

“Test of Mercury Vapor Emission from Fly Ash Bricks: Important Finding”

**Invited presentation at the Portland Cement Association
Fall Meeting’s Annual Technical Session**

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By

Henry Liu

Freight Pipeline Company

Columbia, Missouri

Current usages of fly ash:

- As an admixture for concrete (concrete containing 10% to 20% fly ash)
- Highway roadbed and embankment
- Soil conditioner to stabilize building foundation
- Improving soil for planting (neutralize acid in acidic soil)
- **Many other usages**

Why use fly ash to make bricks?

1. In spite of the various uses of fly ash, at present only 1/3 of the fly ash generated in the U.S. is used; the remaining 2/3 (>40 million tons a year) is unused. There is a national need for increased beneficial use of fly ash. Making bricks is a potential new usage of fly ash.

Why use fly ash to make bricks? -- continued--

2. The U.S. uses 9 billion bricks annually. Because each ton of fly ash can make about 400 bricks, to make all the bricks needed in the U.S. will require the use of 23 million tons of fly ash annually, which is about 50% of the currently-not-used fly ash in the U.S. This means two things:

(1) There is sufficient amount of not-used fly ash in the U.S. to make enough bricks for the entire nation.

(2) Brick is a huge market for future use of the currently-not-used fly ash.

Environmental benefits of using fly ash to make bricks:

- 1. It solves a solid waste disposal problem, thereby reducing landfill need.**
- 2. It reduces the use of cement for making concrete bricks, thereby reducing emission of CO₂ and reducing global warming. (1 ton of CO₂ is generated for 1 ton of cement manufactured.)**
- 3. It reduces the use of clay bricks which must be fired to 2100°F by burning fossil fuel– a process that causes air pollution and global warming.**

How is the “durable fly ash brick” made ?

1. **Get Class C fly ash from power plants.**
2. **Add and mix with 10% to 20% water. The mixture also contains a small amount of air entrainment agent, and a small amount of color pigments if bricks of a color different from the natural fly ash color are to be made.**
3. **Feed the mixture into molds and compact.**
4. **Cure the green bricks either by steam or mist.**
5. **Ready for shipment and use.**

Advantages of Durable Fly Ash Brick:

- **Is durable (passes ASTM standards C62 on freeze-thaw resistance)**
- **Has high strength (much exceeds ASTM standard C62 of 3,000 psi.)**
- **Room temperature manufacturing, which conserves energy and reduces cost.**
- **More uniform in shape and dimensions, which saves cement and labor cost in laying bricks.**

NSF Funding

In 2006, Freight Pipeline Company (FPC) won a \$500,000 grant from National Science Foundation (NSF) to develop the durable fly ash brick technology for commercial use in two years. The R&D is to be completed by the end of 2007.

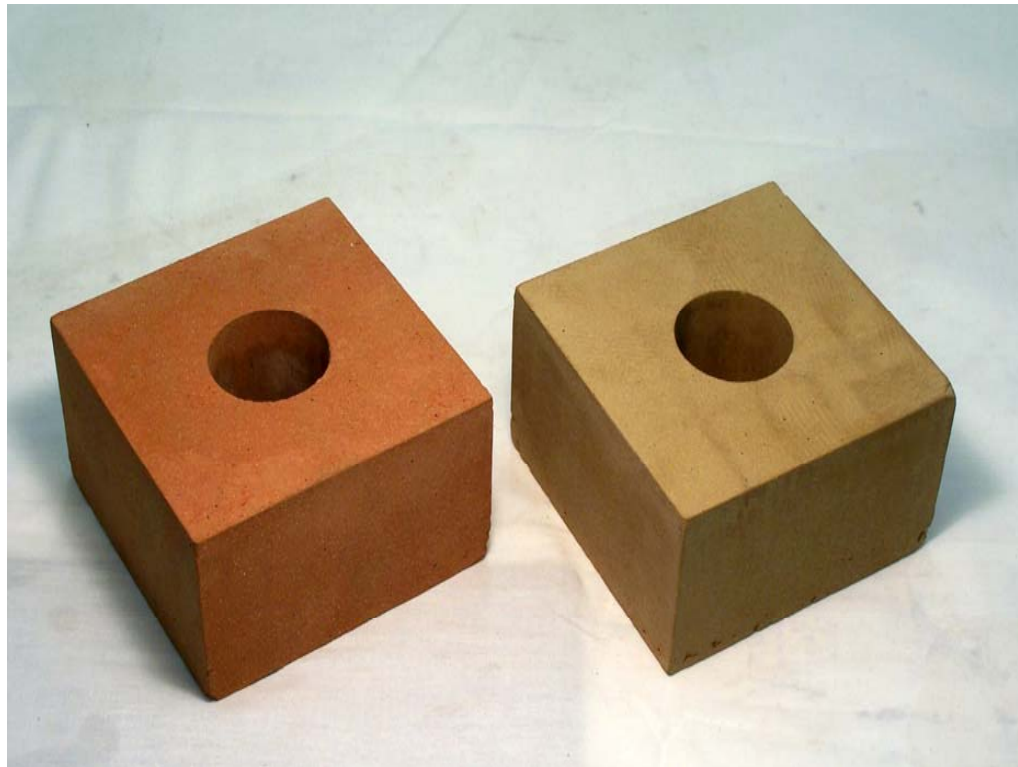
Accomplishments of the On-going NSF Project:

1. Made colored fly ash bricks



Accomplishments (continued):

2. Made cored (perforated) fly ash bricks



Accomplishments (continued):

3. Won invention contest

In 2006, the durable fly ash brick was selected by the History Channel and the Inventors Hall of Fame as one of 25 Modern Marvels Inventions; it was selected from more than 4,000 inventions considered.

Accomplishments (continued):

4. Free exhibition

In 2006, samples of the durable fly ash brick were exhibited **free-of-charge** at five museums in the U.S. (Los Angeles, Chicago, Boston, New York City and Akron Inventors Hall of Fame Museum), and at the International Exhibition Center in Shanghai, China.

Accomplishments (continued):

5. Patents (Pending) on “Durable Fly Ash Bricks”:

- (1) U.S. Patent**
- (2) Chinese Patent**
- (3) PCT (Patent Cooperation Treaty)**

NSF-SBIR Phase 2 Grant Project

“Compacting Fly Ash to Make Bricks”

Task 1: Test Variability of Class C Fly Ash (Done)

Task 2: Test Different Mixing Methods (Done)

Task 3: Test Brick Coloring (Done)

Task 4: Test Coring of Bricks (Done)

Task 5: Test Properties of Fly Ash Bricks (90% done)

Task 6: Test Environmental Concerns (80% done)

→ **6.1. Mercury vapor emission from fly ash brick (done)**

6.2. Pollutants leachate from fly ash brick (done)

6.3. Radon emission from fly ash brick (incomplete)

Test of Mercury Vapor Emission from Fly Ash Bricks

Purpose:

1. To measure the emission of mercury from fly ash bricks.
2. To determine whether the measured rate of mercury emission poses any health hazard.

Emission Rate and Flux

Emission rate is the weight of the matter (such as **mercury**) emitted in unit time from an object (such as **brick**). The unit used here is **Ng/h** (nano-grams per hour).

Emission flux is the emission rate per unit surface area of the object (brick). The unit used here is **Ng/h/m²** (nano-grams per hour per square meter).

Test of Mercury Vapor Emission from Fly Ash Bricks

Approach:

1. Use the dynamic flux method to measure the emission **flux** of mercury by fly ash bricks placed in an environmental chamber (**dynamic flux chamber**).
2. Determine potential health hazard from the measured **flux** of mercury emission.

Relation between emission flux, F , and the concentration of pollutant (Hg) in air, C :

$$C = \frac{AF}{EV_o} \dots\dots\dots (1)$$

Where A = surface area of the object (brick); m^2 .

C = concentration of pollutant (mercury) in air; Ng/m^3 .

E = exchange rate of air for building; $1/h$.

F = emission flux of pollutant; $Ng/h/m^2$.

V_o = volume of building; m^3 .

