Garage and Basement Scenario 1: Gasoline Usage

Location: Garage or Basement, 20 ft x 10 ft x 8 ft

Features:

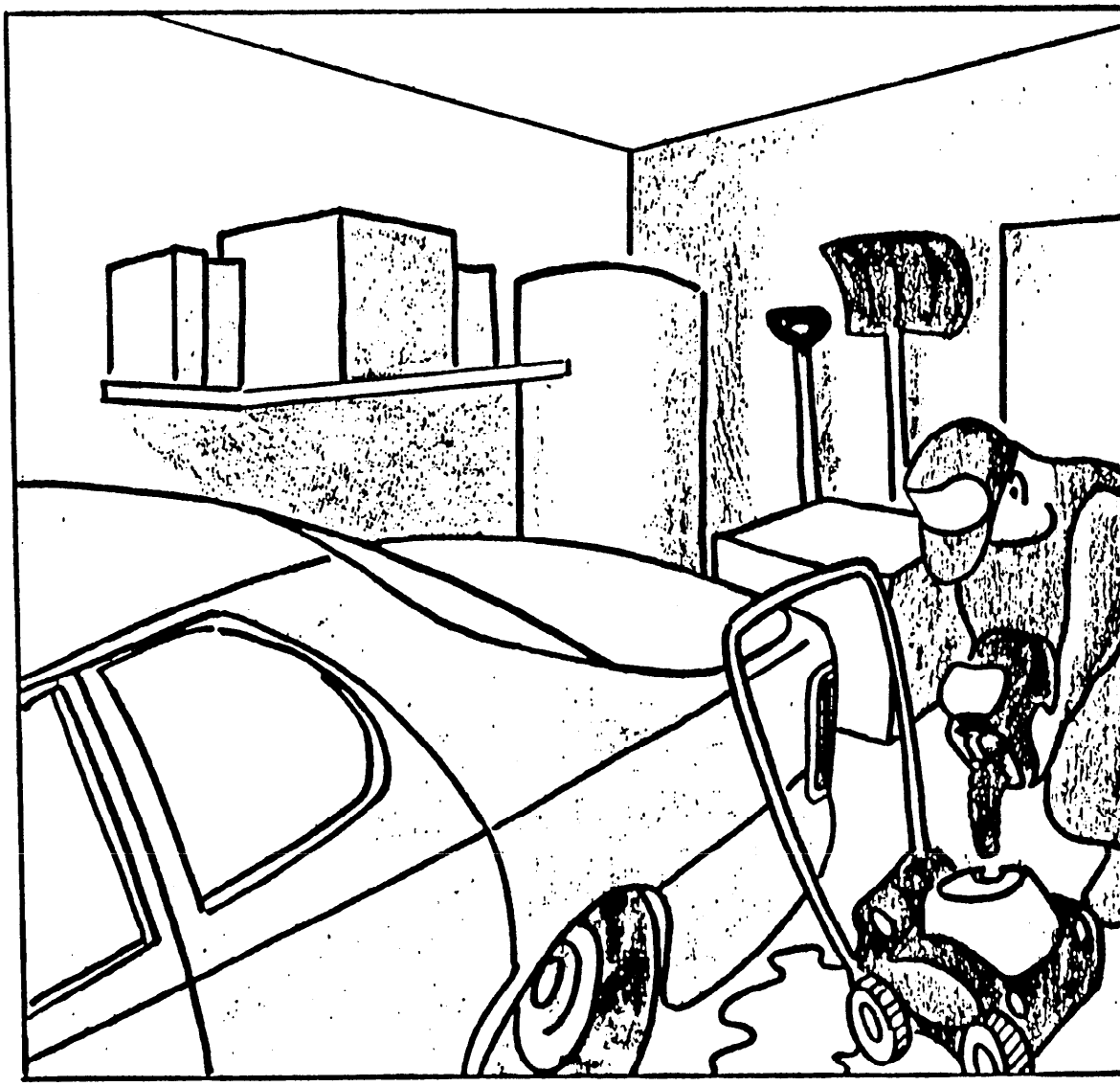
- Other appliances such as:
  - gas fired furnace
  - washer and dryer (electric or gas fired)
  - gasoline utilizing equipment such as lawn motorcycles
- 30 gallon gas fired water heater, located in cor

Quantity: 1 gallon of gasoline in container

Source: Evaporation of liquid from use of gasoline, vapor tra water heater

Activity: Activity or movement in the direct vicinity of the wat

Garage and Basement Scenario 2: Refueling



Garage and Basement Scenario 2: Refueling

A common scenario involves a person refueling a piece of equipm
uses gasoline such as a lawn mover, weed wacker or motorcycle.
tank is accidentally overfilled or the opening is missed. This result
moderate quantity of gasoline being spilled on the floor. The vapor
gasoline use travel to the water heater located in the vicinity. Ther
movement in the direct vicinity of the water heater. (Examples of f
from just refueling and no spillage were not identified directly in ou

Garage and Basement Scenario 2: Refueling

Location: Garage or Basement, 20 ft x 10 ft x 8 ft

Features:

