Journal of Construction Education
Summer 1999, Vol. 4, No. 2, pp. 207-213

1522-8150/99/$3.00/General Manuscript

# Building Code Amendment Justification Research: Poor Indoor Air Quality Mitigation Relative to Attached Garages in a Single Family Residence Scenario

**John D. Murphy Jr. and Joe Beebe**
Colorado State University
Fort Collins, Colorado

This paper reports on research that utilized the Sealed Housing for Evaporation Determination (SHED) method for measuring auto emissions in a confined space to facilitate measurement of "off-gassing" of automobiles in a simulated garage space. Results show there is adequate evidence that a pollutant source is likely to exist in the garage space, to the extent that migration of the pollutant into the living space needs to be mitigated. This data is used to justify the statement that building codes should require a dedicated exhaust vent (passive minimum) for any garage attached to a residential family unit.

**Key Words:** Indoor Air Quality, Residential Building Codes, Space Ventilation Requirements

## Introduction

Indoor air quality is becoming a phrase that is more widely heard; yet standards and governmental intervention are yet to be widely instituted. The term indoor air quality can be thought of as a general term referencing the need for air that is of the quality to support healthy, comfortable, and productive occupation of indoor spaces. While there are many facets of air quality that cross over the indoor vs. outdoor line, the literature, and thus research, has focused mostly on outdoor air quality in the past. Although there is justification for this in that our indoor air can always be traced back to an outdoor air source, a majority of United States population spends approximately 21 hours of the day in some type of indoor environment (Warsco, 1992). Research has shown that average levels for many air pollutants may be two to five times higher in buildings than for ambient levels (those levels of pollutants found in outside air at the same building sample)(Committee on Environment and Public Works, 1989). With this being the case, there is justified argument for creation of some governmental standards to lead society in the direction of healthier indoor environments (Murphy, Jensen, and O'Marra, 1994). While many would be of the opinion that we do not need more government intervention, building code usage/reference has proven to be a worthwhile avenue by which to set minimum, standards for health and safety in the design and construction of buildings and space. This paper argues that building codes may be the most effective point to begin protecting the public in a residential setting regarding the ill effects of poor indoor air quality.

Further supporting the need for standards are the legal issues regarding liabilities of poor indoor air quality. These litigation issues have become more of a concern to designers and constructors specifically related to products liability and owners premises liability, among other aspects

(Murphy et al., 1994) (Murphy, O'Marra, Jensen, 1995). Most legal cases can be shown to be complicated by the lace of standards for indoor air quality.

One indoor air pollutant that is commonly accepted as dangerous to ones health, is the existence of hydrocarbons in occupied spaces. In addition, those that are very learned in the area of indoor air pollutants would agree that there is some level of concern from off-gassing volatile organic compounds, ozone, insulation products, formaldehyde, etc. that are common from certain plastics, finishes, and other products. In the United States, an attached garage for a single-family unit, supporting one or more vehicles, has become the norm. It can be argued that the garage is a common source for many of the pollutant sources mentioned above. After reviewing the Building Code (UBC) 1994, the National Building Code (BOCA) 1996, and the Standard Building Code (SBC) 1994, the authors found no references to requirements that would mitigate the possible migration of indoor air pollutants from the garage space to the living spaces. The typical reference in all three of these codes, regarding the garage, dealt with fire protection separation from the living space.

This paper reports on research that focuses on just one physical source of possible pollutants located in the garage – that being the automobile itself. In isolating on the automobile as a specific pollutant source, the researchers hope to validate the need for building code change that will apply a simple solution to mitigating the garage as a point source of possible indoor air pollution. The suggested amendment to building code is to require a minimum ventilation mechanism specifically for the garage. This, in conjunction with present fire rating separation requirements, would create an isolated air exchange scenario for the garage space.