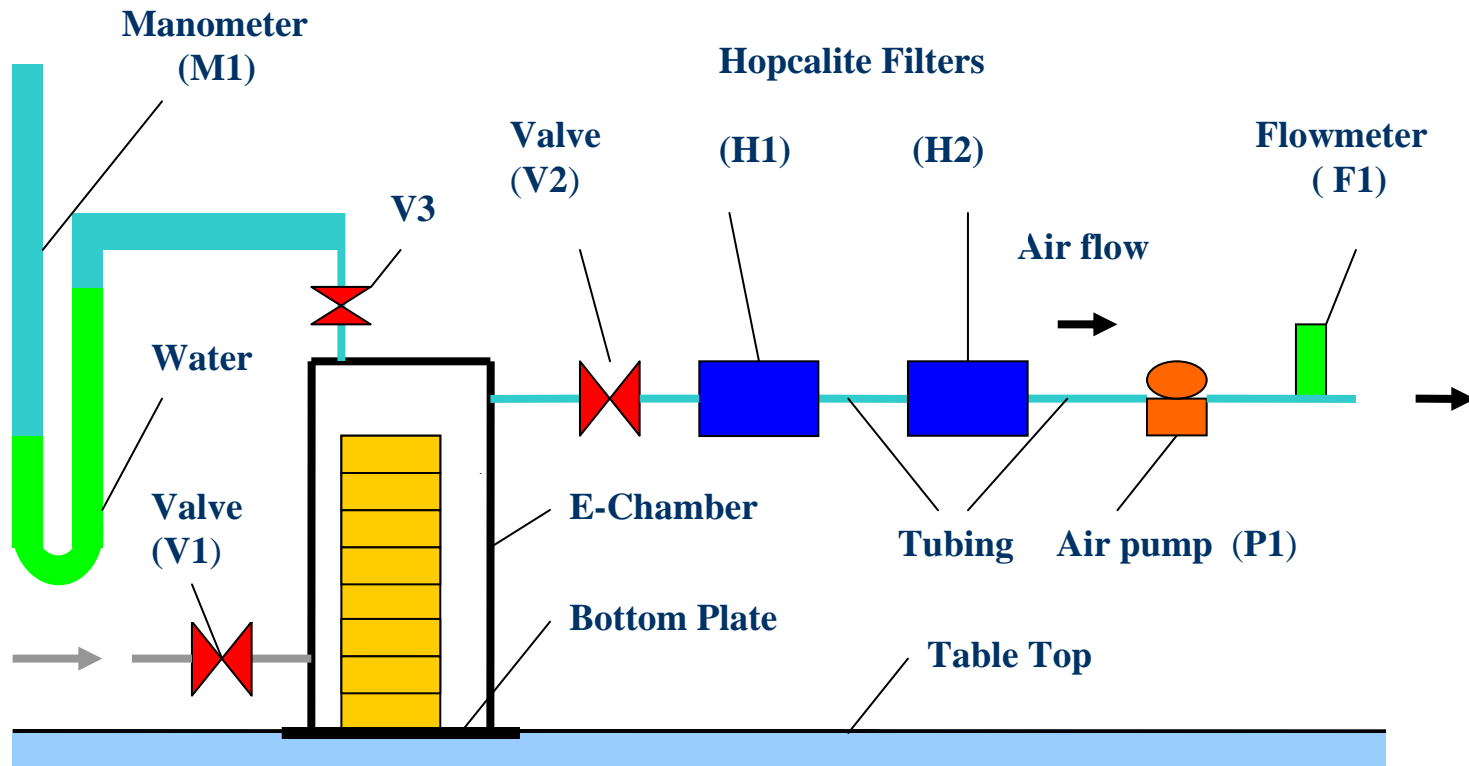
Criterion for determination of the safe level of mercury emission flux from fly ash bricks

Using EPA requirement that the mercury concentration in air should not exceed 1.0 microgram/m³, and using ASHRAE requirement that homes should have a minimum air exchange rate of 0.25 per hour, Eq. 1 in the previous slide reduces to:

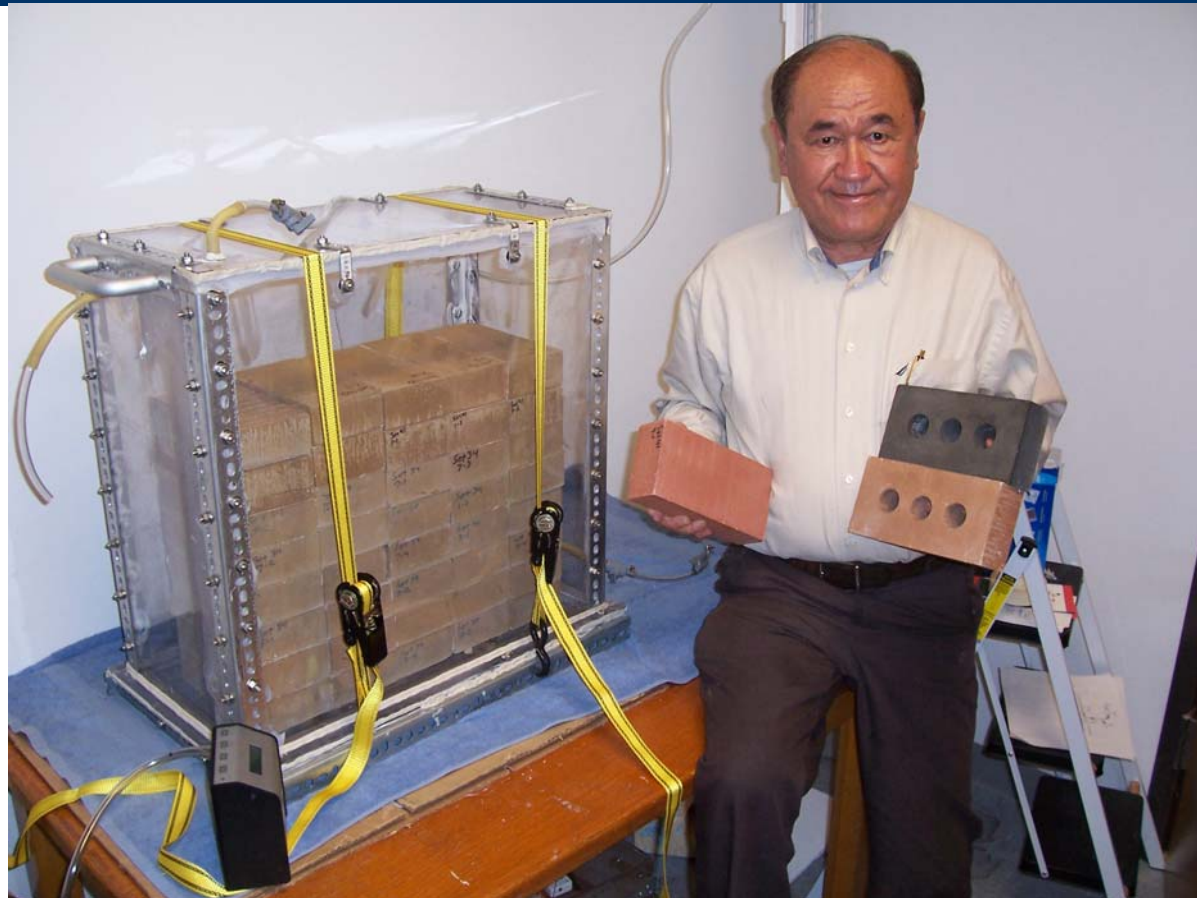
$$F < 410 \text{ Ng/h/m}^2$$

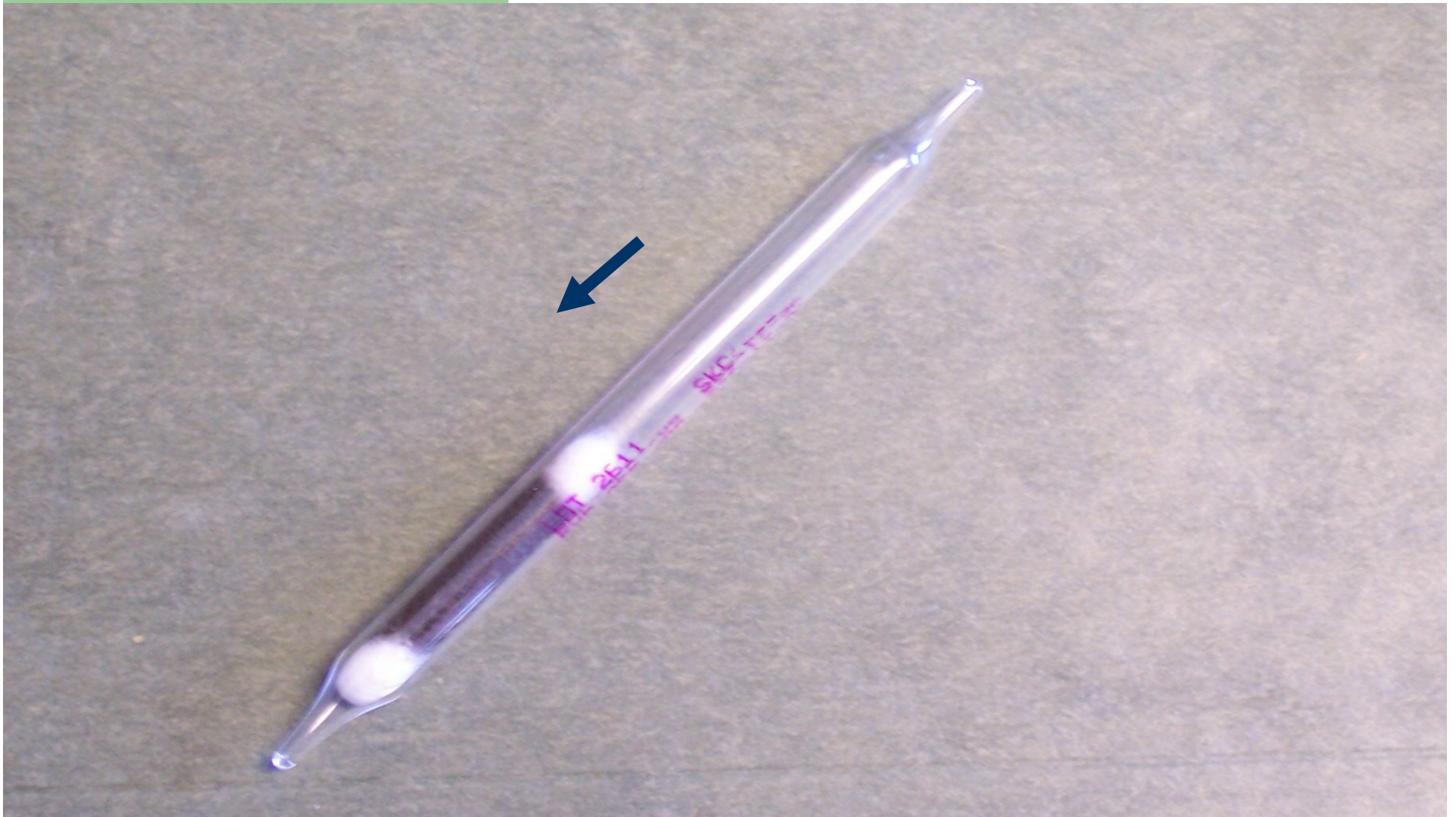
Thus, if the measured mercury emission flux, F , is less than 410 Ng/h/m², the bricks are safe for indoor use.

Experiment to determine mercury emission from fly ash bricks: Test Setup



mercury emission Test Setup





Hopcalite filter for adsorption of mercury

Mercury Vapor Emission Test Procedure:

1. Run the test with 40 bricks in the E-chamber
2. Run the test with no bricks in the E-chamber
3. Run the test without E-chamber (i.e., ambient air quality test)
4. From the results of the three tests mentioned above, determine whether the bricks release mercury vapor. If so, how much? – whether the **safe limit $F < 410 \text{ Ng/h/m}^2$** is exceeded or not.