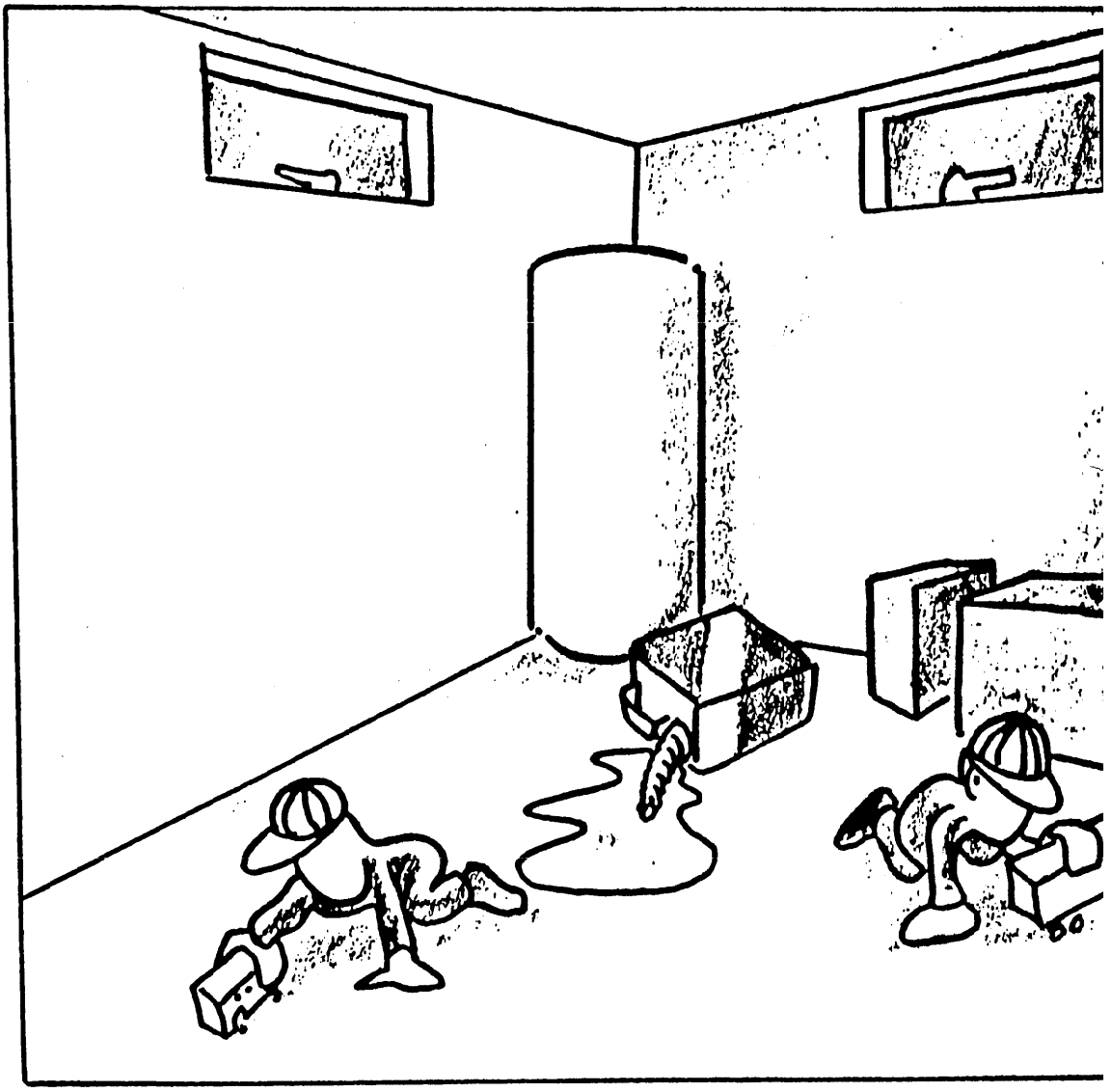
- Other appliances such as:
  - gas fired furnace
  - washer and dryer (electric or gas fired)
  - gasoline utilizing equipment such as lawn motorcycles
- 30 gallon gas fired water heater, located in cor

Quantity: 1 quart of gasoline spilled

Source: Spill and evaporation of liquid during refueling opera

Activity: Activity or movement in the direct vicinity of the wat

Garage and Basement Scenario 3: Children Playing



Garage and Basement Scenario 3: Children Playing

A common scenario involves children playing in the garage or bas
tipping over a container of gasoline. They generally knock the ca
allowing the container to empty a steady rate, or they attempt to f
the container of gasoline. In both scenarios, there is a large amo
gasoline spilled near the water heater and activity.

Garage and Basement Scenario 3: Children playing

Location: Garage or Basement, 20 ft x 10 ft x 8 ft

Features:

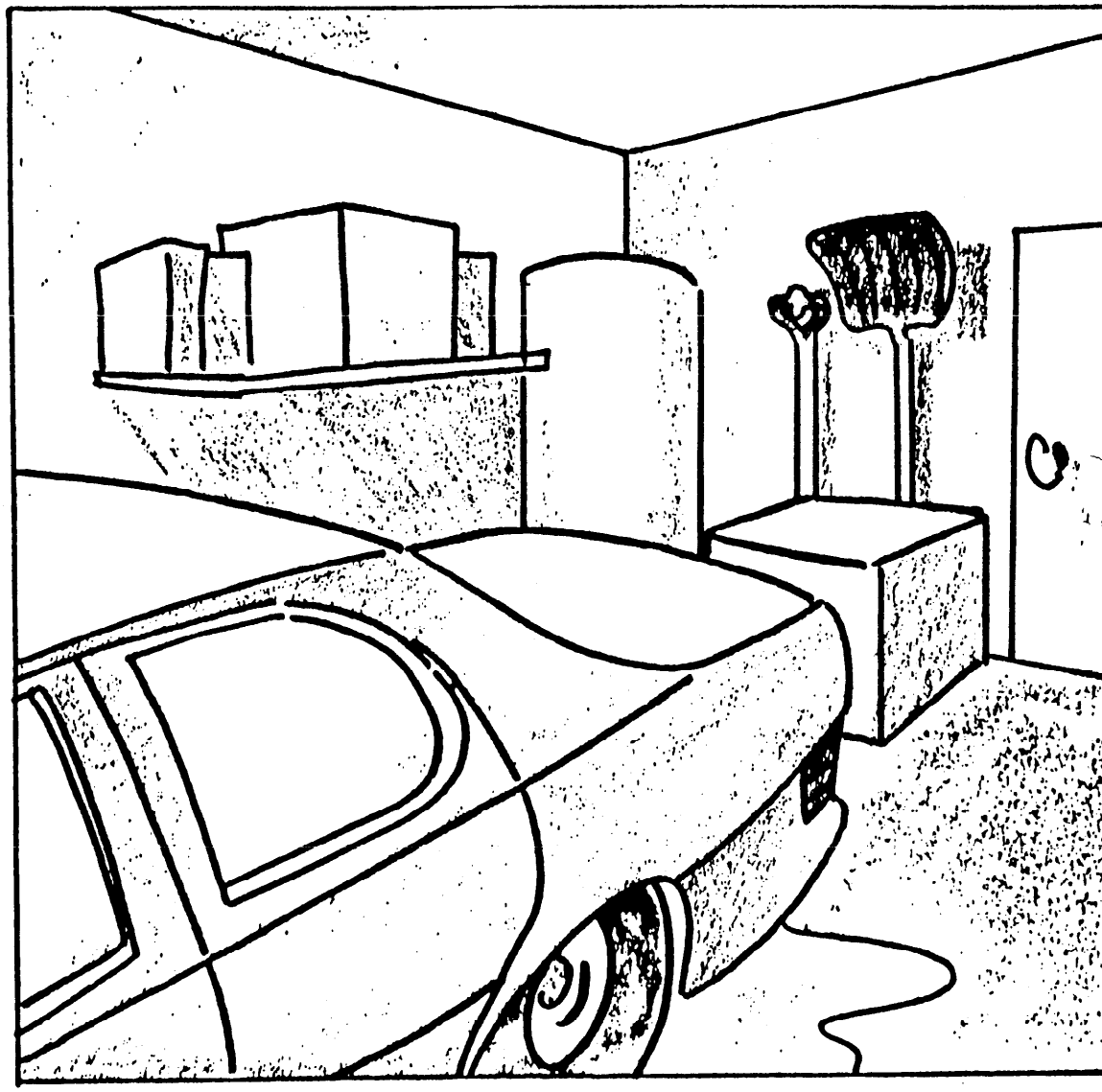
- Other appliances such as:
  - gas fired furnace
  - washer and dryer (electric or gas fired)
  - gasoline utilizing equipment such as lawn motorcycles
- 30 gallon gas fired water heater, located in cor

Quantity: 1-5 gallons of gasoline in container

Source: Spillage of gasoline, vapor travel to the water heate

Activity: Activity or movement in the direct vicinity of the wat

Garage Scenario 1: Leakage



Garage Scenario 1: Leakage

A common scenario involves the slow leak of gasoline from the fue
vehicle stored in the garage. The rate of gasoline loss is relatively
gasoline vaporizes and steadily buildup a flammable concentration
until ignited by the water heater.

Garage Scenario 1: Leakage

Location: Garage, 20 ft x 10 ft x 8 ft

Features:
- Vehicle
- Cement floor
- 30 gallon gas fired water heater, located in co

Quantity: Slow leakage of gasoline from the fuel tank

Source: Evaporation of liquid from the spill of gasoline, vap
water heater

Activity: No activity or movement in the direct vicinity of the

The National Fuel Gas Code and Model Codes contain requi adequate air for combustion, ventilation, and dilution of flue within the building which may impact testing.

Requirements are specified for:

- Equipment located in unconfined spaces
- Equipment located in confined spaces (volume < than 50 ft^3 per hour of total input rating of all appliances installed in that
- Equipment located in buildings of unusually tight constructior

These requirements are intended to prevent carbon monoxic but may impact flammable vapor buildup.

These requirements have been incorporated into planned te ensure that scenarios represent actual approved installatio conditions.

- Scenarios involving the utility room and bathrooms will requ proper/specified ventilation openings.

- Building used for basement and garage scenarios will need as to "tightness."

The use of 18 inches as a height requirement in residential g back over 40 years to the National Electric Code.

"5110 c: Below Grade. Where the lowest floor is below adjacent driveway level, the following shall apply.

1. The entire area of the garage or of any enclosed space includes the garage shall be classified as a Class I, Divi up to a level 18 inches above the garage floor..."[1]

The use of the Class I, Division 2 classification indicates that elevation requirement was to prevent flammable vapor ignitio

[1]National Electric Code, NFPA-1953

The National Electrical Code defines the following as a Class location:

"Location in which volatile flammable liquids or flammable gases a processed, or used, but in which the liquids, vapors, or gases will confined within closed containers or closed systems from which th escape only in case of accidental rupture or breakdown of such c systems, or in case of abnormal operation of equipment."[2]

In these locations explosion proof, or intrinsically safe equipr required.

[2]National Electric Code, NFPA 70-1990

The National Gas Fuel Code and Model Codes have adopted versions of the 18" Rule since its introduction by the National Code.

- National Fuel Gas Code - 1974 edition
- Southern Standard Building Code - 1961 edition
- CABO One and Two Family Dwelling Code - 1971 edition

**This task is essentially complete. The scenarios will be mod
needed, based on the findings from the remaining activities.**

- Obtain and review the Miami Fire Department/People's Gas
  (Connor Adams)
- Review Ron Hall's data
- Review the Southern California Gas data
- Review data from Ed Downing

The Analytical Modeling Task will be presented in the follov

- Objective
- Description of the Model
- Results of Verification Experiment for the Source Compone
- Dispersion Component Results
- Status

The language of the 18 inch rule in the Model Codes has evo the years.

