits per household could total from $40 to $50 over the life of the product.

Under the same assumptions as above excepting that only those 1.0 million new homes constructed with new water heaters would be affected, the estimated dollar amount saved from the elimination of the deaths, injuries, and property damage would range from about $50 million to about $60 million. The estimated expected benefits per household could total from $50 to $60 over the life of the product.

Thus, under the latter assumptions, any cost less than about $50 to $60 to implement changes to the design or location of water heaters would yield net benefits to the consumer. Under the former assumptions, net benefits would occur if the cost to implement the changes was less than about $40 to $50.

FOOTNOTES

1/ Kenneth T. Taylor, National Fire Protection Association, Special Report, Residential Structure Fires Involving Flammable, Combustible Liquids, 1980-1984 Fire Experience, July 1987.

2/ ibid. These data also are reported in Gauthier, Wendell H., Murphy, Robert M., Downing, Edward F.,III, Water Heaters and Flammable Vapors, Gauthier & Murphy, Metairie, Louisiana, p.6.

3/ "Fires from Gasoline Ignited by Gas Water Heaters," memorandum from William Rowe, EPHA, U.S. Consumer Product Safety Commission, to Joseph Z. Fandey, Project Manager, Gas Voluntary Standards Project, December 13, 1991.

4/ Correspondence from Edward F. Downing, III, Gauthier & Murphy, to Mr. Joe Fandey, U.S. Consumer Product Safety Commission, October 19, 1991.

5/ idem.

6/ Dorothy P. Rice, Ellen J. Mackenzie, and Associates, Cost of Injury in the United States, A Report to Congress, 1989, pp. 153-156.

7/ Correspondence from Edward F. Downing, III, Gauthier & Murphy, to Joseph Fandey, op. Cit.

8/ Jury Verdict Research, Inc., Personal Injury Valuation Handbooks, "Burns", p.6. These three cases did not involve the ignition of flammable vapors by gas-fired water heaters, but did involve similar injuries. Two of the cases involved second and third degree burns over two-thirds and 80 percent, respectively, of the victims' bodies and the third case involved severe burns and facial scarring.

9/ ibid., P. 2.

10/Telephone conversation between Gauthier & Murphy and Joseph Z. Fandey, ESEE.

11/Dana Chase Publications, Appliance, April 1991.

12/This estimate is based on the material from the Personal Injury Valuation Handbooks. Previous research and studies by the Directorate for Economic Analysis about the costs of lifetime medical care associated with similar types of injuries indicates that this estimate may be conservative.

UNITED STATES GOVERNMENT

MEMORANDUM

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

NOV 2 1 1991

TO : Joseph Z. Fandey, Project Manager, ESEE

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.

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.

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

MEMORANDUM

DATE: May 9, 1994

TO : Joseph Z. Fandey
Project Manager Gas Voluntary Standards, ESEE

Through: Robert E. Frye
Director, Hazard Analysis Division (EPHA)

FROM : William L. Rowe, EPHA (301) 504-0470, ext. 1271

SUBJECT: Summary of Data on Gas-Fueled Water Heaters and Flammable Vapors

Attached is a table summarizing national gas-fueled water heater data. These data are the annual averages based on 1986 through 1991; 1991 is the most recent available year. The data appear to suggest that gasoline and other flammable liquids, in bold on the accompanying table, accounted for:

- Twenty percent (1,961 incidents) of the fires associated with gas-fueled water heaters.
- Fifty-four percent (316 people) of the injuries associated with gas-fueled water heaters.
- Forty-four percent (17 people) of the deaths associated with gas-fueled water heaters.
- Thirty percent ($26,339,000) a third of the property loss associated with gas-fueled water heaters.

The importance of gasoline and other flammable liquids was also observed when the location of the fires was reviewed. During the same six years, 46 percent of these fires were in garages.

Attachment

cc:
Dr. Verhalen

50

There were three primary hazards scenarios, based on a review of 42 recent Epidemiological Investigations, that resulted in the ignition of flammable vapors by gas water heaters: children playing, use of gasoline as a solvent, and spills and leaks.

Children Playing

A 2-year old male died from thermal burns sustained when a water heater ignited gasoline as he played in the utility room near a plastic gasoline container which melted in the fire.

An 8-year old female was staying with her grandparents, and opened the outside door to the utility room where gasoline was stored for a lawn mower . There was an explosion that self extinguished. She died at a burn center two weeks later. The gas company had mailed leaflets to all their customers warning customers about storing combustibles too close to their water heaters.

A 2-year old male died of burns after 2 days in the hospital. He had been using a riding toy in the basement while his mother was cleaning there . She saw him standing in a puddle holding a one gallon can of gasoline. The vapors then reached the water heater and ignited burning the boy and his clothing.

Gasoline as a Solvent

A 9-moth old son, his 26-year old father, and his 22-year old mother died of burns from gasoline vapor ignited by the water heater. It was located in the kitchen of their basement apartment where the father was cleaning automotive parts with an open container of gasoline.

A 42-year old female was using gasoline to remove carpet backing from the floor of a newly purchased home. The gasoline was ignited by the gas water heater 20 feet from her. She died 23 days later.

A 17-year old male sustained 2° burns from gasoline and was hospitalized for five days. He was cleaning paint brushes with gasoline near a gas water heater.

Gasoline Spill or Leak

An 80-year old female was admitted to the hospital for smoke inhalation suffered in a house fire. The fire resulted from a dog knocking over a can of gasoline on the porch.

A 14-year old male was hospitalized with 60 percent 3° burns. He disconnected the fuel line of his motorcycle in the basement. The leaking gasoline was ignited by the water heater.

cc: Dr. Verhalen

Attachment

Annual Average Estimates of the Number of Fires, Injuries, Deaths, and Property Loss Associated with Gas-Fueled Water Heaters, 1986-1991

Material First Ignited	Fires		Injuries		Deaths		Property Loss	
	Number	Percent	Number	Percent	Number	Percent	Thousand $	Percent
Total	9,844	100*	586	100	40	100*	87,420	100.0
Gasoline	**1,337**	**13.6**	**239**	**40.8**	**14**	**36.0**	**20,179**	**23.1**
Other Liquid	**624**	**6.3**	**77**	**13.1**	**3**	**7.9**	**6,160**	**7.1**
Fuel Gas	1,547	15.7	110	18.9	12	29.0	15,330	17.5
All Other	6,336	64.7	160	27.2	11	27.2	45,751	52.3

Information in "Bold" type represents gasoline and other flammable liquids

Source: CPSC/EPHA, from data obtained from the National Fire Protection Association and the U.S. Fire Administration

* Percentages do not total 100.0 due to independent rounding.

