

# Vapor Pressure of Solid HD

**James H. Buchanan, Leonard C. Buettner, and David E. Tevault**  
**Research and Technology Directorate**  
**U.S. Army Edgewood Chemical Biological Center**  
**AMSRD-ECB-RT-P**  
**Aberdeen Proving Ground, MD 21010**



# Report Documentation Page

*Form Approved*  
*OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE <b>15 NOV 2004</b>	2. REPORT TYPE <b>N/A</b>	3. DATES COVERED -			
4. TITLE AND SUBTITLE <b>Vapor Pressure of Solid HD</b>		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Research and Technology Directorate U.S. Army Edgewood Chemical Biological Center AMSRD-ECB-RT-P Aberdeen Proving Ground, MD 21010</b>		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADM001849, 2004 Scientific Conference on Chemical and Biological Defense Research. Held in Hunt Valley, Maryland on 15-17 November 2004 . , The original document contains color images.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT  <b>UU</b>	18. NUMBER OF PAGES  <b>15</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

# Vapor Pressure Calculation

$$P_{\text{HD}} = n_{\text{HD}} RT/V$$

$$P_{\text{total}} = (n_{\text{HD}} + n_{\text{carrier}}) RT/V$$

$$P_{\text{HD}} = P_{\text{total}} \cdot n_{\text{HD}} / (n_{\text{HD}} + n_{\text{carrier}})$$

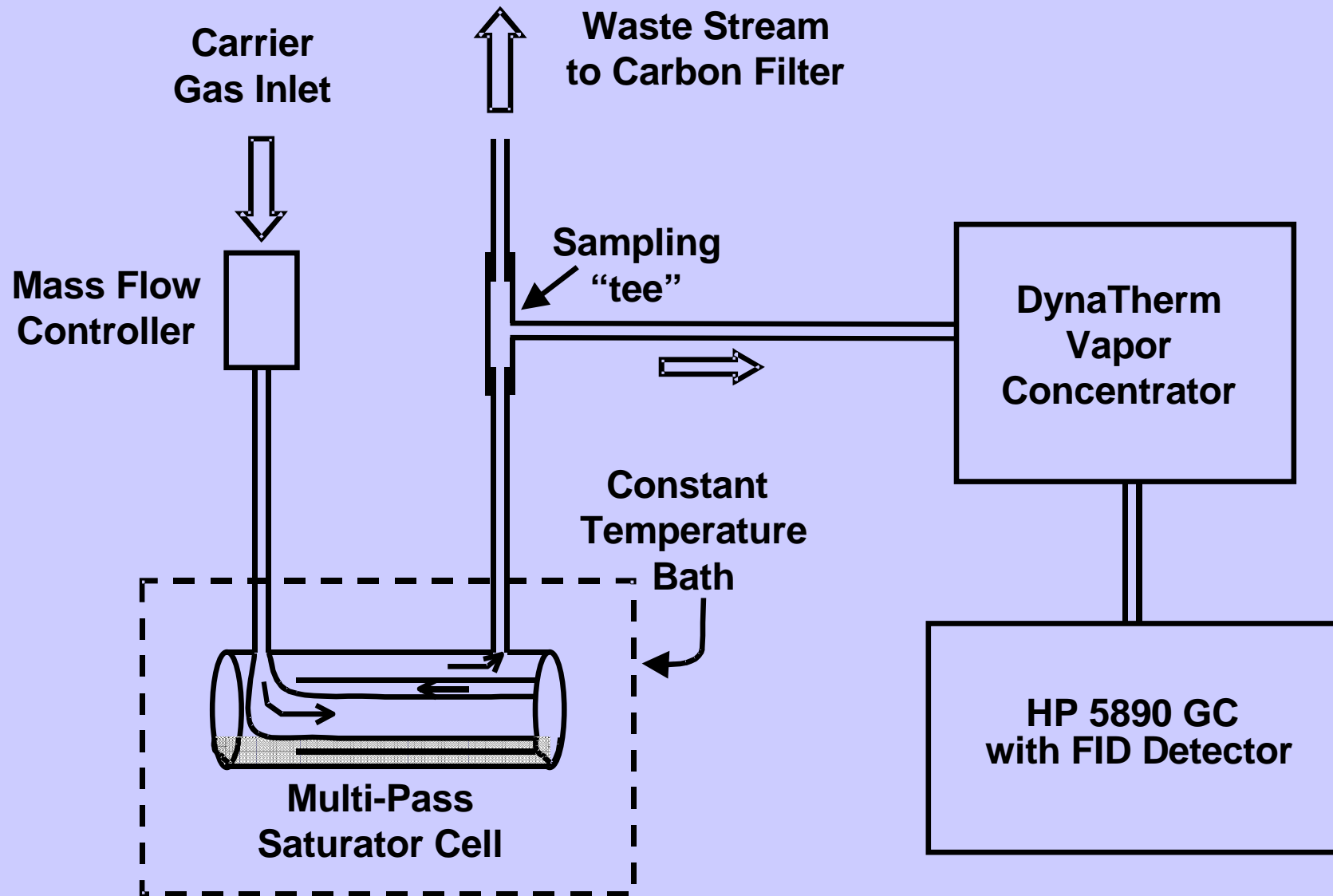
$P_{\text{HD}}$  = partial pressure of saturated HD