## Methodology

A laboratory study was conducted to measure evaporation emissions from in-use vehicles using the Sealed Housing for Evaporation Determination (SHED) method. This SHED method utilized a sealed metal chamber of approximate dimensions 8 feet tall by 10 feet wide by 22 feet long. Twenty light duty cars and trucks were obtained for the study. A graphic of study methodology is shown in Figure 1.

As one can see, each automobile underwent the "hot soak test" which includes allowing each subject vehicle to "outgas" inside the chamber immediately following an emissions dynomometer test of 41 minutes (Environmental Protection Agency, 1996). This provided a standard level of "warm up" for each subject vehicle, resulting in a high level of comparability with this data. Evaporation emissions were measured using the same analysis equipment for all subject vehicles. A limitation of this study is that the concentration analyzer equipment utilized did not differentiate between types of hydrocarbons, instead calculating total hydrocarbons (THC). Calculations for total mass of THC were completed as follows:

$$\text{MASSTHC} = \text{Volume } (\text{ft}^3\text{STD}) \text{ X Denisty}^{\text{gms}}/\text{ft}^3\text{STD X concent.THC } (\text{parts}/10^6\text{parts})$$

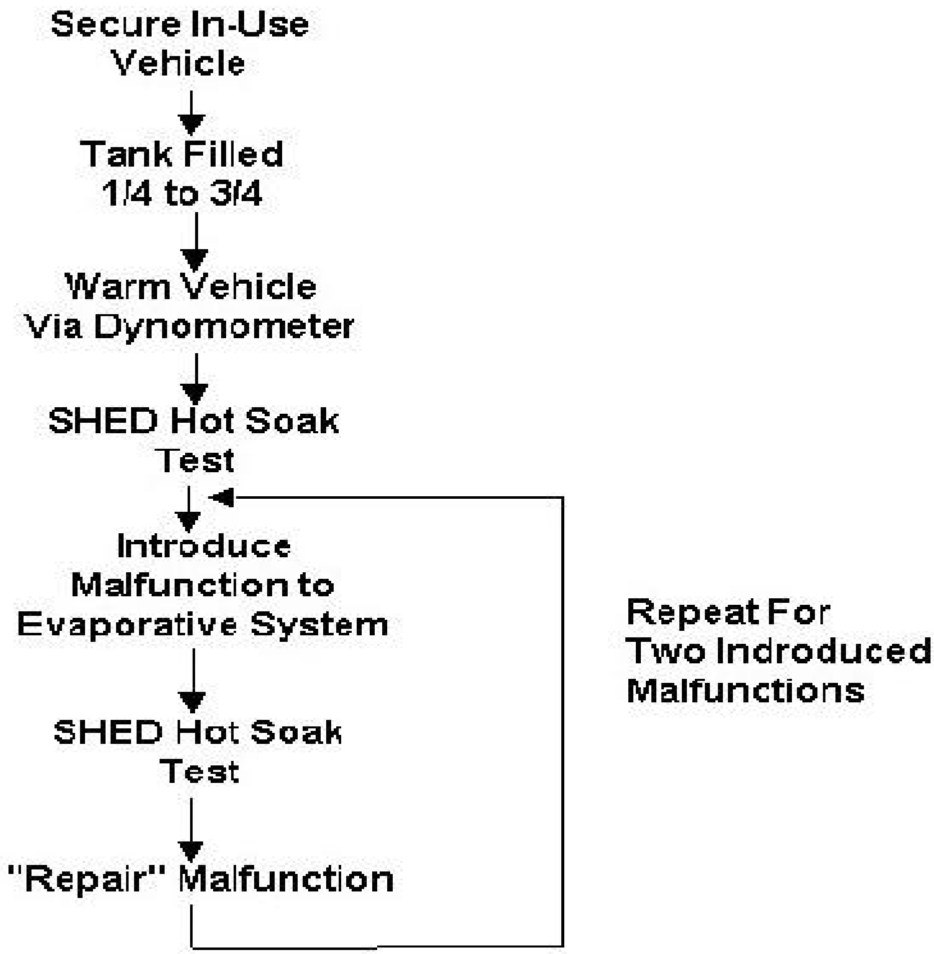


*Figure 1.* Methodology of emissions evaporation measurement testing.