UNITED STATES GOVERNMENT

MEMORANDUM

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

Date: April 14, 1994

TO : Joseph Z. Fandey, ESEE

THROUGH: Robert T. Garrett, Acting Director ESEL

FROM : Albert Eugene Martin, ESEL

SUBJECT: Water heater test project.

INTRODUCTION

The Engineering Sciences Engineering Laboratory (ESEL) began in January 1993 to design engineering tests, as requested, to investigate the propagation of a vapor cloud from a gasoline spill. Tests of vapor cloud propogation began in September of 1993. ESEL also investigated the performance of a simple device that could prevent the ignition of a gasoline vapor cloud by the flame in the water heater.

APPARATUS AND PROCEDURES

Five water heater samples were received at ESEL. These were connected to water and fuel gas sources per the manufacturers' instruction. These were operated in the combustion test laboratory. The velocity of the exhaust gases was measured with one of the hot wire anemometers in this lab. A D.C. blower was fitted to the top of the exhaust stack. This permits air to be drawn through the water heater at the velocity created by the pilot fire or the burner as appropriate.

The gasoline vapor cloud propagation measurements were made in a test room in the Fire Lab at the National Institute of Standards and Technology (NIST). These tests were performed with ESEL equipment and by ESEL staff. The work was done in a room built with gypsum board walls and fitted with a blow out safety door. These equipments and fixtures are described in Appendix A.

A Rosemont Model 880 analyzer was procured for the tests of vapor cloud propagation. This unit is a Non Dispersive Infra Red (NDIR) gas analyzer set up to measure the percent of "Lower Explosive Limit" (LEL) of gasoline vapors. This LEL unit is calibrated, by Rosemont, so that the user, ESEL, could perform "span calibrations" from a mixture of propane and nitrogen flowed into the analyzer. The ESEL performed this calibration daily using concentrations of 1.79, 0.821 and zero percent propane in nitrogen. These concentrations are equivalent to 94.2, 43.2 and zero percent LEL of gasoline vapor. Additional equipment used in the fire lab test cell was the required pumps, valves, rotameters, gages, thermocouples and tubing connecting the test points to the analyzer.

The data from the analyzer and four thermocouples in the

cell were collected by a 286 computer. This permitted quick analysis of each day's test results.

Tests to measure the effect, if any, of a barrier around the base of the water heater were run using the Hood Test System in The Combustion Test Lab at ESEL. This facility measures the products of combustion of hydrocarbon fires at short intervals. These data are used to compute the mass of combustion components of interest including Carbon Dioxide, CO_2, and Carbon Monoxide, CO.

The water heater was connected to a fuel gas (methane) line and to water inlet and outlet lines. All operating parameters were set to manufacturers specifications. The water heater operation was controlled by using the thermostat setting. Measurement of CO and CO_2 concentrations were noted with and without the barrier. The effect of "blocking" the space between the heater and barrier was also measured.

RESULTS

Appendix A compiles the gasoline vapor cloud propagation tests. This presents graphics of each test showing the percent L.E.L versus time. Annotations are made for significant events in the test run. These data show that dangerous levels of gasoline vapor concentrations occur at the pilot light when 2000 ml, approximately 1/2 gallon, is spilled 18 inches from the centerline of a water heater sitting on the floor. This is believed to be the most common installation. When elevated six inches these data show that dangerous levels are not reached at the pilot light location.

With the water heater on the floor and a barrier, made of 14 inch wide aluminum flashing, placed around the base and taped to the floor the L.E.L. concentrations are reduced well below safe levels.

Appendix B reports the results of operating a water heater with and without the barrier. These data for CO and CO_2 concentrations are the same in each case.

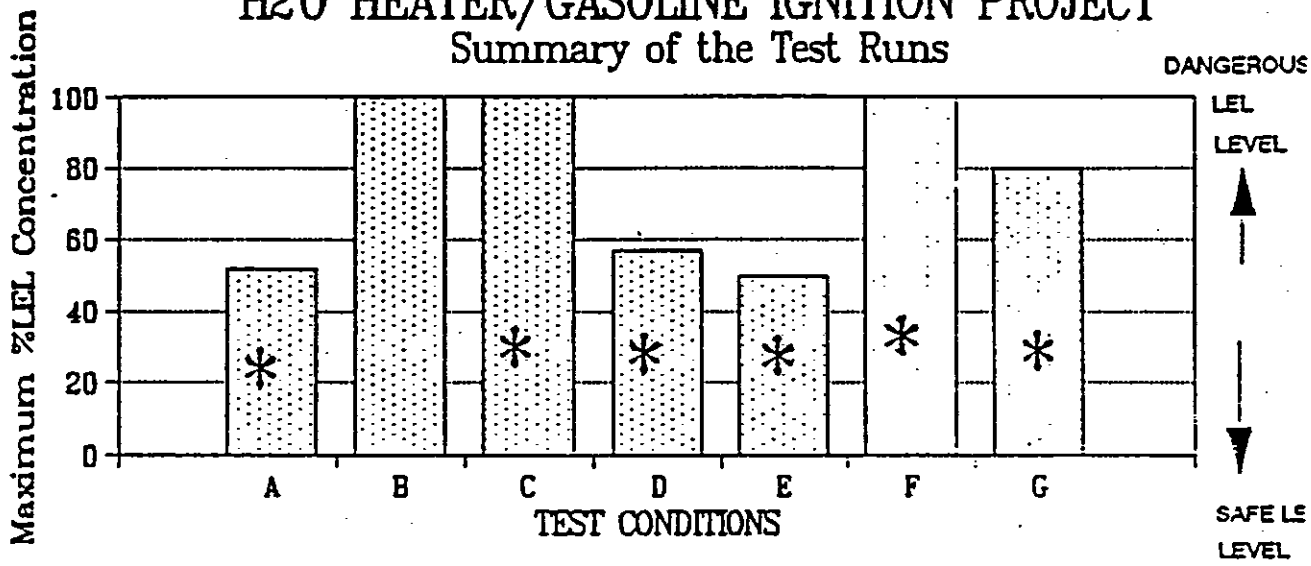
The work performed at ESEL shows that in those communities where water heaters are installed six inches or more above the floor the risk of ignition of spilled gasoline is minimal. These data also show that a simple 14 inch high barrier of light weight sheet metal taped to the floor prevents spilled gasoline vapors from reaching the flame in a water heater.

cc: George Sushinsky ESEL.

