

# Evaluation of Chemical Sensor Technologies for Air Filter Lifetime and Performance Monitoring

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# OBJECTIVES & PAYOFFS

## Objectives

- Evaluate sensor technologies for implementation in a residual life indicator for carbon air filters
- Alert users when filter needs replacing

## Payoffs

- Gas sensors required by new DoD systems
  - ▶ JSGPM
  - ▶ JTCOPS
  - ▶ Air Monitor for Scuba Tank
  - ▶ Automobile/HVAC Dual Use
- Condition based monitoring provides
  - ▶ Increased User Confidence
  - ▶ Optimum Frequency of Filter Replacement

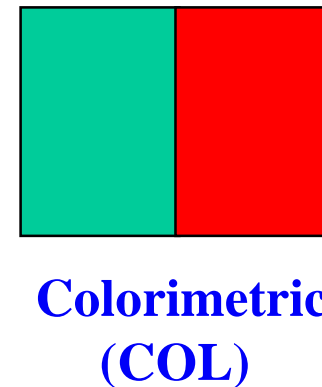
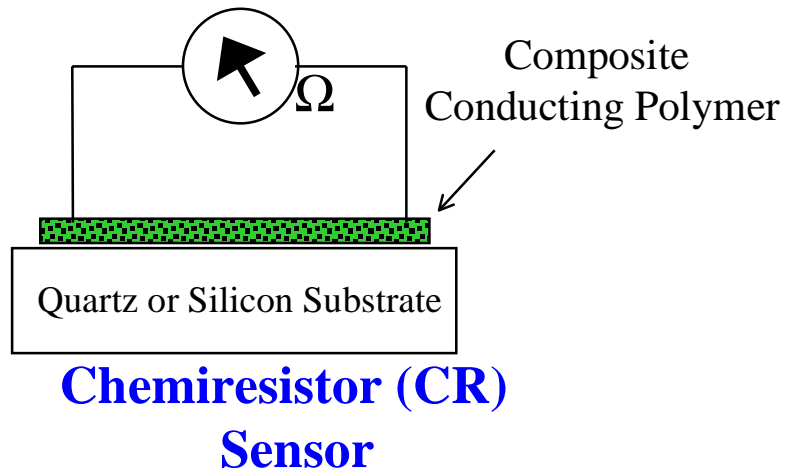
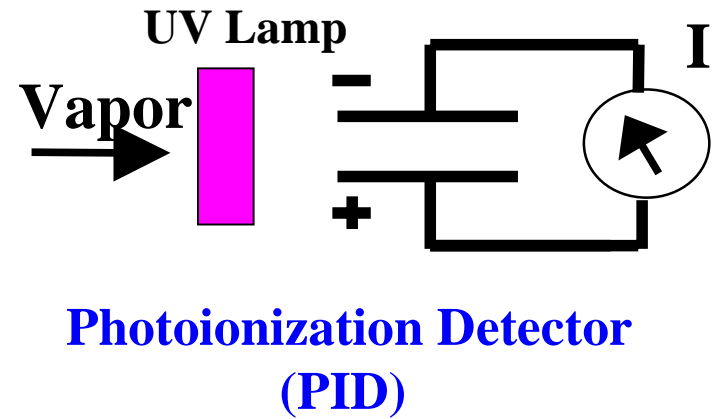
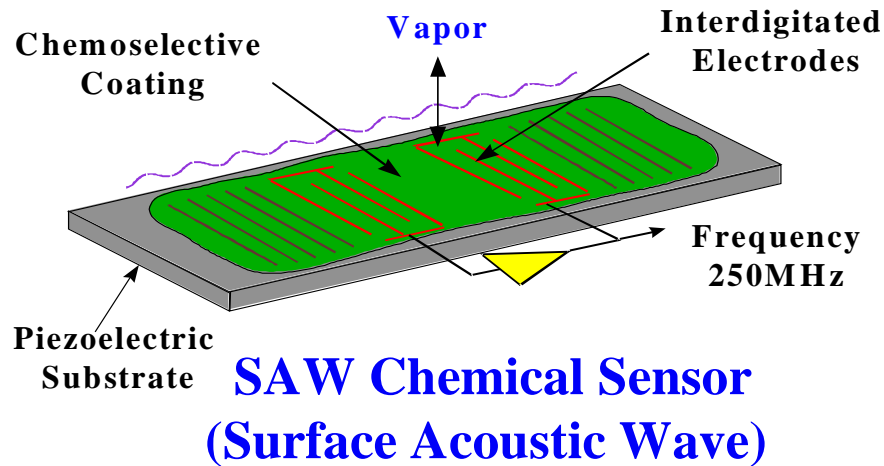
# SENSOR REQUIREMENTS