$P_{\text{total}}$  = total system pressure ( $P_{\text{HD}} + P_{\text{carrier}}$ )

$n_{\text{HD}}$  = moles HD

$n_{\text{carrier}}$  = moles carrier gas (dry air)

# Experimental Set-Up



# Parameters

## **Controlled**

**Bath Temperature**

**Saturator Flow Rate**

**Sample Collection Time**

**Sample Flow Rate**

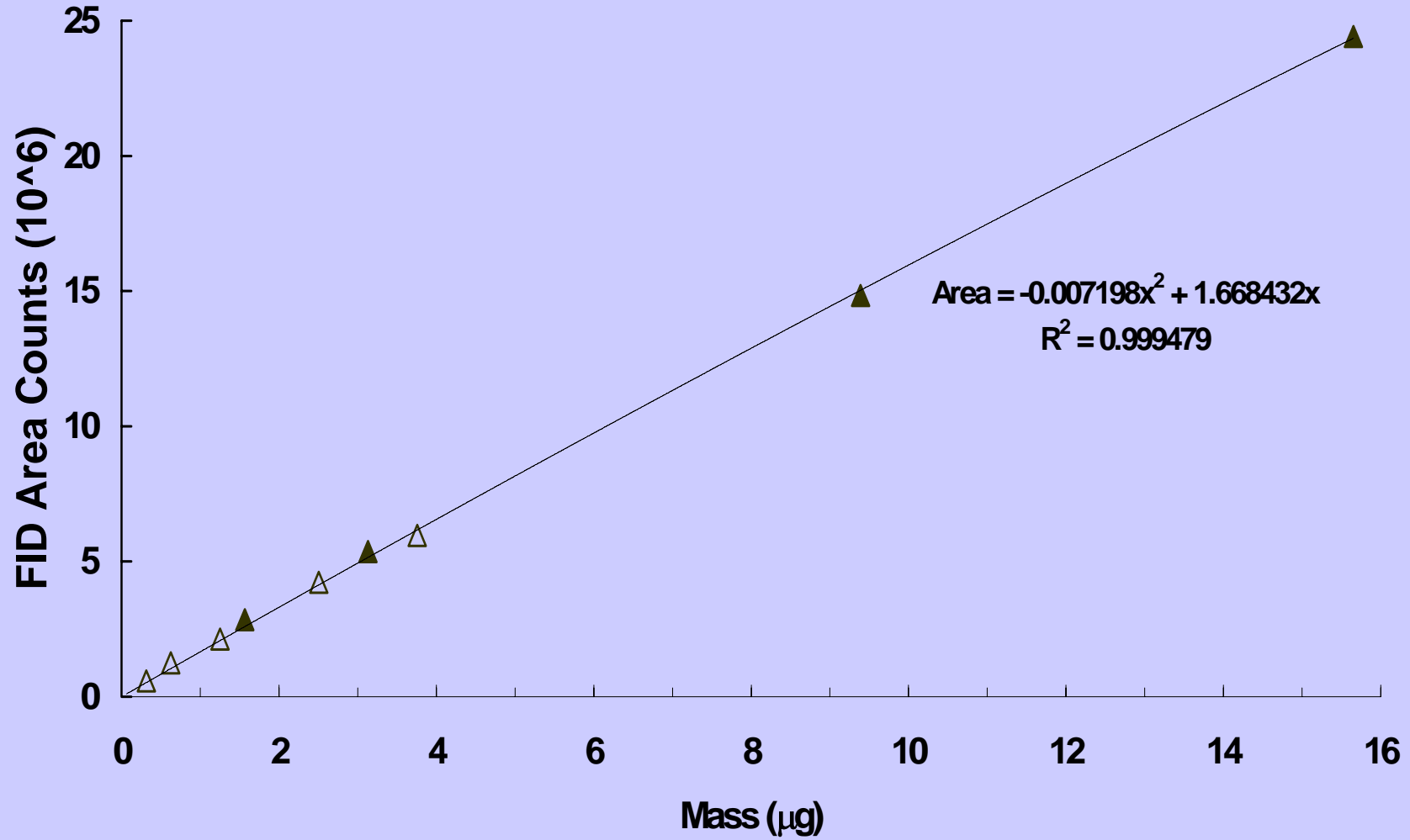