Test Result

Table 1 Mercury emission from flyash bricks (Set 2: Improved Test)

Test Condition (1)	Aver. Air Flow Rate Q_o (L/min) (2)	Test Period T (hrs) (3)	Air Flow Vol. V (m ³) (4)	Vacuum in Height of Water (mm) (5)	Mercury on Filter (Ng)		Captured Mercury Concen. C_2 (Ng/m ³) (9)	Filter Efficiency E_1 (%) (10)	C_m (Ng/m ³) (11)	Hg Flux. (Ng/h/m ³) (12)
					H1 (6)	H2 (7)				
40 Bricks	4.12	191.6	47.1	58-125	110 (25.7)	52 (-32.3)	-0.141	100	0.542	-0.081
Ambient Air	4.00	167.5	40.2	0	120 (35.7)	98 (13.7)	1.20	61.6	1.44	--
Empty Chamber	4.25	169.0	43.1	36-41	110 (25.7)	90 (5.7)	0.726	77.8	0.766	-0.12

Summary of Test Result (Improved Test)

- 1. To get reliable test data, the minimum period for each test run is about one week (7 days). Longer test periods yield more accurate and reliable results.**

Summary of Test Result (Improved Test)

2. The background level of mercury contained on each Hopcalite filter, as told by the filter manufacturer, was an average of **50** Ng for each 500mg filter. In contrast, the values measured from testing 3 blank Hopcalite filters are **83**, **84** and **86** Ng per filter. This shows that the average value supplied by the manufacturer is inaccurate. One should test at least 3 blank filters and use the tested values to determine the average background level of mercury on each filter.

Summary of Test Result (Improved Test)

3. The concentration of mercury measured in the air entering the test filters is the highest for the ambient air (**1.44 Ng/m³**), the second highest for the air coming from an empty chamber (**0.77 Ng/m³**), and the lowest for the chamber containing 40 bricks (**0.54 Ng/m³**). What this means is that the fly ash bricks not only do not pollute the air around them, they actually absorb mercury from the ambient air, making the ambient air cleaner.

This result is consistent with the 2003 finding by David Hassett and Loreal Heebink (“Long-Term Mercury Release from CCBS [12]”, which concluded that “Coal combustion by-products (CCBs) were acting as mercury sinks rather than release agents.”

Summary of Test Result (Improved Test)

4. The measured mercury flux emitted by the bricks is **-0.08 Ng/h/m²**, approximately. The negative sign confirms that the bricks adsorb instead of emit mercury. Even had the sign been positive, the value **0.08 Ng/h/m²** would still be 5,000 times smaller than the limiting value of 410 Ng/h/m² mentioned before, and hence would be very, very safe.

Summary of Test Result (Improved Test)

- 5. Due to the trace amount of mercury contained in the air in this study, the Hopcalite filters have efficiencies less than 100%. Two such filters had to be used in series in each test to determine the filter efficiency, so that the amount of mercury in the air can be determined accurately.**

CONCLUSION

1. Fly ash bricks do not release mercury into the ambient air. To the contrary, they adsorb mercury from the air.

(This means that using fly ash bricks indoors will benefit rather than damage the indoor air quality !!!)

CONCLUSION

– continued--

2. Even though at this time the exact mechanism of how fly ash brick adsorb mercury is not known, it must be due to surface adsorption rather than absorption.
3. It would be of interest to determine in future research whether the brick also adsorb other heavy metals present in air.

CONCLUSION

– continued--

- 4. At low concentration of mercury the Hopcalite filters are not 100% efficient. Two identical filters in series (double filter) should be used to determine the filter efficiency, so that the concentration of mercury in air can be determined accurately.**

CONCLUSION

– continued--

- 5. The bricks used in this study were made from the fly ash of the Thomas Hill Power Plant in Missouri. The ash contains less than 0.1 ppm (part per million) of mercury. Additional tests will be done with a Class C fly ash that contains much higher concentration of mercury, to see if the bricks still adsorb rather than emit mercury.**

CONCLUSION

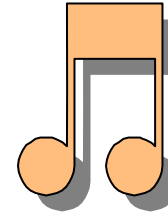
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- 6. The methodology used here to determine mercury emission from fly ash bricks can be used for testing other products made of fly ash or other coal ashes. It can also be used for testing emission from other materials such as concrete products, rock, or soil.**

ACKNOWLEDGMENT

Support of this research project by the **National Science Foundation (NSF)** is highly appreciated!

Holly-luya!
This is the last slide!



Thank You!