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- ➔ **Sensor must be able to withstand harsh filter environment**
- ➔ **Sensor must be able to respond to a wide variety of agents and toxic industrial chemicals (TIC's)**
- ➔ **Sensor must not give false alarm due to changes in temperature, RH, or flow rate**
- ➔ **Sensor must not interfere significantly with filter performance**
- ➔ **Extended shelf and operational life is desirable**
- ➔ **Low cost and reusability are desirable technology attributes**
- ➔ **Low milliwatt or zero power requirements are desirable**

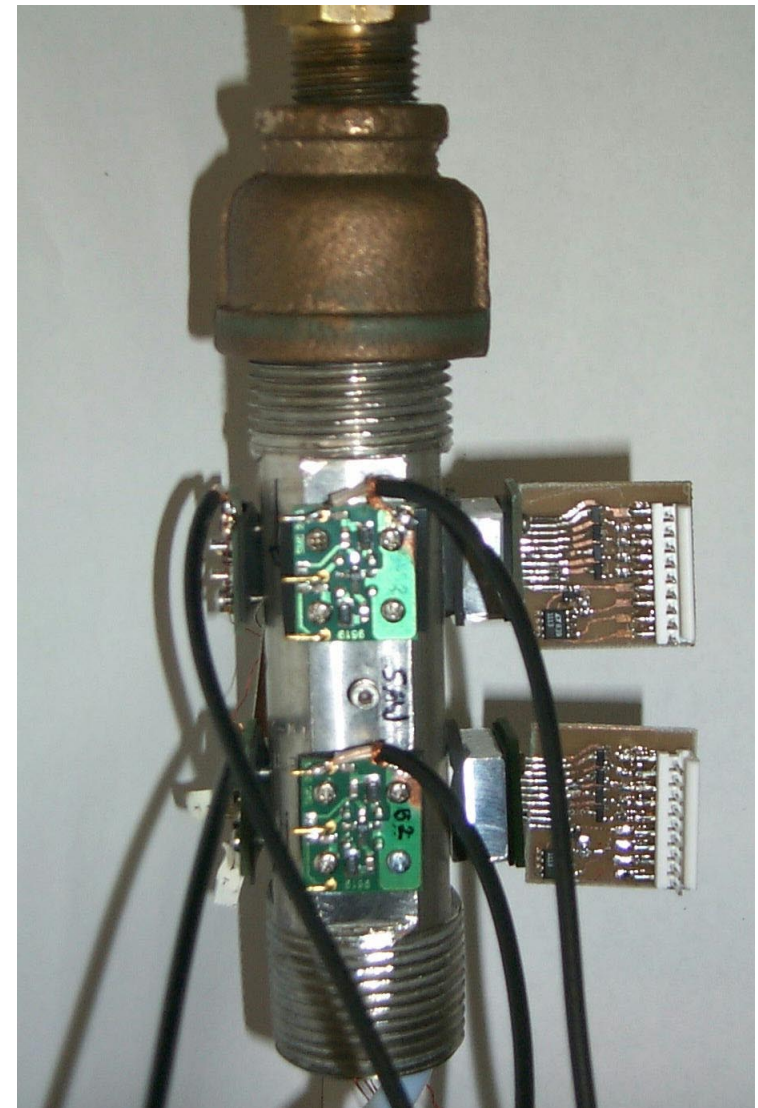
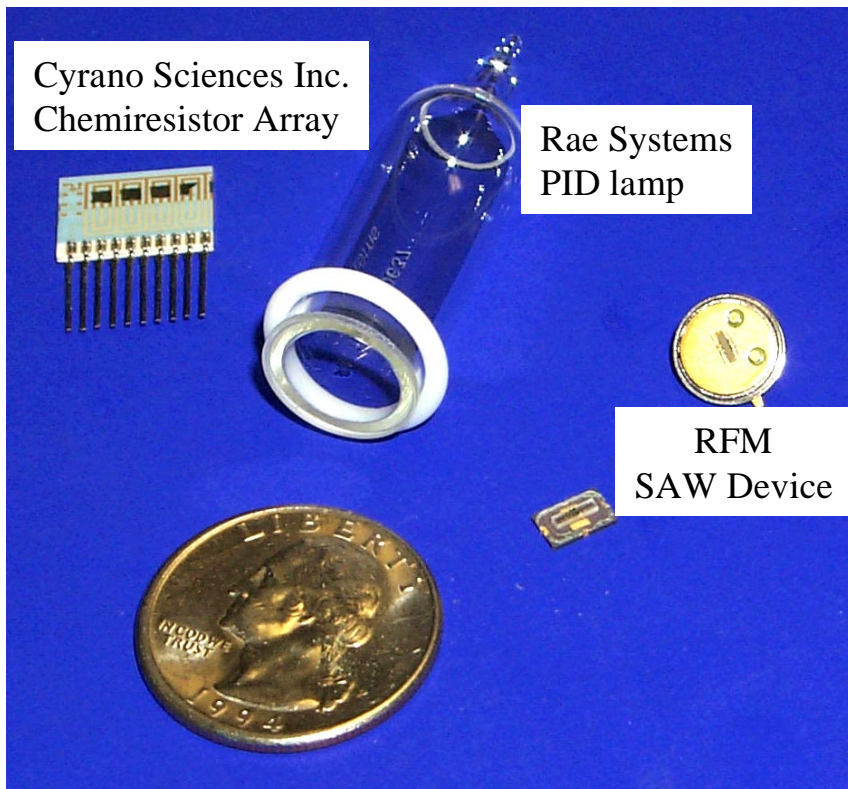
# CHEMICAL SENSOR TRANSDUCERS