APPENDIX A

H2O HEATER/GASOLINE IGNITION PROJECT

Summary of the Test Runs



A: 6 in elevation / 2000 mL spill / Pilot cover off

B: On the floor / 2000 mL spill / Pilot cover on

C: On the floor / 2000 mL spill / Pilot cover on / Aluminum Flashing uncaulked to floor pan

D: On the floor / 2000 mL spill / Pilot cover on / ALuminum Flashing caulked to floor pan

E: On the floor / 2000 mL spill / Pilot cover on / ALuminum Flashing with 3 1/4" holes caulked to pan

F: On the floor /1 Gallon spill / Pilot cover on / Aluminum Flashing with 3 1/4" holes caulked to pan

G: On the floor / 1 Gallon spill / Pilot cover on / Aluminum Flashing without holes caulked to pan

* Forced air blown in the enclosed test chamber

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT

Summary of Test Results

All tests were performed with heater "C" at 18 in from the centerline of the heater to the point of gasoline spill.

*** Forced air blown in the enclosed test chamber.**

DATE	TEST CONDITIONS	RESULTS
10/28/93	450 mL of gasoline spilled; Sample line 2 is 2" off the floor, line 3=6" off the floor, line 4=bottom of the air inlet of heater. This arrangement has been used for the test runs through 11/12/93 am. Heater is on the floor	Sample line 1 (pilot) did not reach a dangerous LEL level. The maximum LEL level of 45% occurred around 400 sec (6.7 min) after the spill.
11/1/93	Heater is on the floor; 450 mL of gasoline spilled	Two test runs have been performed--the first run showed the pilot reached a max. of 85% LEL and the second 100%. Both reached max. values 1 or 2 min after the spill.
11/2/93	Heater is on the floor; 450 mL of gasoline spilled	NO DATA; Stack blower lacked power supply.
11/3/93 am	Heater is on the floor; 450 mL of gasoline spilled	Sample line 1 (pilot) reached 100% LEL 100 sec after the spill
11/3/93 pm	Heater is on the floor; 450 mL of gasoline spilled	Sample line 1 (pilot) reached 100% LEL 100 sec after the spill
11/4/93	Heater is raised 12" off the floor; 1000 mL of gasoline spilled	No Data for the morning run; Exhaust fan was on when testing was in progress. Afternoon run shows no indication of dangerous LEL levels.
11/8/93	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	NO DATA; Power failure occurred in the fire research building at NIST.
11/9/93 am	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	Sample line 2 reaches >100% LEL. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 1% to 26% over the course of 4600 sec (1 hr., 17 min).
11/9/93 pm	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	Sample line 2 reaches >100% LEL. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 1% to 15% over the course of 3500 sec (58 min).
11/12/93 am	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	Sample line 2 reaches >100% LEL @ 120 sec (2 min) after the spill. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 1% to 35% over the course of 2800 sec (47 min).

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT

Summary of Test Results

* Forced air blown in the enclosed test chamber.

DATE	TEST CONDITIONS	RESULTS
11/12/93 pm	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled; sample line 2=3"off the floor, line 3=4.5" and line 4=6". This sample line arrangement has been maintained for the remainder of the test runs.	Sample line 2 reaches >100% LEL @ 40 sec after the spill. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 2% to 36% over the course of 3400 sec (56 min).
11/16/93	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample line 2 reaches >100% LEL @ 180 sec (3 min) after the spill. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 17% to 25% over the course of 3000 sec-(50 min).
11/17/93 am * A	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample line 2 reaches >100% LEL @ 180 sec (3 min) after the spill. The fan was pulsed (turned on/off) once @ 2300 sec (38 min) after the spill and turned on for 10 min @ 2400 sec (40 min). The LEL concentration @ the pilot did not reach a dangerous level, but reached a steady state of 52%.
11/17/93 pm * A	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample line 2 reaches >100% LEL @ 190 sec (3 min. 10 sec) after the spill. The fan was pulsed once @ 440 sec (7 min) after the spill and pulsed 10 times @ 950 sec (15.8 min). The LEL concentration @ the pilot did not reach a dangerous level, but reached a steady state of 52%.
11/18/93 am *	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample lines 2 and 3 reach >100% LEL @ 166 sec and 168 sec, respectively. When the fan was pulsed (turned on/off) ten times, the hot wire anemometer read an air velocity of 459 ft/min and the pilot (line 1) concentration jumped from 7.4% to 45.7% LEL. The pilot never reached a dangerous LEL level.
11/18/93 pm B	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; pilot cover is ON the heater	Sample line 1 (pilot) reaches >100% LEL 62 sec after the spill. The pilot maintained its >100% LEL level for about 800 sec (13 min). At about 890 sec (15 min), the pilot LEL level dropped to about 73%.

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT

Summary of Test Results

* Forced air blown in the enclosed test chamber.

DATE	TEST CONDITIONS	RESULTS
11/19/93 pm * 	Water heater was placed on the floor pan; pilot cover is ON the heater throughout the remainder of the tests; 2000 mL of gasoline was spilled; aluminum flashing is around the water heater, resting on the floor pan (flashing is not caulked)	Sample line 1 (pilot) reaches a maximum of about 61% LEL @ 2110 sec (35 min) after the gasoline spill. The liquid gasoline crept underneath the flashing. "Pulsing" (turning fan on/off) was performed to determine what sort of characteristics the sample line @ the pilot will exhibit. The pilot reached about 61% LEL after 2 sets of 10 pulses in 1 sec intervals. After every set of pulses, the hot wire anemometer read air velocities from 100 to 200 feet/min. It appears the pilot cover prevents some of the stronger vapor concentration from coming in.
11/22/93 am * C	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is around the water heater, resting on the floor pan (flashing is not caulked)	Sample line 1 (pilot) reaches >100% LEL @ 180 sec (3 min) after the spill. The fan was pulsed 10 times (turned on and off) from the time of the spill to the time when 100% LEL was reached. The liquid gasoline crept underneath the flashing. When the pilot reached >100% LEL, other sample lines were switched and observed. After about 6 min (360 sec) and 10 pulses, the pilot was at 91% LEL. 15 min after the spill, the fan was pulsed 10 times and the pilot reaches 74% LEL. Without the aid of the fan, the pilot does not reach dangerous LEL levels.
11/22/93 pm * D	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan.	Sample line 1 (pilot) reaches a maximum of about 57% LEL @ 880 sec (15 min) after the gasoline spill. The caulking prevented liquid gasoline from going underneath the flashing. "Pulsing" (turning fan on/off) was performed to determine what sort of characteristics the sample line @ the pilot will exhibit. The pilot reached a steady state of about 57% LEL after 6 sets of pulses: 2 sets of 8 pulses in 5 sec intervals, 2 sets of 8 pulses in 1 sec intervals, and 2 sets of 10 pulses in 1 sec intervals. After every set of pulses, the hot wire anemometer read air velocities from 100 to 200 feet/min.