- The exception for the garages that are above the level of the been removed.

- The location has been extended from garages to any area w flammable vapors are likely to be present.

Analytical Modeling Task Objective

The objective of the Analytical Modeling Task is to provide i the selection of key parameters for testing:

- Verification and/or identification of scenario patterns
- Assess parameter sensitivity for experimental tests
- Evaluate incident scenarios
- Provide theoretically based extension of experimental results

The model is comprehensive and consists of two major com source and the dispersion. Source features include:

- Prediction of simultaneous spreading of liquid, diffusion, and
- Both convective mass transfer and diffusion limited regimes
- A comprehensive energy balance for varying spill surface the properties as well as source characteristics
- Includes effects of multicomponents

The dispersion component describes how vapor disperses fr

- The dispersion component is transient, two-dimensional, and relevant conservation equations.

- Pool emissions are grouped either as a single (lumped) vapo species.

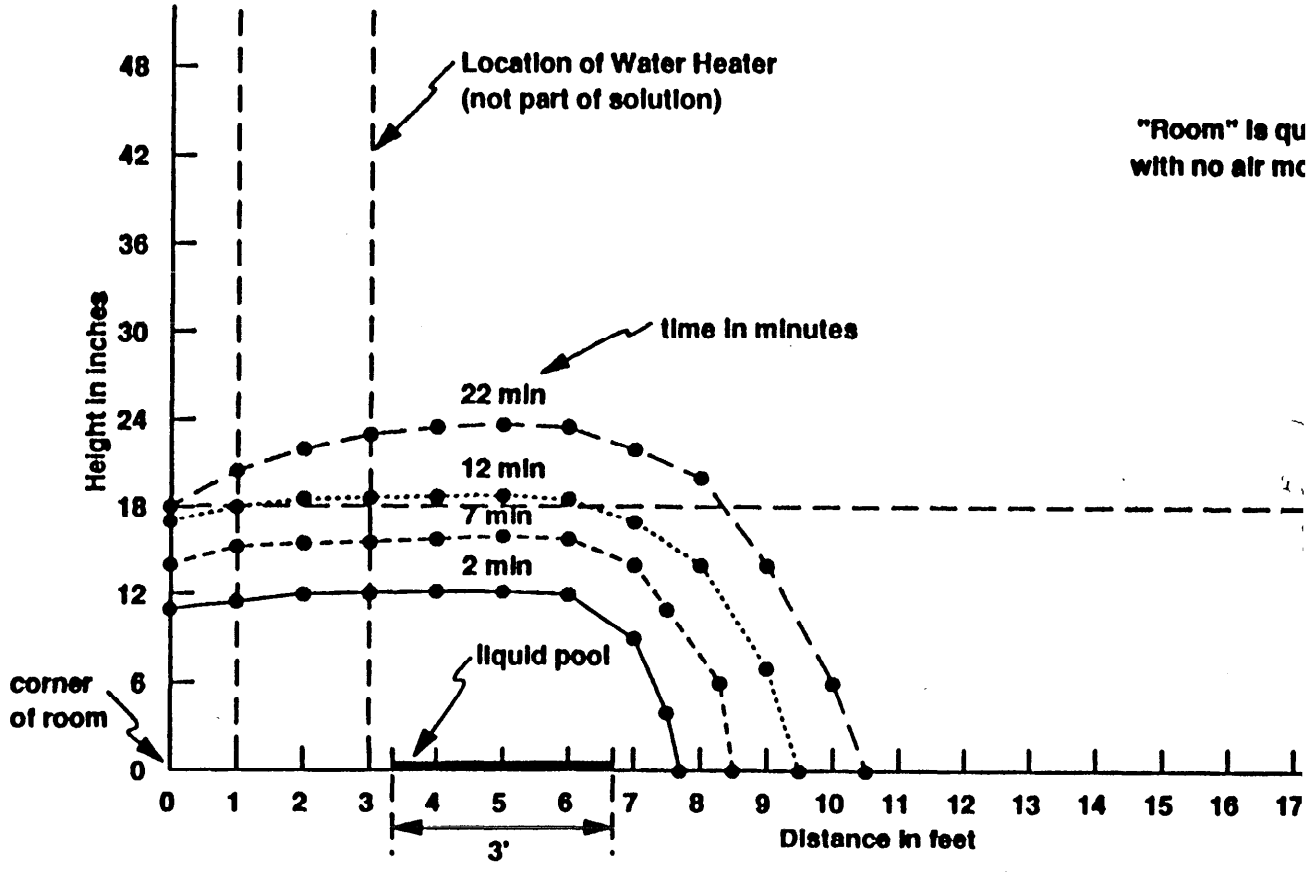
The source component of the Analytical Model is complete a verified with small-scale experiments.

Surface	Quan. (oz)	Area (in^2)	Depth (in)	Temp. (°F)	Average Mass Flux Actual (lb/ft^2s)	Predicted by Model (lb/ft^2s)
Plastic	.16	35	--	45	2.09×10^{-5}	2.05×10^{-5}
Carpet	.86	35	--	72	3.64×10^{-5}	4.31×10^{-5}
Pyrex	1.2	10	.24	52	2.34×10^{-5}	2.67×10^{-5}

References

1. Dehaan, J., Ph.D. Thesis, 1993
2. Arthur D. Little, Inc., Small-Scale Experiments, 1993

The lumped vapor dispersion solution indicates the position flammable limit in space and time.