# TECHNOLOGY COMPARISON

Variable Parameter	SAW		CR		PID	Colorimetric	
Sensitivity to Medium MW Gases	High		High		High	High	
Sensitivity to permanent gases	No		No		High	Yes	No
Sensitivity to Wide Range of Vapors/Gases	Yes		Yes		Yes	No	Yes
Performance to untested Vapor	Yes		Yes		Yes	No	Yes
Requires Large Array	No		No		No	Yes	No
Time to Initial Gas Signal Response	Fast		Fast		Fast	Fast	
Time to Equilibrated Gas Signal Response	Fast		Fast		Fast	Slow	
Ability To Quantify Concentration	Yes		Yes		Yes	Yes	
Ability To Provide Alarm Confidence	High		High		High	High	
Dynamic Range	Large		Large		Small	Small	
Signal Temperature Sensitivity	High	Low	Low		High	Low	
Signal Humidity Sensitivity	Moderate	Low	Moderate		Low	Low	
Signal Pressure Sensitivity	Low		Low		Low	Low	
System Longevity To Humidity Exposure	High		High		High	High	
Shelf Life	Long		Long		Moderate	Long	
Operational Longevity	Long		Long		Moderate	Moderate	
Form Factor	Small		Small		Moderate	Small	
Component Cost	Cheap		Cheap		Moderate	Cheap	
Computational Requirements	Low		Low		Low	Low	
Power Requirements	Low		Low		Low	Low	Zero
Consumables	None		None		Yes	Yes	
Reusability	Yes		Yes	Yes	No	No	
Technology Maturity	Long		Mod	Short	Long	Long	Short