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT

Summary of Test Results

* Forced air blown in the enclosed test chamber.

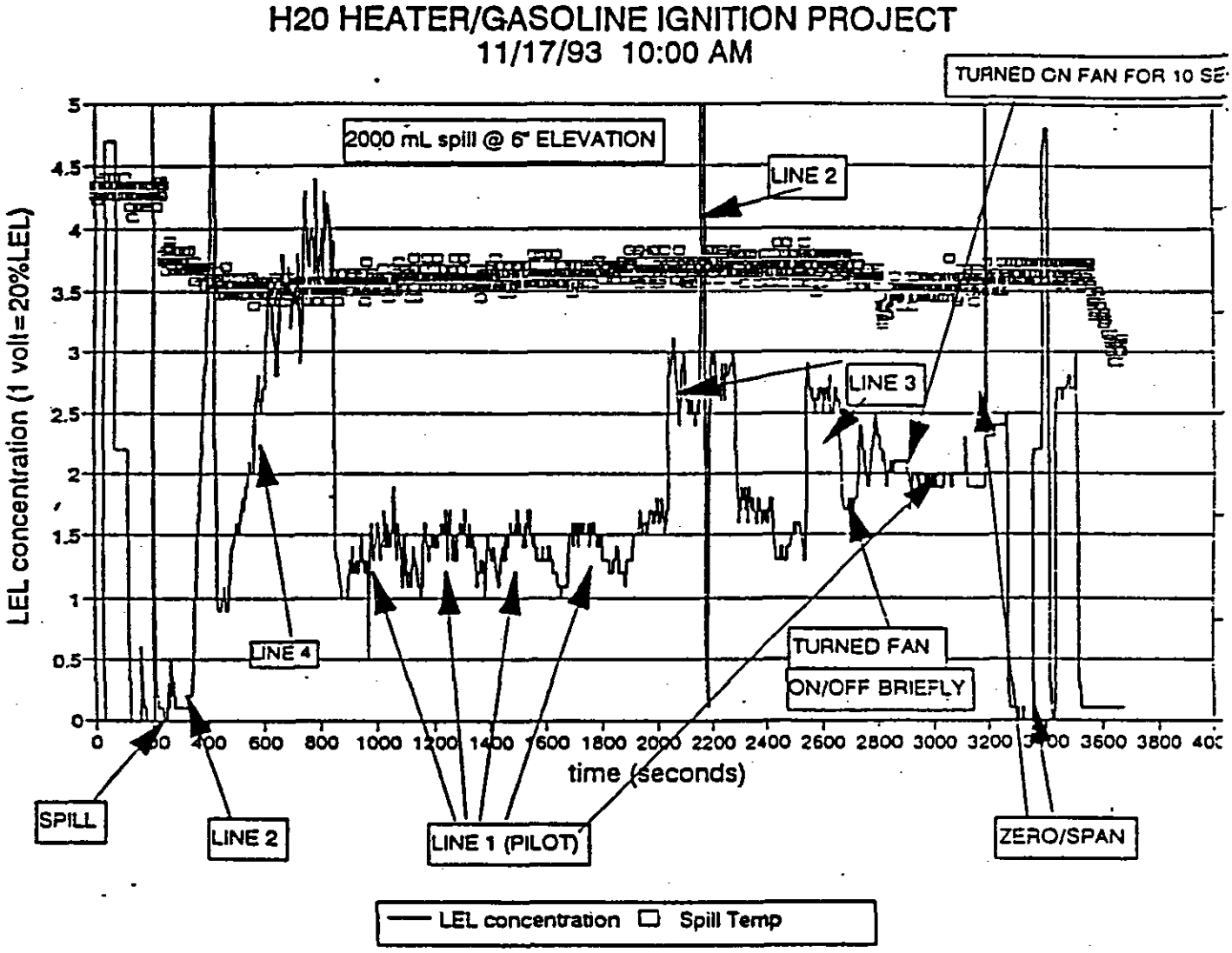
DATE	TEST CONDITIONS	RESULTS
11/23/93 pm * D	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan	Sample line 1 (pilot) reaches a maximum of about 57% LEL @ 1360 sec (23 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed to determine what sort of characteristics the sample line @ the pilot will exhibit. The pilot reached a steady state of about 57% LEL after 5 sets of pulses: 3 sets of 2 pulses in 1 sec intervals, a set of 6 pulses in 1 sec intervals, and a set of 5 pulses in 1 sec intervals. After every set of pulses, the hot wire anemometer read air velocities from 60 to 120 feet/min.
11/24/93 am *	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan	Sample line 1 (pilot) reaches a maximum of about 54% LEL @ 1890 sec (32 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed a few minutes after sample line 2 saturated (>100% LEL). 2½ minutes after the spill, sample line 2 (3" off the floor) saturated. The pilot reached a steady state of about 50% LEL after 7 sets of pulses: 2 sets of 5 pulses in 4 sec intervals, 2 sets of 8 pulses in 2 sec intervals, a set of 5 pulses in 2 sec intervals, and 2 sets of 10 pulses in 2 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.
11/30/93 am * E	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing).	Sample line 1 (pilot) reaches a maximum of about 50% LEL @ 2640 sec (44 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed a few minutes after sample line 2 (3" off the floor) saturated (>100%). 2½ minutes after the spill, sample line 2 saturated. The pilot reached a steady state of about 50% LEL after 7 sets of pulses: 2 sets of 5 pulses in 4 sec intervals, 2 sets of 8 pulses in 2 sec intervals, a set of 5 pulses in 2 sec intervals, and 2 sets of 10 pulses in 2 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT
Summary of Test Results

* Forced air blown in the enclosed test chamber.