In the quiescent room, vapor "piles" up in corner and reache in approximately 12 minutes.

The formulation of the analytical model is complete and deb

- The source component has been verified with small-scale ex
- The results from the dispersion component with lumped pool have been demonstrated.
- The dispersion component with emissions modeled as four s been debugged.
- Verification of the complete model will be executed in small-s scale experiments.
- Results from the analytical model will provide information for matrix and theoretically evaluate incident scenarios.

The Experimental Testing Task will be presented in the follo

- Objective
- Basic Principles
- Small-scale Test
- Test Equipment:
  - facility
  - instrumentation
- Test Plans
- Site Selection
- Status

Experimental Testing Task Objective

The objective of the Experimental Testing Task is to experim determine the characteristics of the ignition of flammable va fired water heaters.

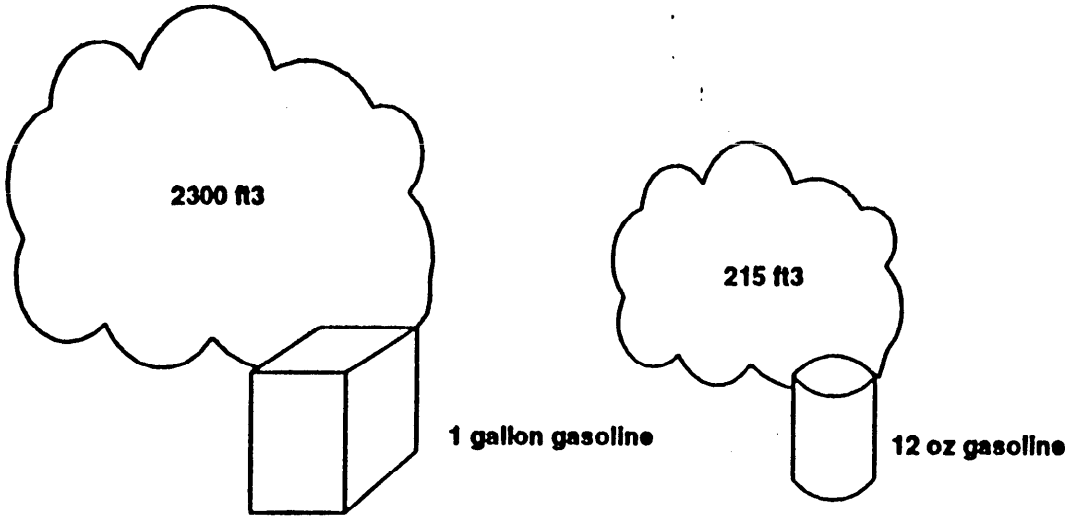
- Selected incident scenarios to be evaluated
- Conditions for the ignition of flammable vapors understood an

Gasoline, the test fluid, is a mixture of approximately 24 hydr varying volatilities and physical properties. These 24 hydroca be grouped into seven categories.

Group	Lower Flammable Limit (Volume %)	Molecula
Butanes	1.8	5
Pentanes	1.4	7
Hexanes	1.2	8
Octane	.8	1
Hexene	1.2	8
Benzene	1.4	7
Toluene	1.2	9

At any position in the vapor, the flammable limit may change these different properties.

To reach the flammable limit, 1.3% gasoline vapor in a comp volume of air and gasoline is required.



A medium sized rag, e.g., a man's "T" shirt, will abso of gasoline vapor without excessive dripping.

Other important principles relate to the weight of gasoline va movement.

- Gasoline vapor is more than twice the density of air and will te at the surface unless disturbed.

- Small movements of air, e.g., initiated by a can spilling or hum movement will aid in dispersing and mixing the gasoline vapor

- Any partially filled container of gasoline contains vapor in equili the liquid. This combustible vapor is immediately released witl air when the container is spilled.