## **Measured**

**Ambient Pressure**

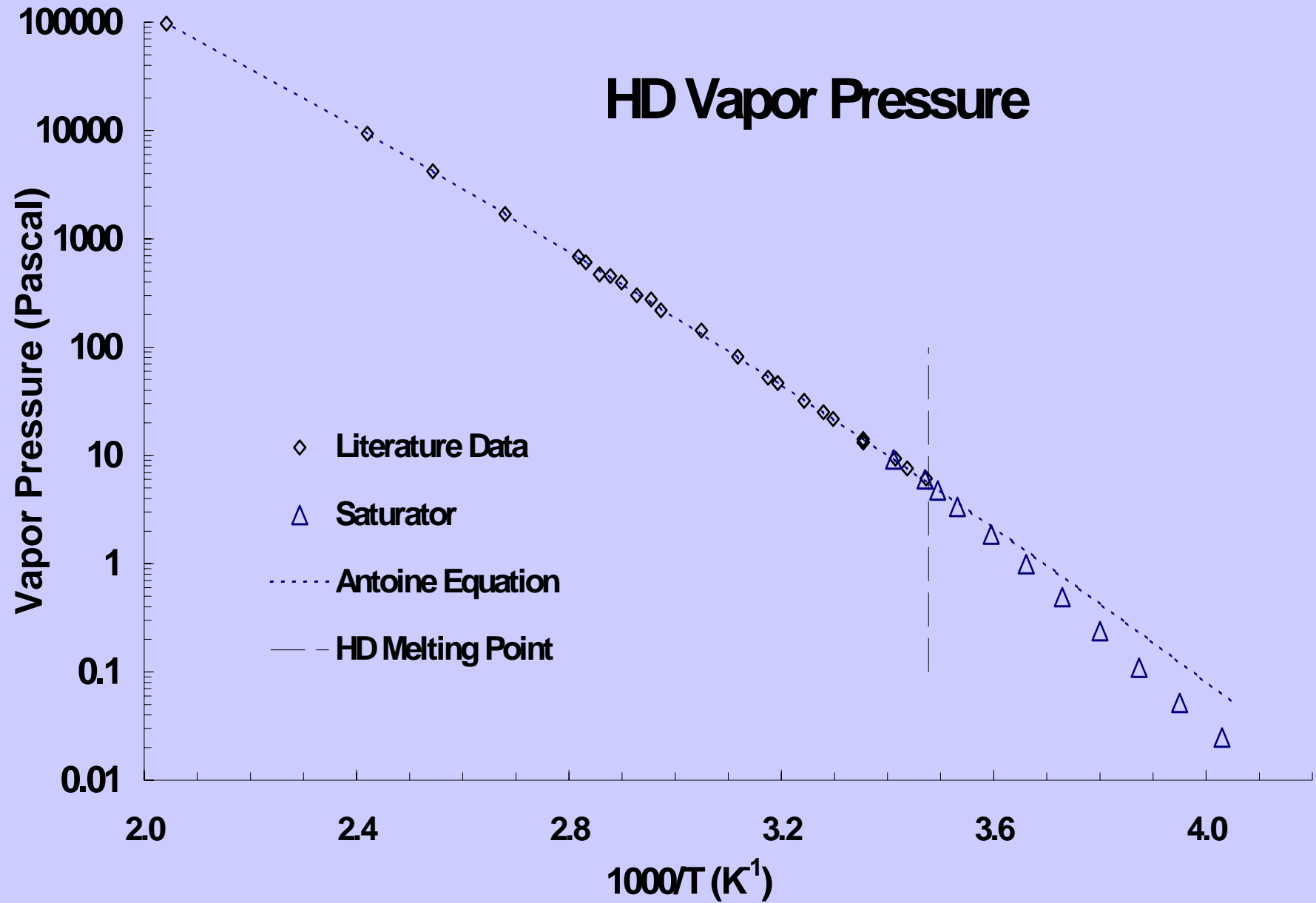
**GC Area**

**GC Response Factor**

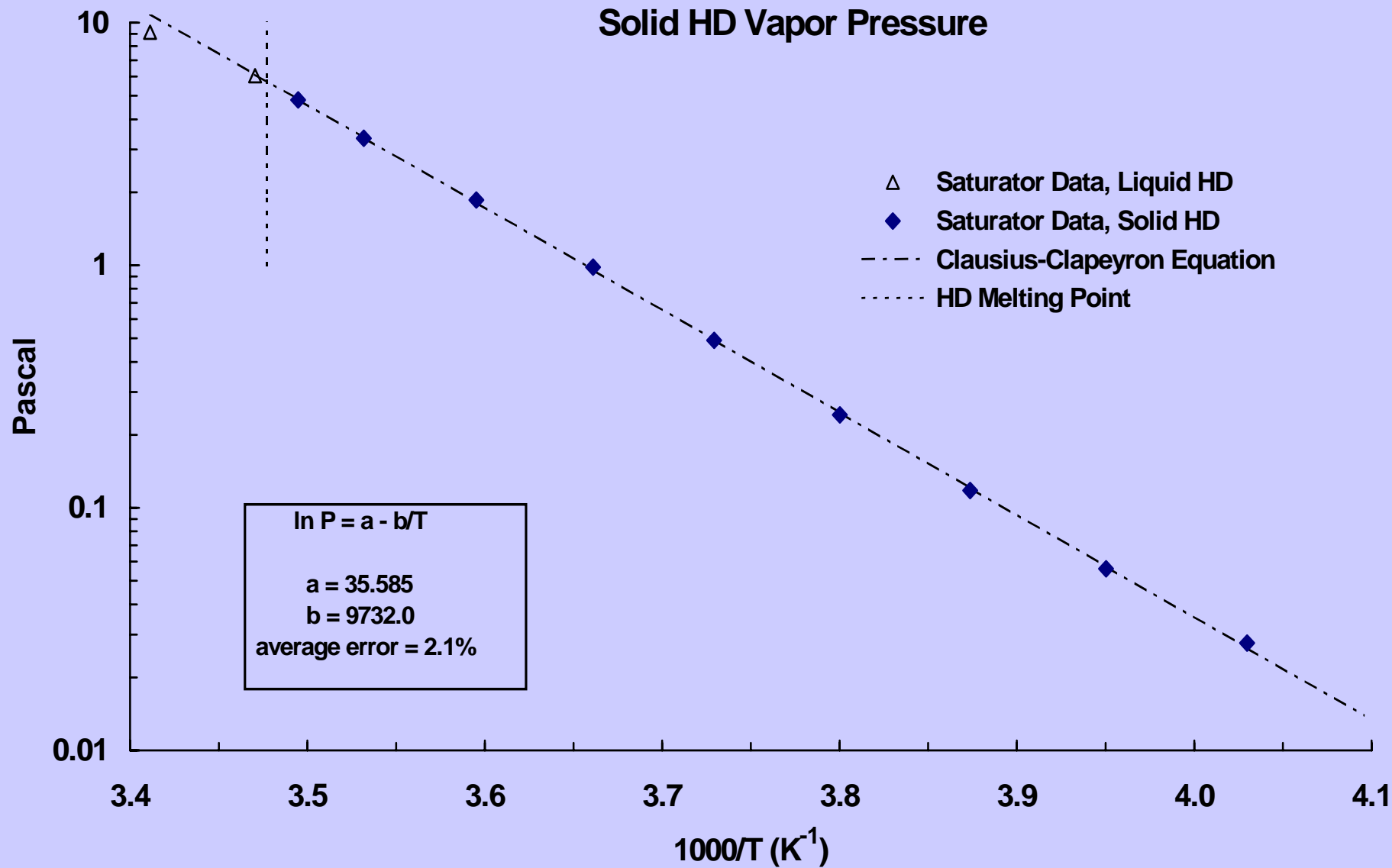
# HD CALIBRATION



# HD Vapor Pressure



# Solid HD Vapor Pressure



## Measured Data

Temperature (°C)	Vapor Pressure (Pa)		Difference (%)
	Measured	Calculated	
20.0*	9.12	9.16	0.43
15.0*	6.04	5.82	3.48
13.0	4.81	4.83	0.47
10.0	3.34	3.37	0.76
5.0	1.86	1.82	2.27
0.0	0.984	0.957	2.70
-5.0	0.490	0.493	0.43
-10.0	0.241	0.247	2.40
-15.0	0.118	0.121	2.56
-20.0	0.0560	0.0573	2.42
-25.0	0.0277	0.0264	4.59

\* Denotes Liquid HD

## Heat of Vaporization Calculated from Antoine Constants

t (°C)	T (°K)	$\Delta H_{\text{vap}}$ (kcal/mole)
14.45	287.61	19.34
14.45	287.61	15.30
20	293.16	15.12
25	298.16	14.96
30	303.16	14.82
35	308.16	14.68
40	313.16	14.55
45	318.16	14.42
50	323.16	14.30
55	328.16	14.18
60	333.16	14.07
65	338.16	13.96

Solid HD

Liquid HD

$\Delta H_{\text{fusion}}$  inferred from this table is 4.0 kcal/mole, in good agreement with the estimate of 4.2 kcal/mole by Buckles (CRLR 542 Special Report, July 1956).