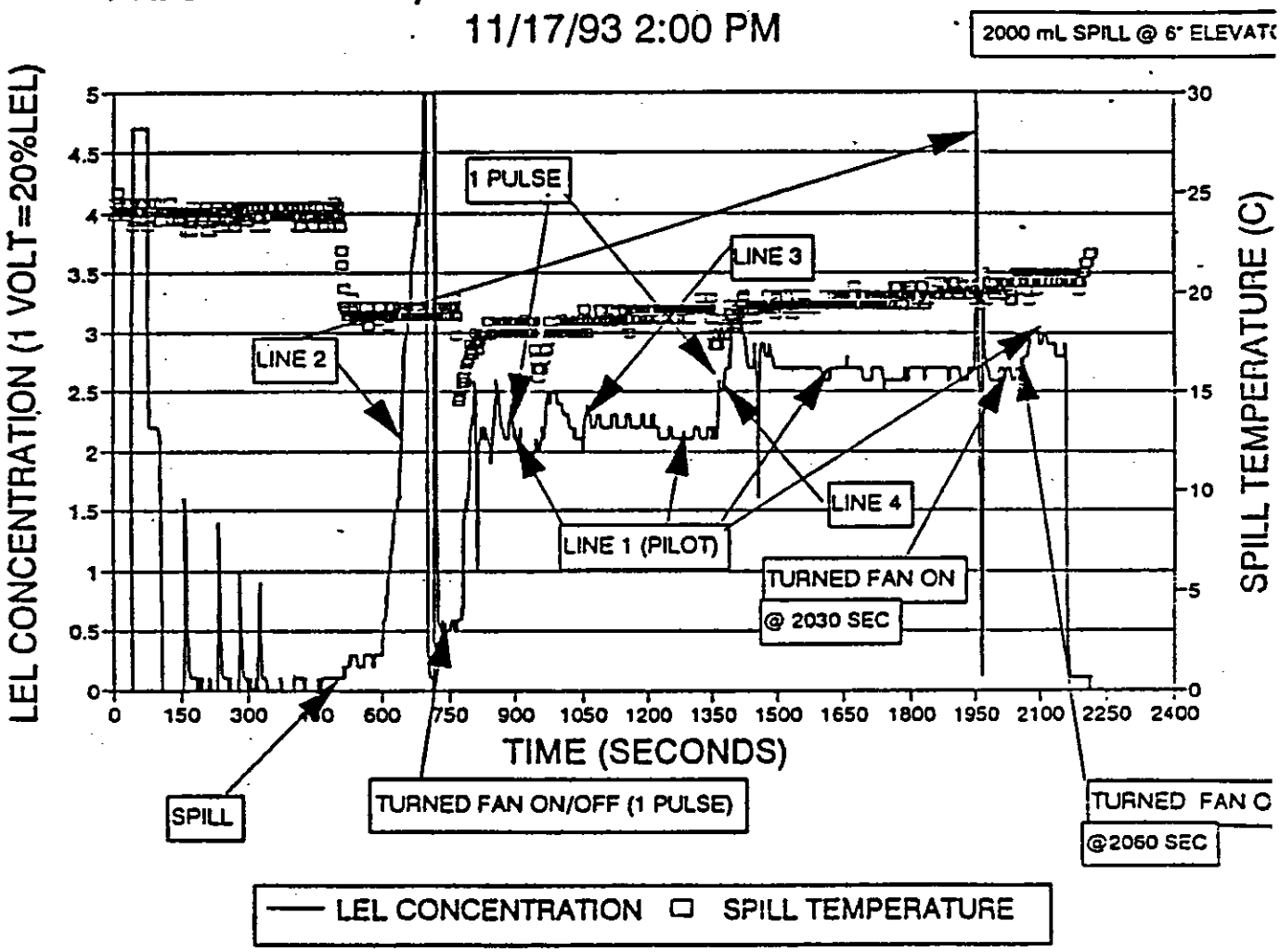
DATE	TEST CONDITIONS	RESULTS
11/30/93 pm * F	Water heater was placed on the floor pan; 1 gallon of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing).	Sample line 1 (pilot) reaches over 100% LEL @ 940 sec (16 min) after the gasoline spill. Periodic "pulsing" (turning fan on/off) was performed every min or 30 sec., three minutes after sample line 2 (3" from the floor) saturated (>100% LEL). The pilot reached over 100% LEL after 9 sets of 5 pulses in 2 sec intervals, with the exception of the first set which was 5 pulses in 4 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.
12/1/93 am * G	Water heater was placed on the floor pan; 1 gallon of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing) that have been covered up with aluminum tape.	Sample line 1 (pilot) reaches a maximum of about 70% LEL @ 2160 sec (36 min) after the gasoline spill. Periodic "pulsing" (turning fan on/off) was performed every 2 min or 1 min, 3½ minutes after sample line 2 (3" off the floor) saturated (>100% LEL). The pilot reached a steady state of about 70% LEL after 19 sets of 5 pulses in 2 sec intervals, with the exception of the first set which was 5 pulses in 4 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.
12/1/93 pm *	Water heater was placed on the floor pan; 1 gallon of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing).	Sample line 1 (pilot) reaches a maximum of about 80% LEL @ 2290 sec (38 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed a few minutes after sample line 2 (3" off the floor) saturated(>100% LEL). 2½ minutes after the spill, sample line 2 saturated. The pilot reached a steady state of about 82% LEL after 7 sets of pulses: 2 sets of 5 pulses in 4 sec intervals, 2 sets of 8 pulses in 2 sec intervals, a set of 5 pulses in 2 sec intervals, and 2 sets of 10 pulses in 2 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.


H20 HEATER/GASOLINE IGNITION PROJECT
11/17/93 10:00 AM
TURNED ON FAN FOR 10 SE
2000 mL spill @ 6" ELEVATION
LINE 2
LINE 3
LINE 4
TURNED FAN
ON/OFF BRIEFLY
SPILL
LINE 2
LINE 1 (PILOT)
ZERO/SPAN
LEL concentration (1 volt=20%LEL)
time (seconds)
LEL concentration
Spill Temp