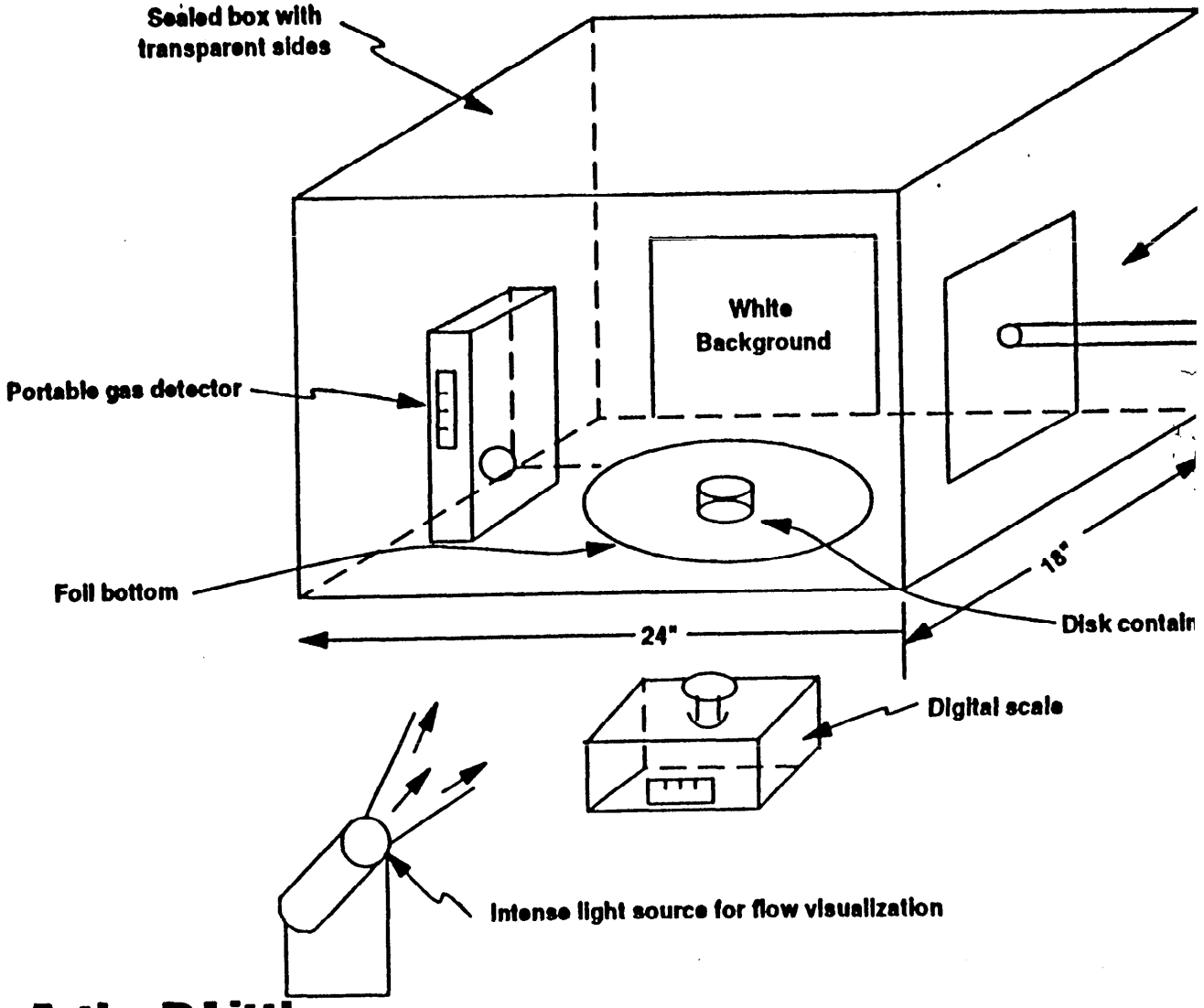
The Failure Analysis Associates' video tape was made availab reviewed.

- This demonstrated the importance of the density of gasoline co air.
- The importance of motion to vapor dispersion is illustrated.
- The tape provided useful information for our flow visualization s

Small-scale (bench-top) tests have been completed to illustr principles and verify analytical model.

- Evaporation rate measured to verify liquid model.
- Shadowgraph method demonstrates effect of motion.
- Portable gas detector verifies vapor dispersion model.

The small scale test facility demonstrates evaporation rate, v dispersion, and the effect of vapor movement.