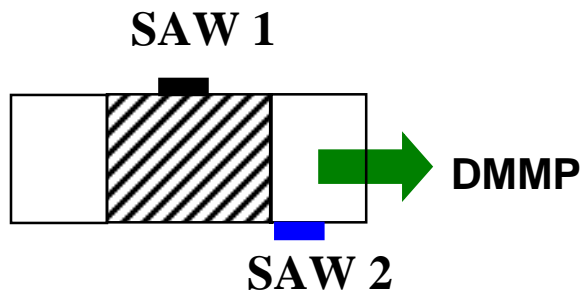
# SIDE-BY-SIDE SENSOR TEST BED



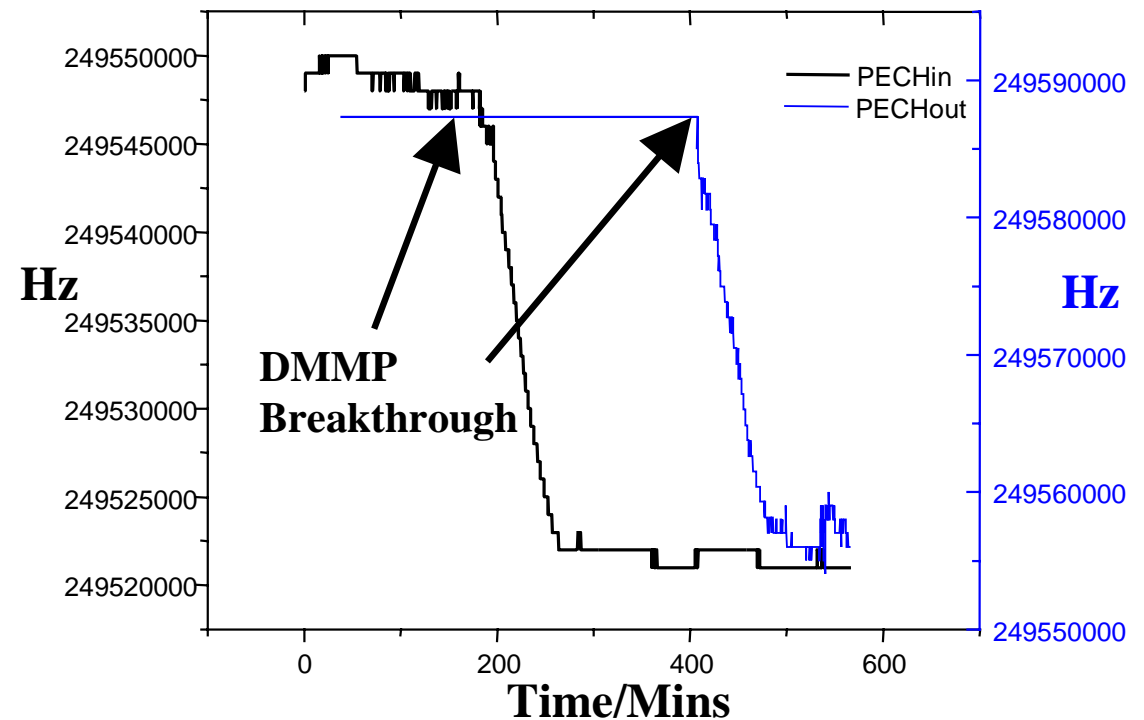
## Side-by-Side Technology Comparison:

- Surface Acoustic Wave (SAW)
- Chemiresistor (CR)
- Photoionization Detector (PID)
- Colorimetric (COL)

# SAW EVALUATION at RH=60% with DMMP CHALLENGE



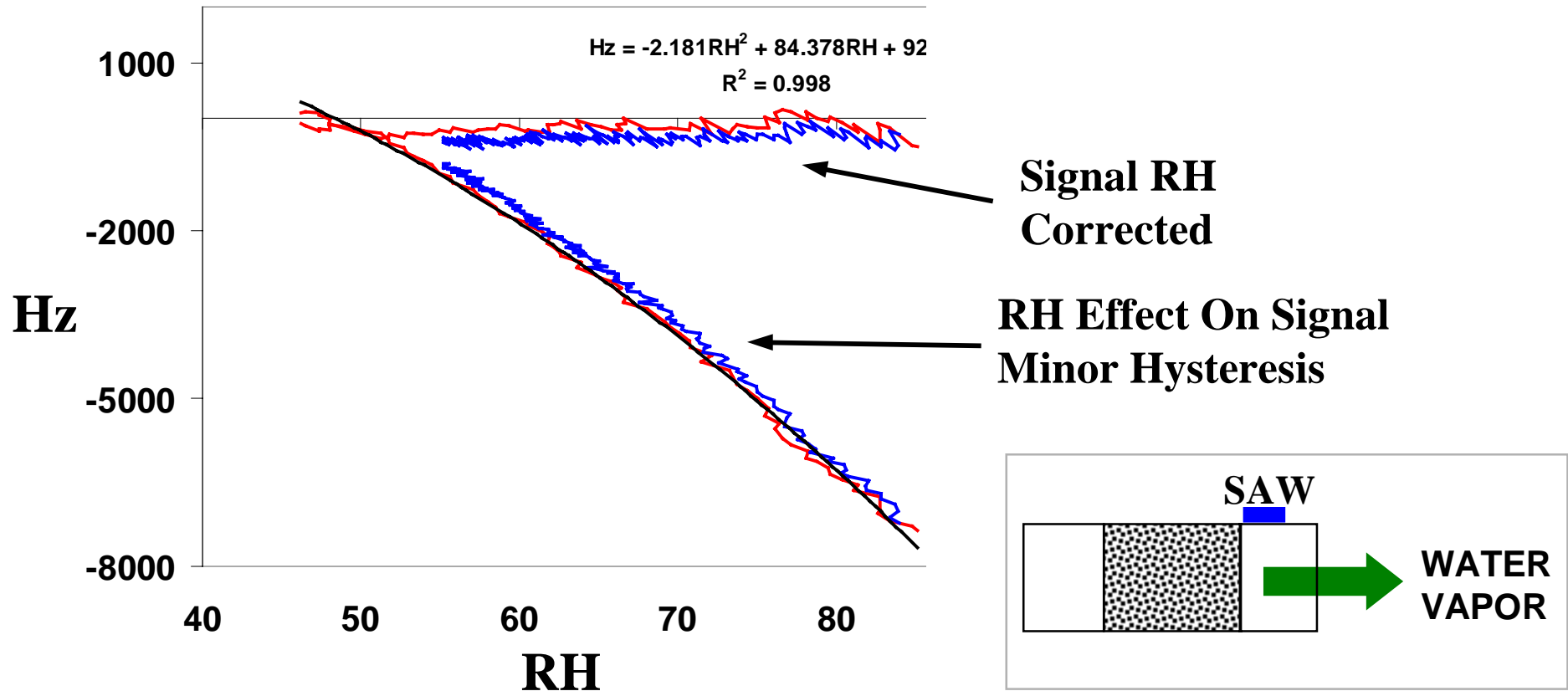
11g BPL Carbon  
DMMP 1500mg/m<sup>3</sup>  
5cm Bed Depth  
2.5cm and 5cm SAW location  
25°C, 60% RH