A

H2O HEATER/GASOLINE IGNITION PROJECT

11/17/93 2:00 PM



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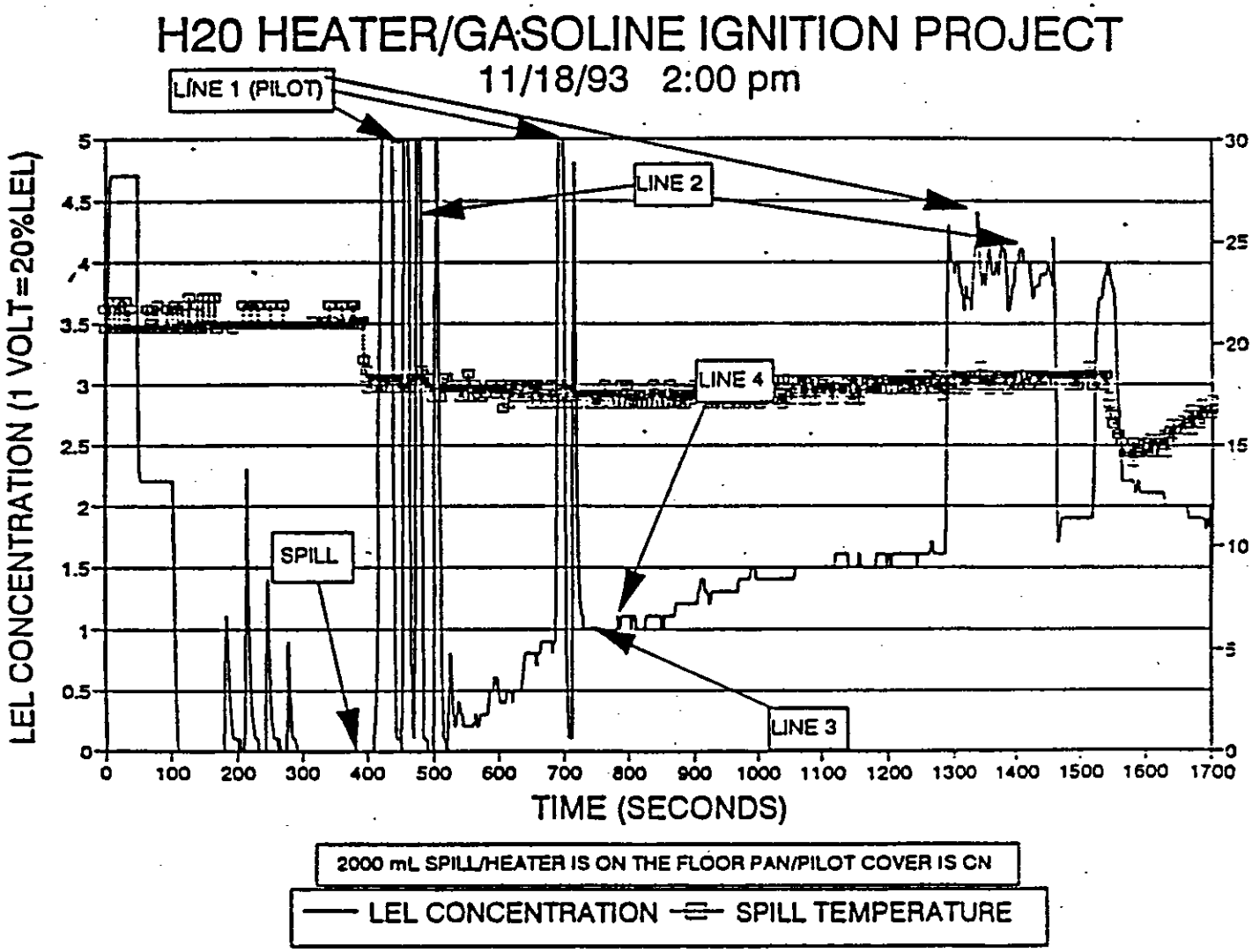
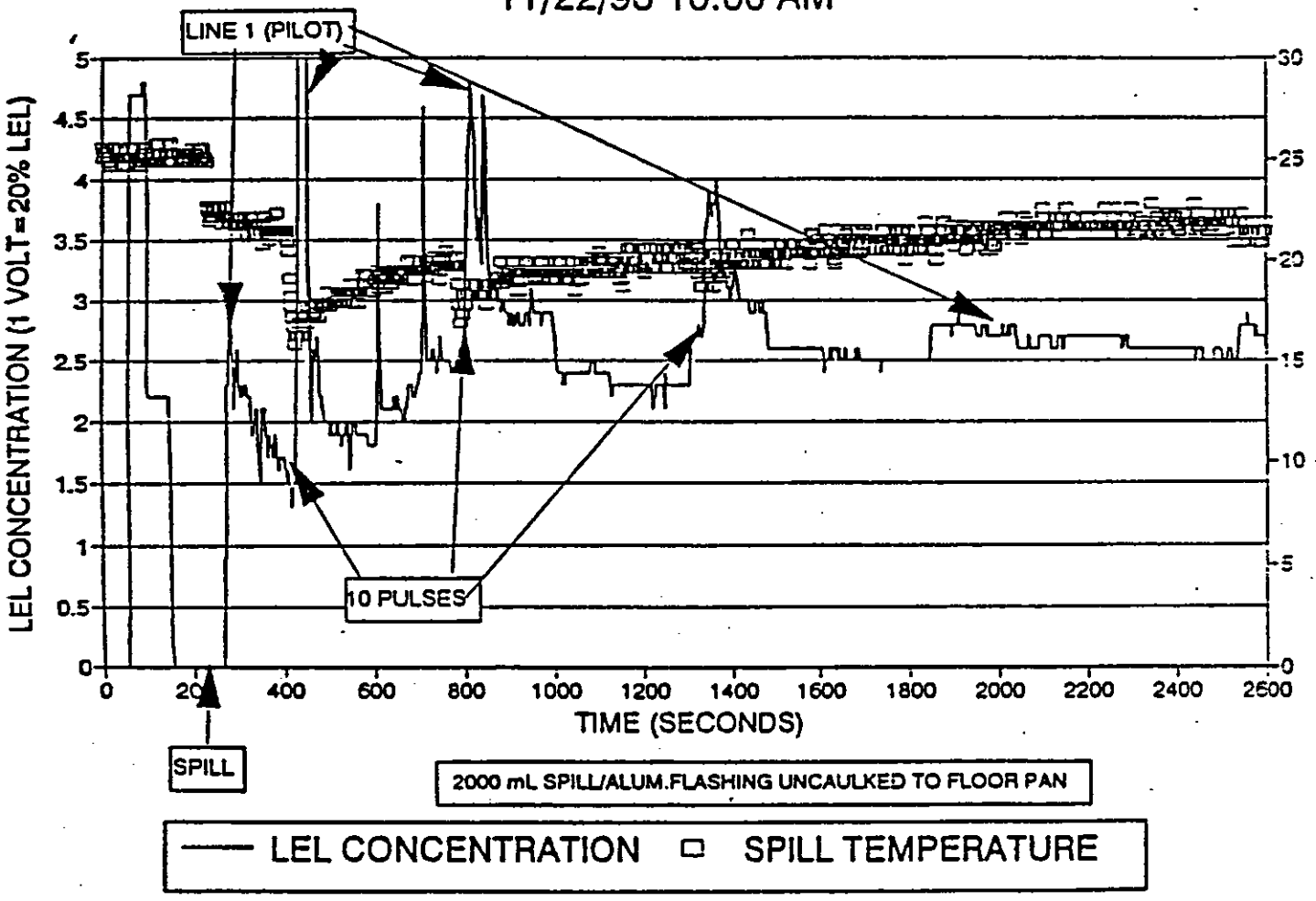