## **Conclusions**

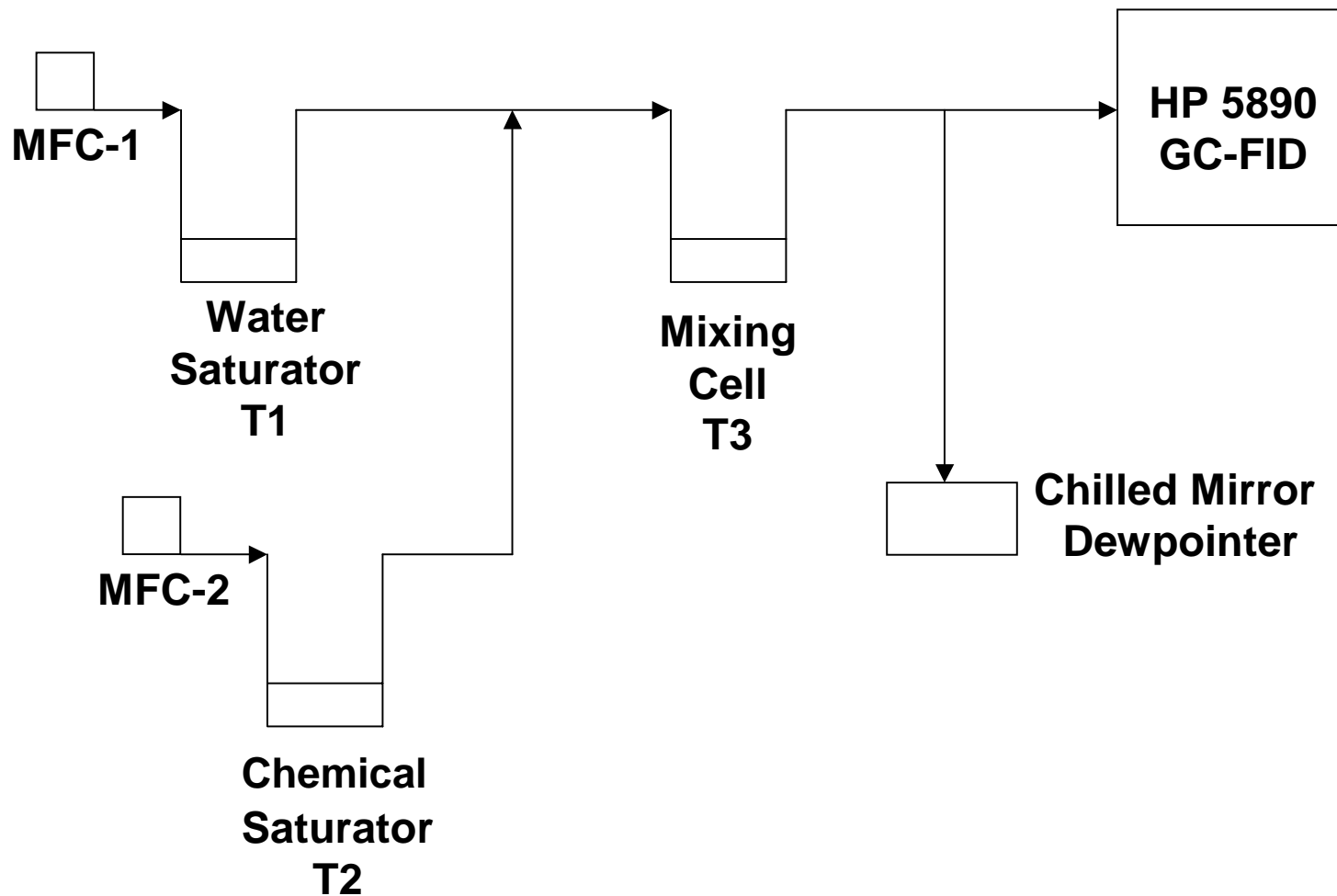
**Solid HD vapor pressure measured for first time**

**Heat of fusion inferred from liquid and solid Antoine equations is 4.0 kcal/mole, in good agreement with the previous estimate**