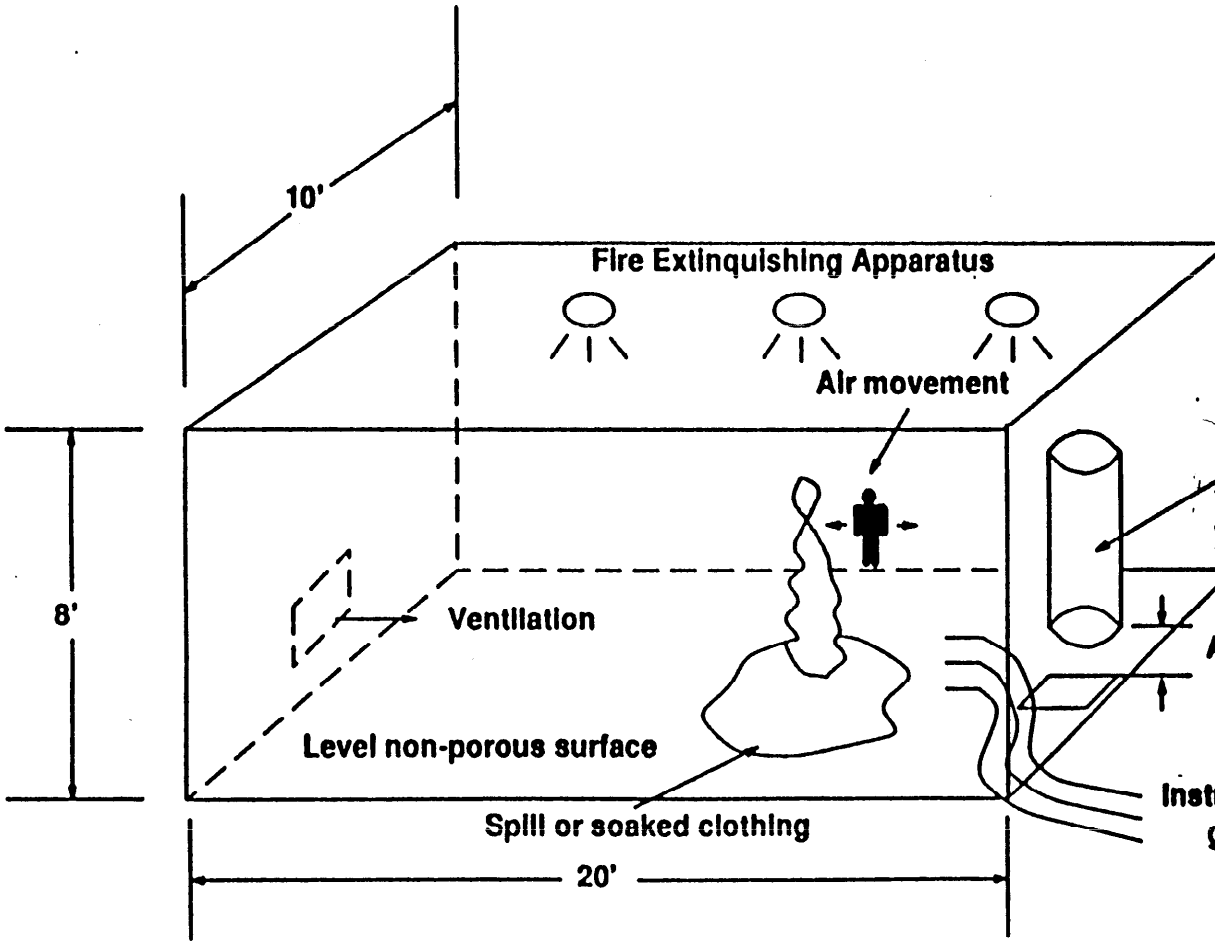


Arthur D Little

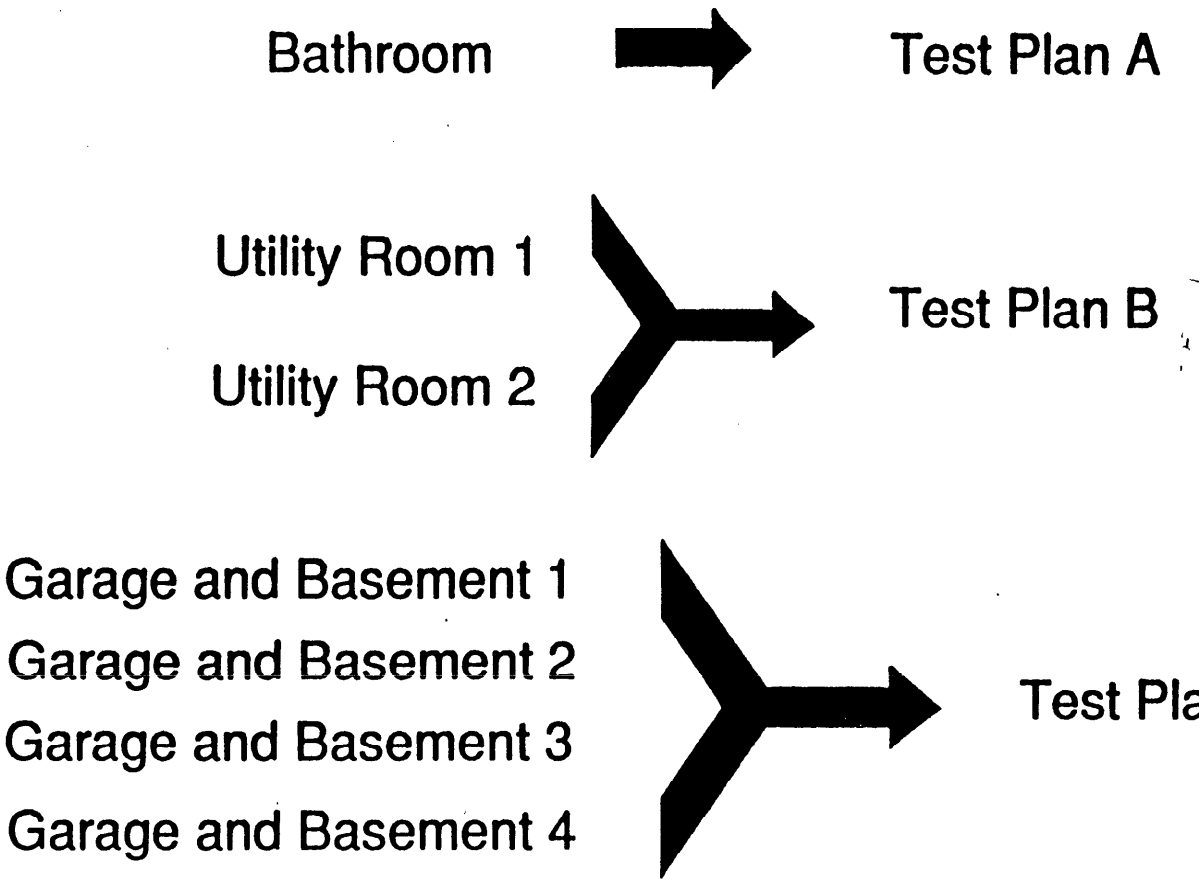
Instrumentation will document the temperature, flow and vapo composition necessary to understand conditions for vapor ig

- Thermocouples will measure temperature
- Anemometry will detect natural air movement into the bumer a rates
- Vapor composition will be determined by four methods:
  - flame ionization detector (FID) readings will be multiplexed detection of flammable limit
  - portable gas detector as back-up to FID
  - gas chromatography for batch determination of sample cor
- Vapor front to be visualized using shadowgraph