From a reading taken from the concentration analyzer, parts per million (ppm) can be read with a published density. From this point the formula can be utilized after adjustments have been made for the altitude (pressure adjustment) and the exact size of the SHED (volume adjustment). These adjustments were made for all calculations for all subject vehicles. To show an example of these completed calculations, a reading for subject vehicle is found to be 200 ppm of THC and a published density of 14.2 grams $ft^3$STD in our SHED which has a standard volume is 1385 cubic feet.

$$MASSTHC = 1385ft^3STD \times 14.2^{gms}/ft^3STD \times 200\ THC\ (parts/10^6)$$

$$MASSTHC = 3.93 \text{ grams of THC}$$

Another aspect of this study was to address the differing states of maintenance found in vehicles. Automotive designs today typically have vapor saving devices intended to lower rates of evaporative emissions. Under varying degrees of disrepair, vehicles may have some of these devised in non-working order. To simulate/allow for these occurrences, malfunctions were introduces to the subject vehicles prior to running the vehicle through a hot soak test again.

Figure 1 shows this sequence. The two malfunctions introduced individually were 1) removing the fuel cap and 2) removing carbon canister fuel tank vapor hose. In the cases where the THC emissions were found to be unusually high in the first soak test, the vehicle may not have been re-tested again. The reason for this is the suspicion that a vapor leak already existed in the vapor saver system and a comparison with an induced defect would be limited in meaning.

## Results

The results of the research can be summarized as shown in Table 1.

Table 1

*Summary of study results*

| |
|---|
| With CAP "Defect" (Avg) 1.58 gms (12) |
| With HOSE "Defect" (Avg) 3.29 gms (11) |
| With UNKNOWN "Defect" (Avg) 8.25 gms (4) |
| With DEFECTS "Corrected" (Avg) 0.53 gms (19 |

As can be seen in Table 1, the average SHED THC evaporation loss was 1.58 grams with the fuel cap removed. The average with (only) the carbon canister fuel tank vapor hose disconnected was 3.29 grams. The average for an unknown defect was 8.25 grams. The average for a system "ok" condition was 0.527 grams. The numbers in parenthesis indicate the number of tests with the stated condition of the vapor saver system. To give some sense of scale on these readings, the Environmental Protection Agency (EPA) allows 2 grams total THC evaporation for vehicle design, calculated by the hot soak test and a procedure called the diurnal breathing loss (DBL) test. The EPA does not have a standard for the hot soak test alone. While the DBL test was not applied in this research, the results from only one of the tests included within the allowed vapor emissions standard can be seen as a statement of emissions greater than or equal to the results obtained in the study.

The results shown in Table 1 do not tell the whole story, however, as some surprising results can be seen in the raw data contained in Appendix A. For example, in several cases, the removal of the fuel cap or canister hose resulted in very little increase in THC evaporation loss compared to "system OK" tests. The reasons for this are not clear. Preliminary information obtained by the researchers suggests that pressure threshold or "head valve" devices can affect initial hydrocarbon losses when vapor saver systems are first vented. The "whoosh" heard when some fuel caps are removed for vehicle refueling is a manifestation of these threshold devices. Obviously, variations in the fuel volatility of the vehicles under test in this study can cause large differences in evaporation losses as well.

Nevertheless, the averages do suggest real differences among vehicle vapor saver "conditions." That is, a missing fuel cap, or broken or disconnected vapor hose at the canister results in a large increase evaporation losses of THC.