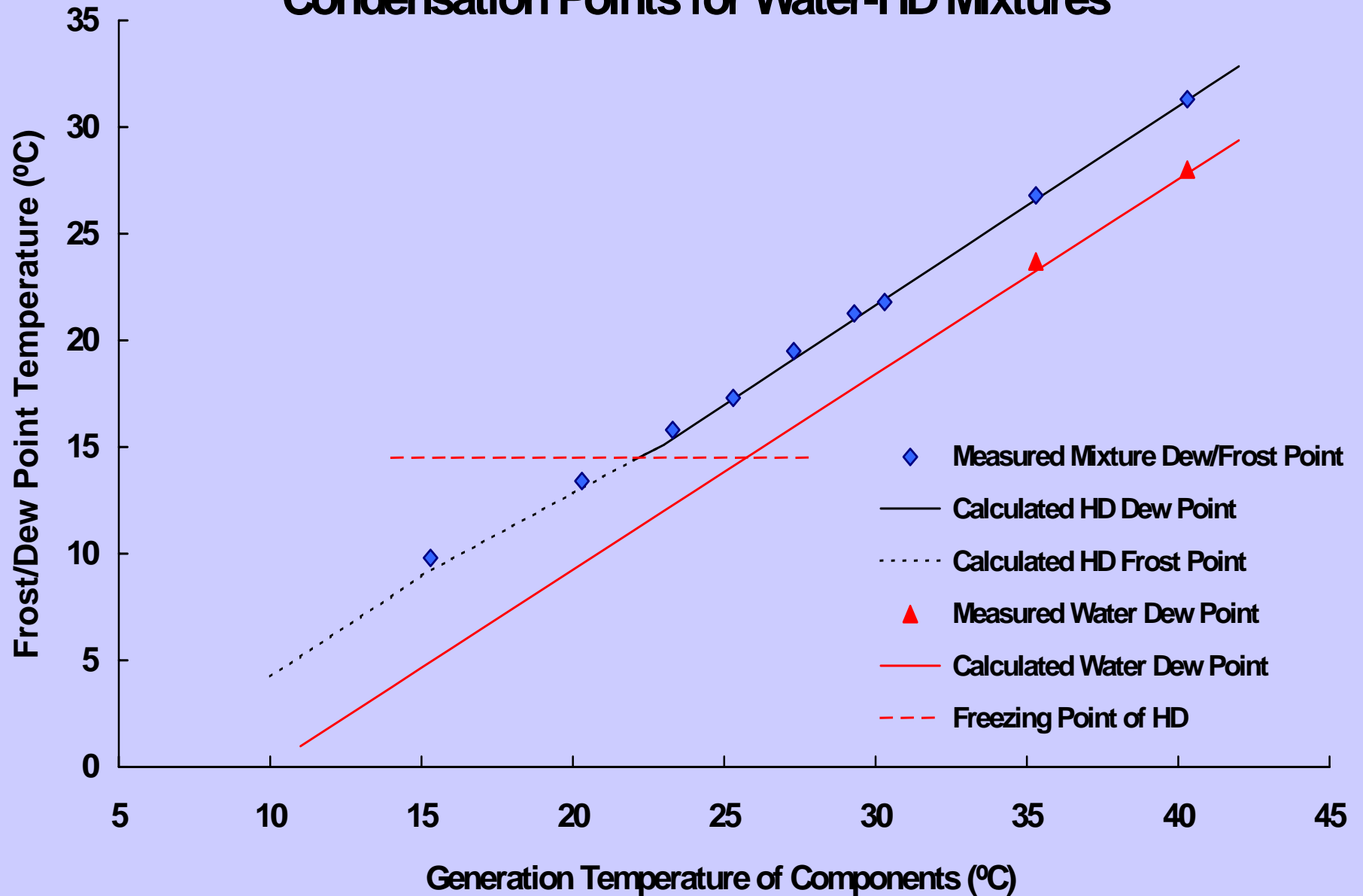
**This work was performed as prologue to measurement of the ambient volatility of HD**