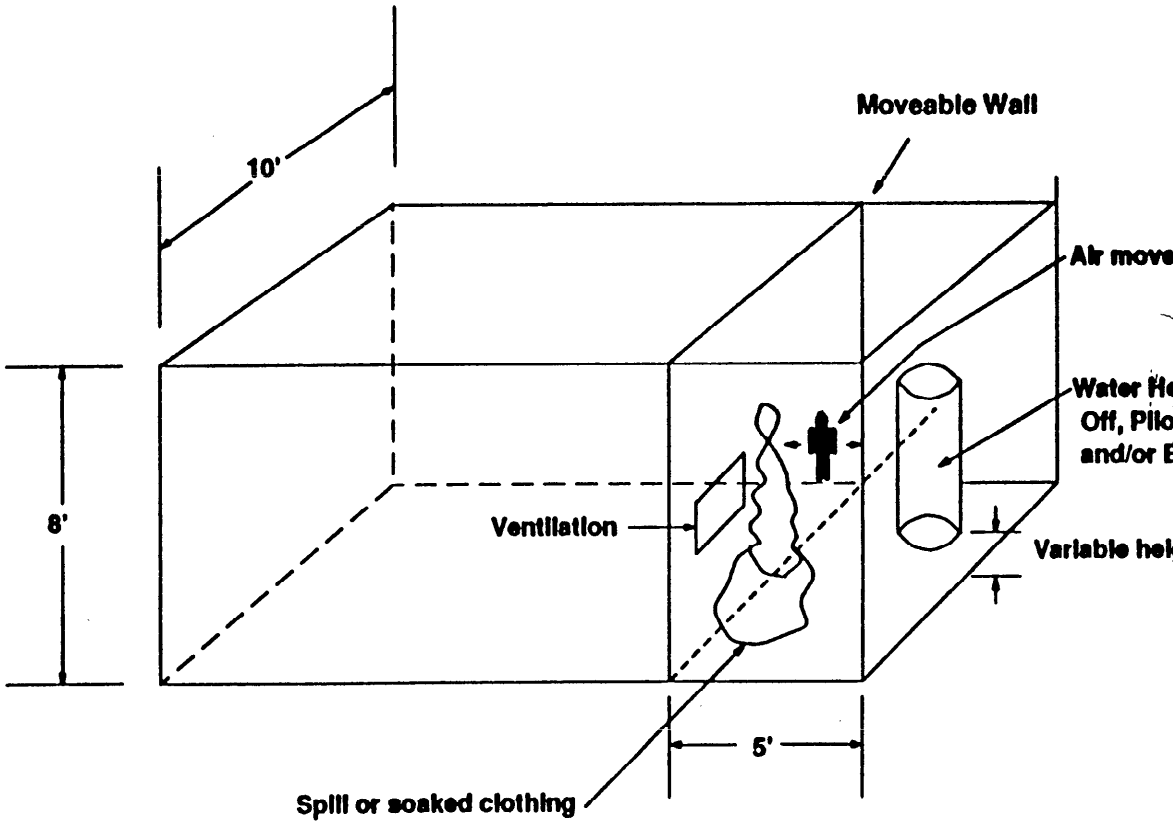
The Full-Scale Test Facility allows for flexibility needed to im test plans.



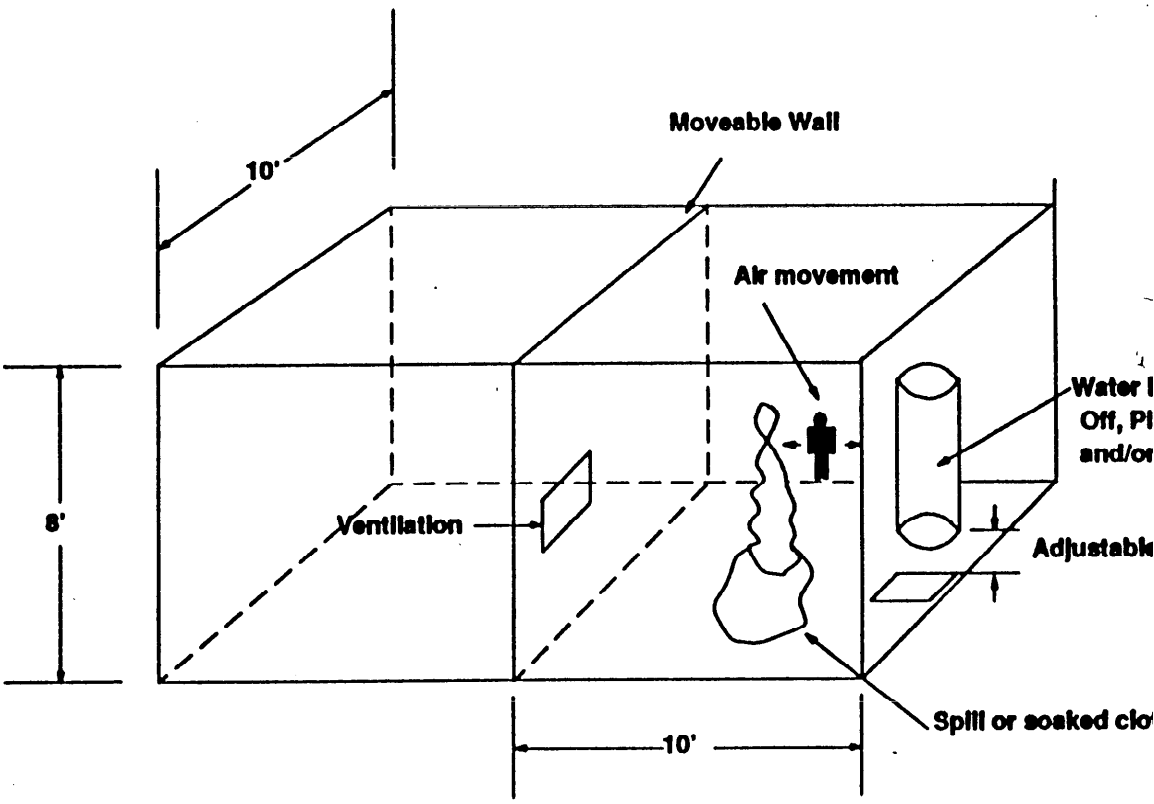
Scenarios from the Data Collection and Analysis Task have de Plan for Experimental Testing. The seven scenarios can be experimentally modeled with three test plans.



Test Plan A models a bathroom with ignition from a spill or so clothing.



Test Plan B models a utility room with ignition from a spill or clothing.



Test Plan C models a garage with ignition from a spill or soak