## Conclusions and Recommendation

The data obtained in this study and related observations indicate real differences in hydrocarbon evaporation emissions between vehicles with *intact* and *functional* vapor saver systems and vehicles with defective vapor saver systems. But, in line with the contention of this paper, what do these results mean with regard to making a judgment as to whether or not to ventilate a garage space. With the understanding that it would be very difficult, and quite possibly invalid, to estimate the state of disrepair of vehicles in a "typical" attached garage, one can still conclude that vehicles parked in a garage are a source of hydrocarbons that are in close proximity to living spaces when the garage is attached . With this in mind, it is the recommendation of the researchers that the building code be amended to include requirements for all garages attached to residential housing units to have a dedicated exhaust system for the garage space(s). This research shows that there is a need for ventilation of garages based solely on comparison between what the EPA allows regarding vehicle design and the rates of evaporative emissions for many different vehicles. This does not take into account the fact that science has not yet shown with any degree of certainty at what level of exposure to hydrocarbons, an other pollutants, human tissue is damaged or disease initiates (ie. threshold of carcinogenicity) (Murphy and Grosse, 1993). This uncertainty strengthens the argument to protect the public from the possibility of harm. Also, differentiating between types of hydrocarbons is not a major issue in that most proponents for better indoor air quality would agree that many of the sources of out-gassing hydrocarbons from an automobile would be considered as not healthy for breathing. The reader should also be cognizant of the fact that this research did not address any of the many other possible pollutant sources typically sound in garage (paint, solvents, gasoline cans, etc.).

## Future Research

The above referenced recommended change to building codes assumes a functionality of the required system. With that in mind, there is a need for further research to become more specific with the requirements. This is necessary to facilitate the proposed change. The next aspects of research to support and detail this recommended amendment to code is to complete research that addresses the following:

1. Formulate a way to specify the proper number of air changes for the garage per day.
2. Formulate an associated required number of air intake grills.
3. Specify the means by which an envelope will be maintained to facilitate required air changes
4. per day.
5. Specify the minimum means by which the garage space can be ventilated.

## References

Committee on Environment and Public Works U.S. Senate. (1989). *Indoor Air Quality of 1989.* (Report No. 19-479, p. 238-291). Washington D.C.: U.S. Government Printing Office.

Murphy, John & Grosse, Larry. (1993). Chrysotile Asbestos in Buildings: A Need for Evaluating the Regulations. *Building Research Journal*. 2 (1), 53-59.

Murphy, J., Jensen, D., & O'Marra, B. (1994). Exploring the Concept of Building Owners' Premises Liability With Respect to Indoor Air Quality and the Need for Governmental Standards. *Indoor Air – An Integrated Approach.* Morawska, Bofinger, and Maroni (Eds.). 445-449. U.K., Elsevier Science Ltd.

Murphy, J., O'Marra, B., and Jensen, D. (1995). Indoor Air Quality and the Issue of Products Liability: Is Air a Product? *An International Conference on Health Buildings in Mild Climates, Conference Proceedings.* Milano, Italy. 3, 1769-73.

Environmental Protection Agency. (1996). *Code of Federal Regulations.* (Protection of Environment, Title 40, Part 86.107). Washington D.C.: U.S. Government Planning Office.

Warsco, Katherine. (1992). Explaining Housing-Related Illness: A Decade of Analysis of Emerging Paradigms. *Housing and Society*. 19 (3), 49-62.