# Ambient Volatility of HD

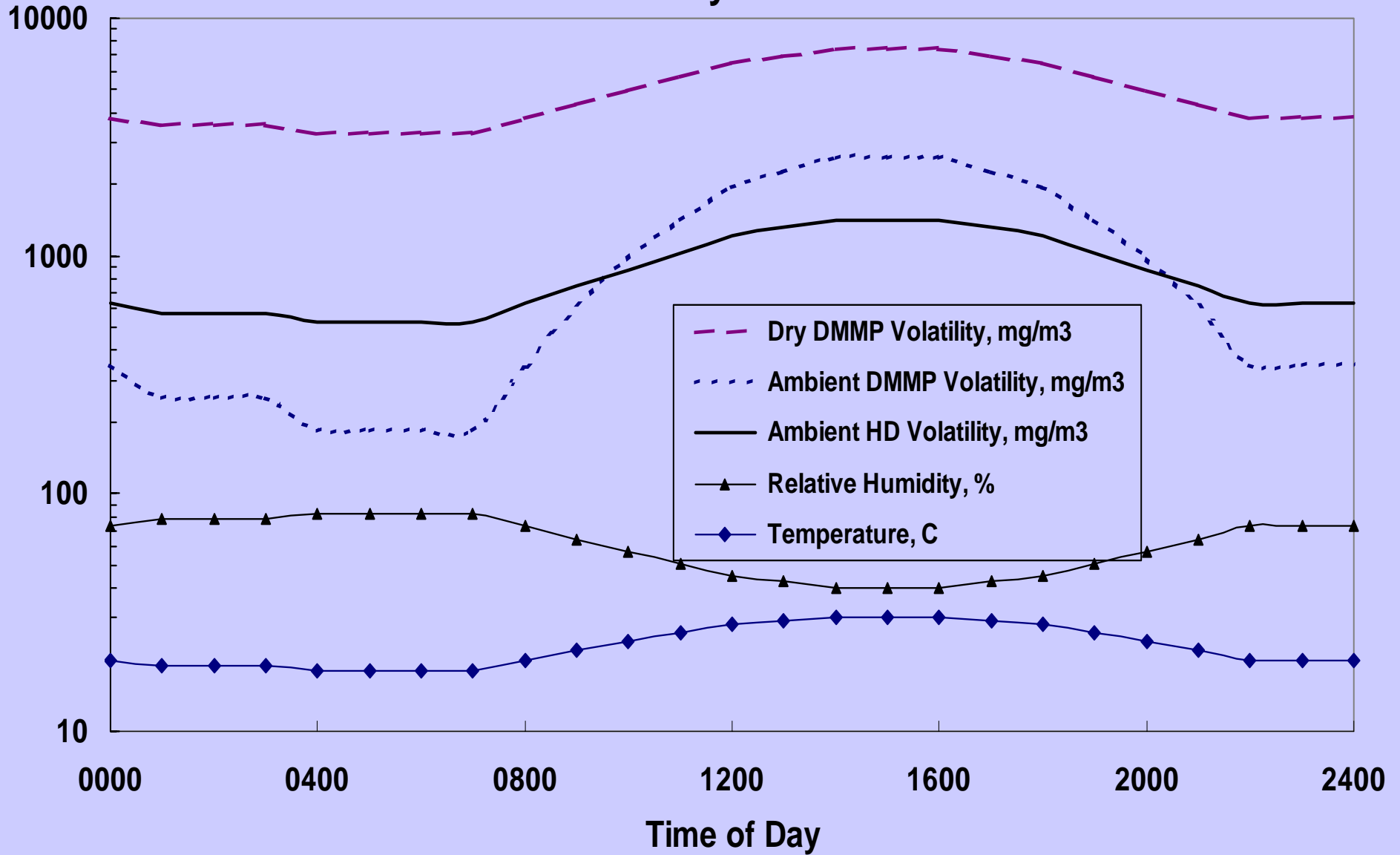
# Experimental Schematic



## Condensation Points for Water-HD Mixtures



# Diurnal Volatility of DMMP and HD



## **Preliminary Observations Concerning the Ambient Volatility of HD**

**In contrast to DMMP, the volatility of HD does not appear to be suppressed by presence of water vapor**

**DMMP has been shown earlier to be suppressed beyond what would be expected based on Raoult's Law alone by as much as 40%**

**Projected conditions could result in volatility reversal, i.e., HD volatility may be expected to be higher than DMMP at high-RH conditions**

**Agent Fate test matrices developed to investigate effect of humidity on HD evaporation rate may be subject to significant simplification since current data suggest minimal effect on HD evaporation rate as a result of high-humidity conditions**