H20 HEATER/GASOLINE IGNITION PROJECT
11/18/93 2:00 pm
LINE 1 (PILOT)
LINE 2
LINE 4
LINE 3
SPILL
LEL CONCENTRATION (1 VOLT=20%LEL)
TIME (SECONDS)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
2000 mL SPILL/HEATER IS ON THE FLOOR PAN/PILOT COVER IS CN
LEL CONCENTRATION
SPILL TEMPERATURE

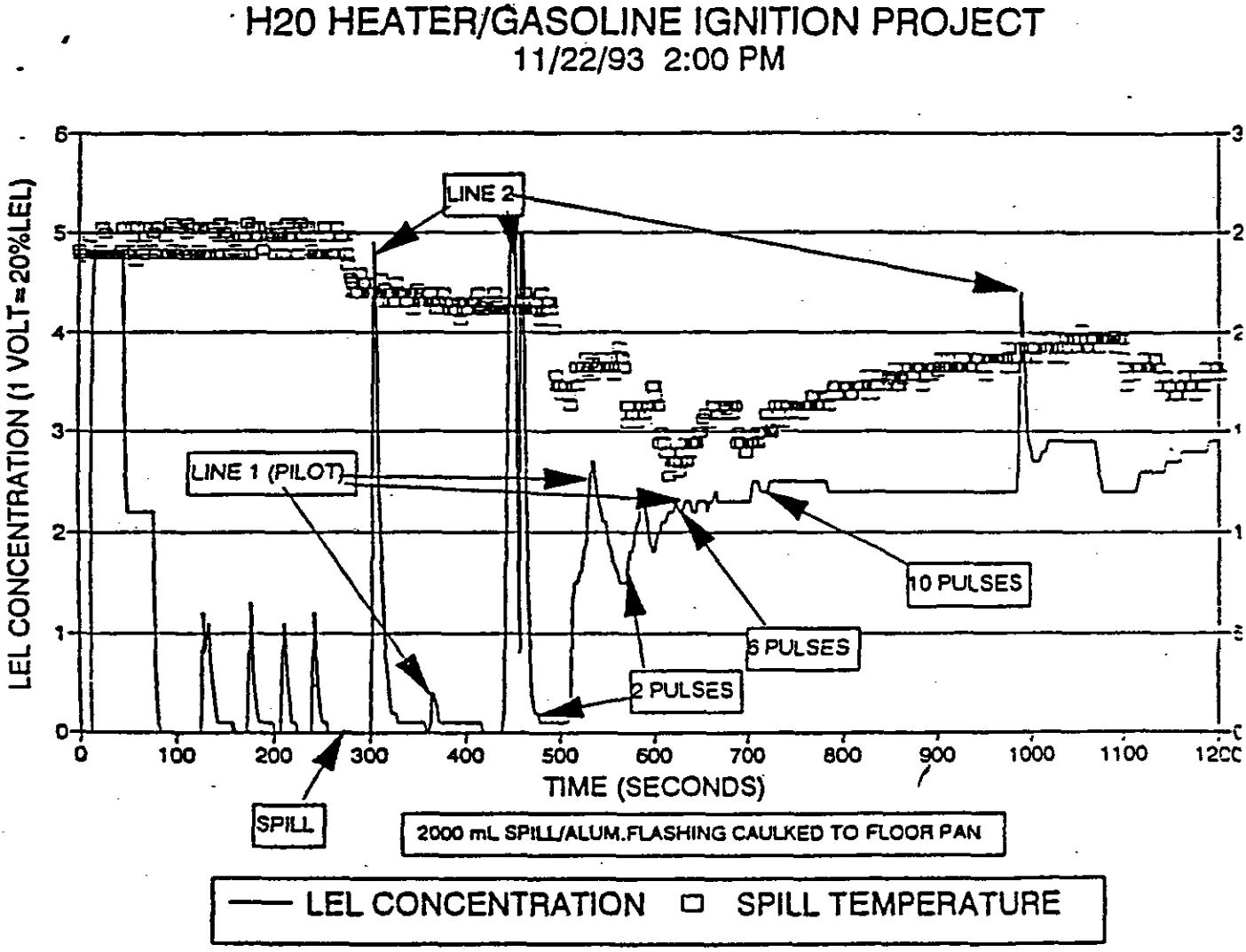
B

H20 HEATER/GASOLINE IGNITION PROJECT

11/22/93 10:00 AM



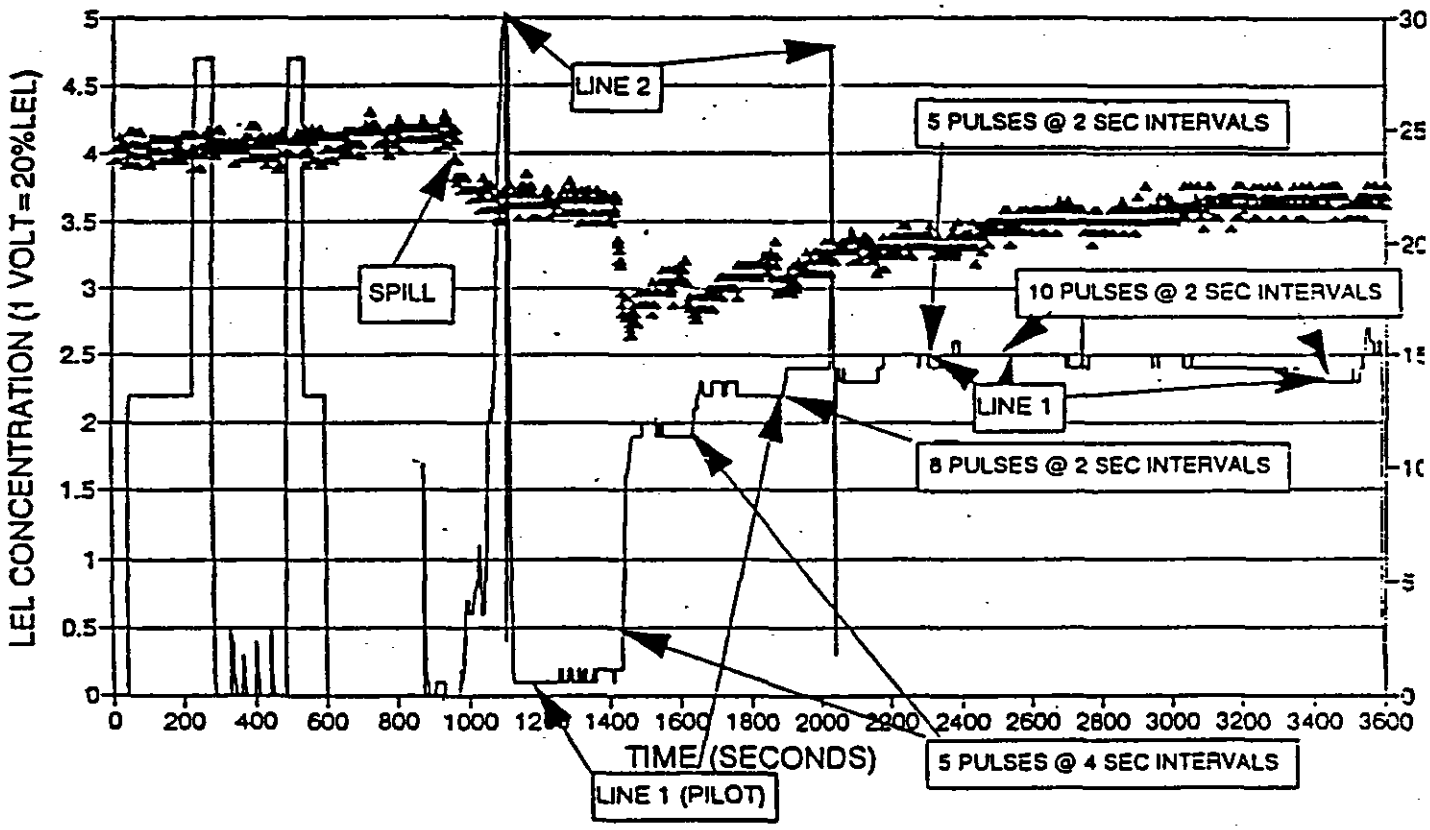
C


H20 HEATER/GASOLINE IGNITION PROJECT
11/22/93 2:00 PM
LEL CONCENTRATION (1 VOLT=20%LEL)
TIME (SECONDS)
LINE 2
LINE 1 (PILOT)
10 PULSES
6 PULSES
2 PULSES
SPILL