# Appendix A

| | | | | Result (HC gms) | | | |
|---|---|---|---|---|---|---|---|
| No | Vehicle | Condition | Avg. Temp | System OK | Cap Off | Hose Off | Comment |
| 1 | ’73 Ford PU | Leak fuel guage | 81.0 | | | 2.69 | |
| 2 | ’93 Chev. PU | Syst. OK | 81.5 | 0.034 | | | |
| 3 | ‘93 Chev. PU | Syst. OK | 85.0 | 0.196 | | | |
| 4 | ’93 Chev. PU | Cap removed | 88.0 | | 1.50 | | |
| 5 | ’86 Chev. Sedan | Syst. OK | 91.0 | 0.304 | | | |
| 6 | ’86 Chev. Sedan | Cap removed | 91.0 | | 0.553 | | |
| 7 | ’92 Saturn SL | Syst. OK | 80.0 | 0.242 | | | |
| 8 | ’92 Saturn SL | Cap removed | 82.0 | | 0.299 | | |
| 9 | ’92 Toyota Sedan | Syst. OK | 82.0 | 0.202 | | | |
| 10 | ’92 Toyota Sedan | Cap removed | 82.5 | | 4.78 | | |
| 11 | ’93 Lumina APV | Cap removed | 81.0 | | 2.43 | | |
| 12 | ’93 Lumina APV | Syst. OK | 84.5 | 1.15 | | | |
| 13 | ’93 Lumina APV | Cap removed | 87.0 | | 2.595 | | |
| 14 | ’93 Lumina APV | Hose off canister | 86.0 | | | 4.714 | |
| 15 | ’93 Lumina APV | Repeat test #14 | 88.0 | | | 6.943 | |
| 16 | ’93 Lumina APV | With EtoH added | 87.5 | | | 3.612 | |
| 17 | ’92 Saturn SL | Hose off canister | 81.5 | | | 0.642 | |
| 18 | ’92 Toyota Sedan | Hose off canister | 82.5 | | | 1.192 | |
| 19 | ’92 Toyota Sedan | Hose off canister | 80.0 | | | 1.197 | |
| 20 | ’80 Chev. Caprice | Syst. OK | 83.0 | 6.394 | | | |
| 21 | ’92 Chry. New Yorker | Syst. OK | 80.0 | 0.120 | | | |
| 22 | ’92 Chry. New Yorker | Hose off canister | 83.0 | 0.124 | | | |
| 23 | ’89 Ford Escort | Syst. OK | 79.0 | 0.092 | | | |
| 24 | Chev. Astro Van | Syst. OK | 83.5 | 0.449 | | | |
| 25 | ’89 Toyota PU | Hose off canister | | | | 0.132 | |
| 26 | ’84 Range Rover | Syst. OK | | 10.660 | | | Grey Mkt. |
| 27 | ’92 Saturn SLI | Cap removed | | | 0.609 | | |
| 28 | ’81 Ford Escort | Hose off canister | 77.5 | | | 9.288 | |
| 29 | “93 Dodge Caravan | Syst. OK | 79.5 | 0.136 | | | |
| 30 | ’93 Dodge Caravan | Hose off canister | 82.5 | | | 1.176 | |
| 31 | ’81 Ford Escort | Syst. OK | 82.5 | 1.514 | | | |
| 32 | ’85 Jeep Cherokee | Syst. OK | 82.5 | 12.921 | | | Canister broken |
| 33 | ’81 Datsun 210 | Syst. OK | 82.0 | 0.49 | | | |
| 34 | ’81 Datsun 210 | Cap removed | 84.0 | | 1.061 | | |
| 35 | ’92 Saturn SL | Syst. OK | 85.5 | 0.202 | | | |
| 36 | ’81 Ford Escort | Syst. OK | 86.0 | 2.435 | | | New canister |
| 37 | ’88 Chev. Corsica | Syst. OK | 8..5 | 0.153 | | | MtoH/EtoH |
| 38 | ’88 Chev. Corsica | Cap removed | 83.5 | | 0.095 | | MtoH/EtoH |
| 39 | ’73 Ford PU | Leak fuel gauge | 82.5 | | | 3.367 | |
| 40 | ’90 Chev. Lumina | Syst. OK | 79.5 | 0.153 | | | |
| 41 | ’90 Chev. Lumina | Cap removed | 78.0 | | 0.305 | | |
| 42 | ’81 Ford Escort | Syst. OK | 81.5 | 1.922 | | | |
| 43 | ’80 Arrow PU | Syst.OK | 83.0 | 3.041 | | | |
| 44 | ’80 Arrow PU | Cap removed | 83.5 | | 3.502 | | |
| 45 | ’91 Honda Accord | Syst. OK | | 0.088 | | | |
| 46 | ’91 Honda Accord | Cap removed | | | 1.195 | | |

“Syst. OK” refers to a visual inspection only