**Sensors Incorporated in Filter Side-Wall or end of bed Provide:**

- ▶ Useful Information Without Signal/Power Cabling Through the Bed
- ▶ A Simpler Manufacturing Implementation

# SAW HUMIDITY RESPONSE

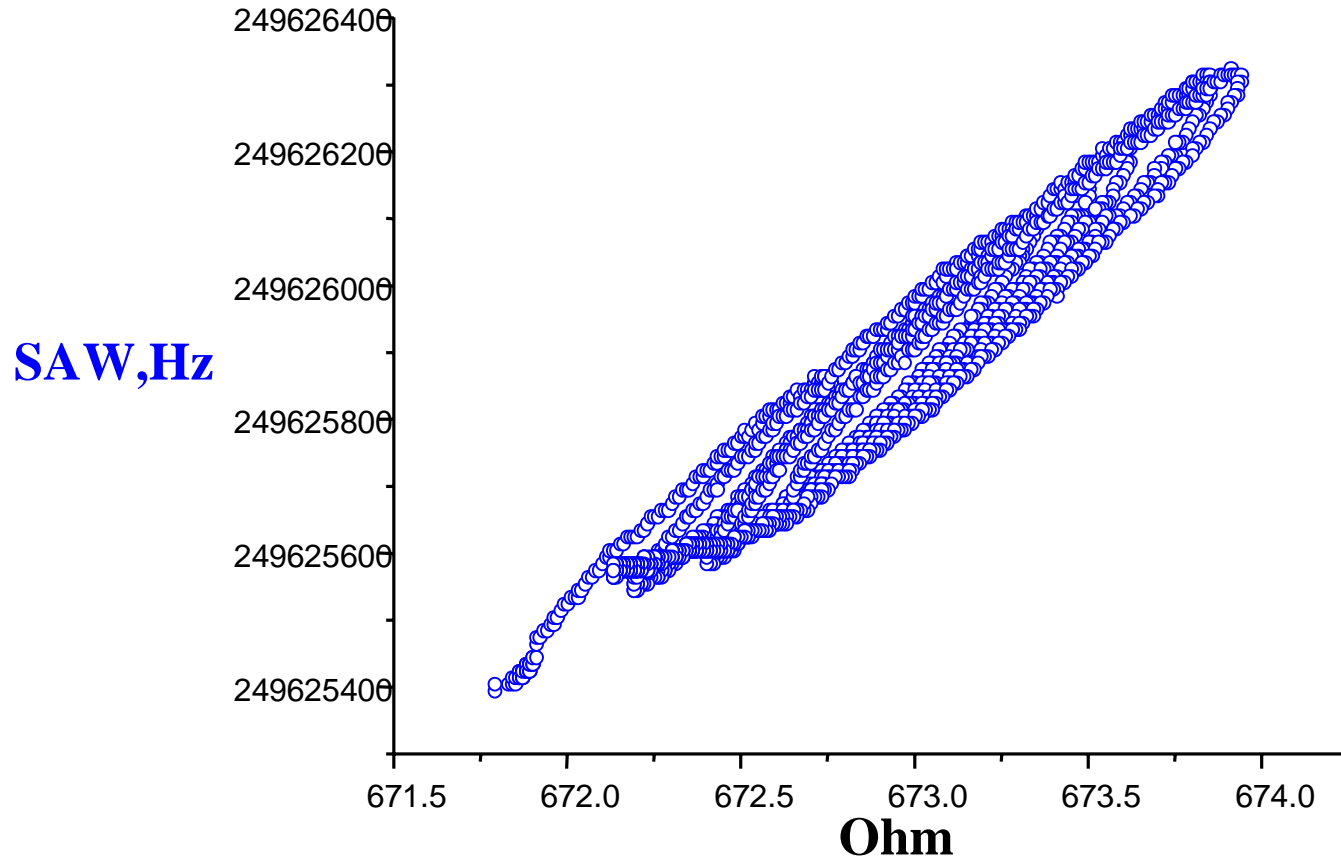


**Signal Response of the Sensor Can Be Corrected