2000 mL SPILL/ALUM.FLASHING CAULKED TO FLOOR PAN
LEL CONCENTRATION
SPILL TEMPERATURE

D

H20 HEATER/GASOLINE IGNITION PROJECT

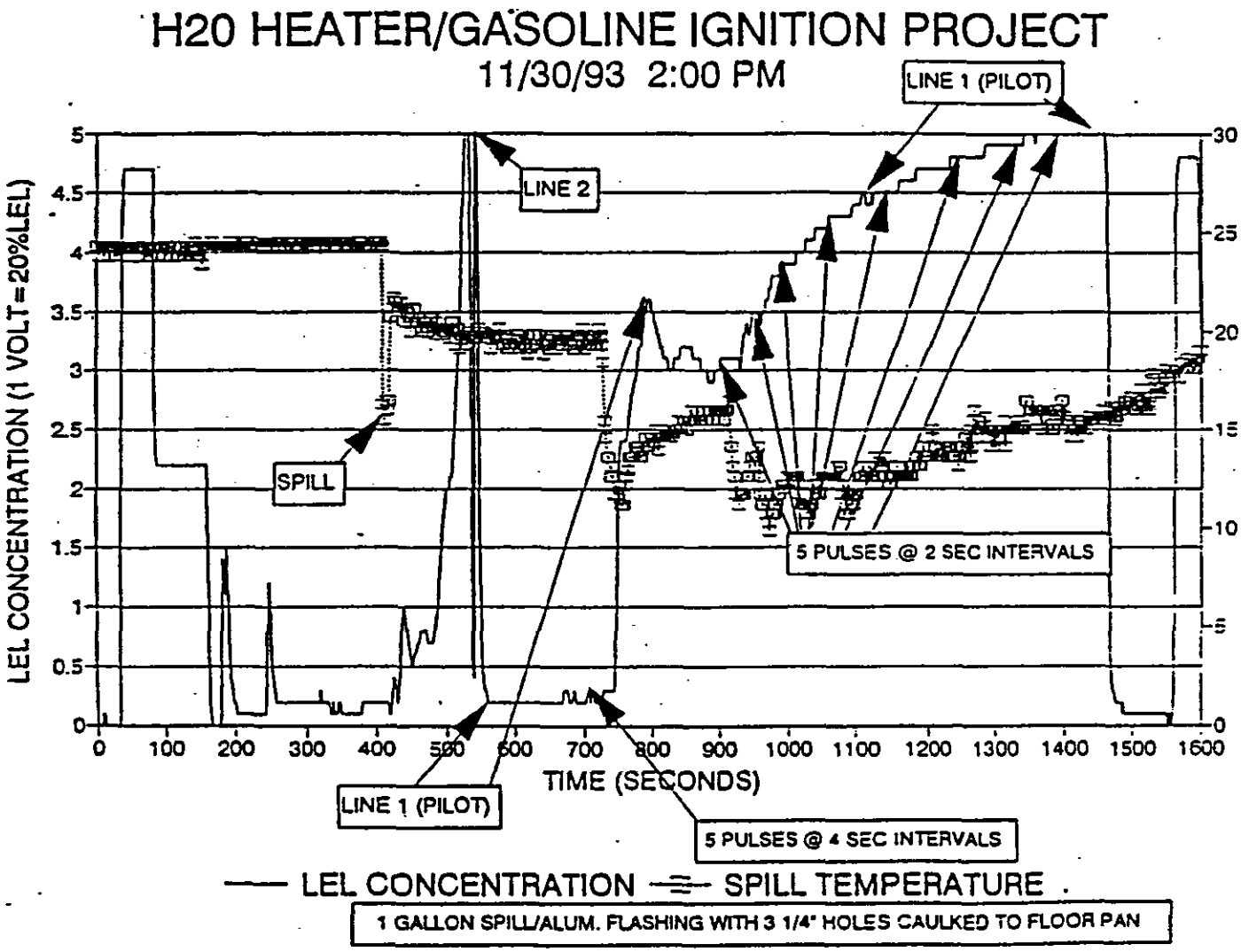
11/30/93 9:00 AM



—— LEL CONCENTRATION ▲ SPILL TEMPERATURE

2000 mL SPILL/ALUM.FLASHING CAULKED/3 1/4" HOLES EQUALLY SPACED AROUND FLASHING

E


H20 HEATER/GASOLINE IGNITION PROJECT
11/30/93 2:00 PM
LINE 1 (PILOT)
LINE 2
SPILL
5 PULSES @ 2 SEC INTERVALS
LINE 1 (PILOT)
5 PULSES @ 4 SEC INTERVALS
LEL CONCENTRATION (1 VOLT=20%LEL)
TIME (SECONDS)
LEL CONCENTRATION
SPILL TEMPERATURE
1 GALLON SPILL/ALUM. FLASHING WITH 3 1/4" HOLES CAULKED TO FLOOR PAN

F