for RH & T Effects**



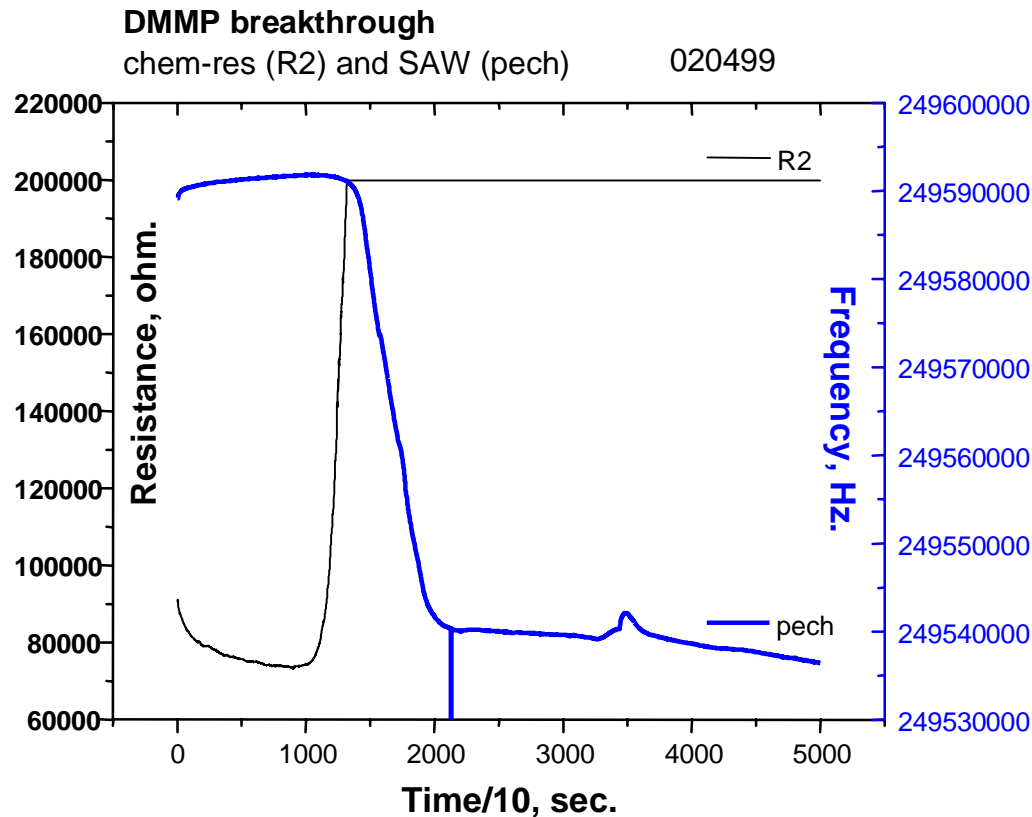
# TEMPERATURE EFFECT on SAW

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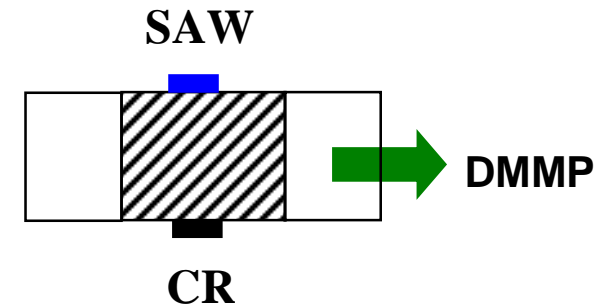
**Temperature Effect on Signal is Predictable  
with Minor Hysteresis Effects**

# CHEMIRESISTOR & SAW RESULTS



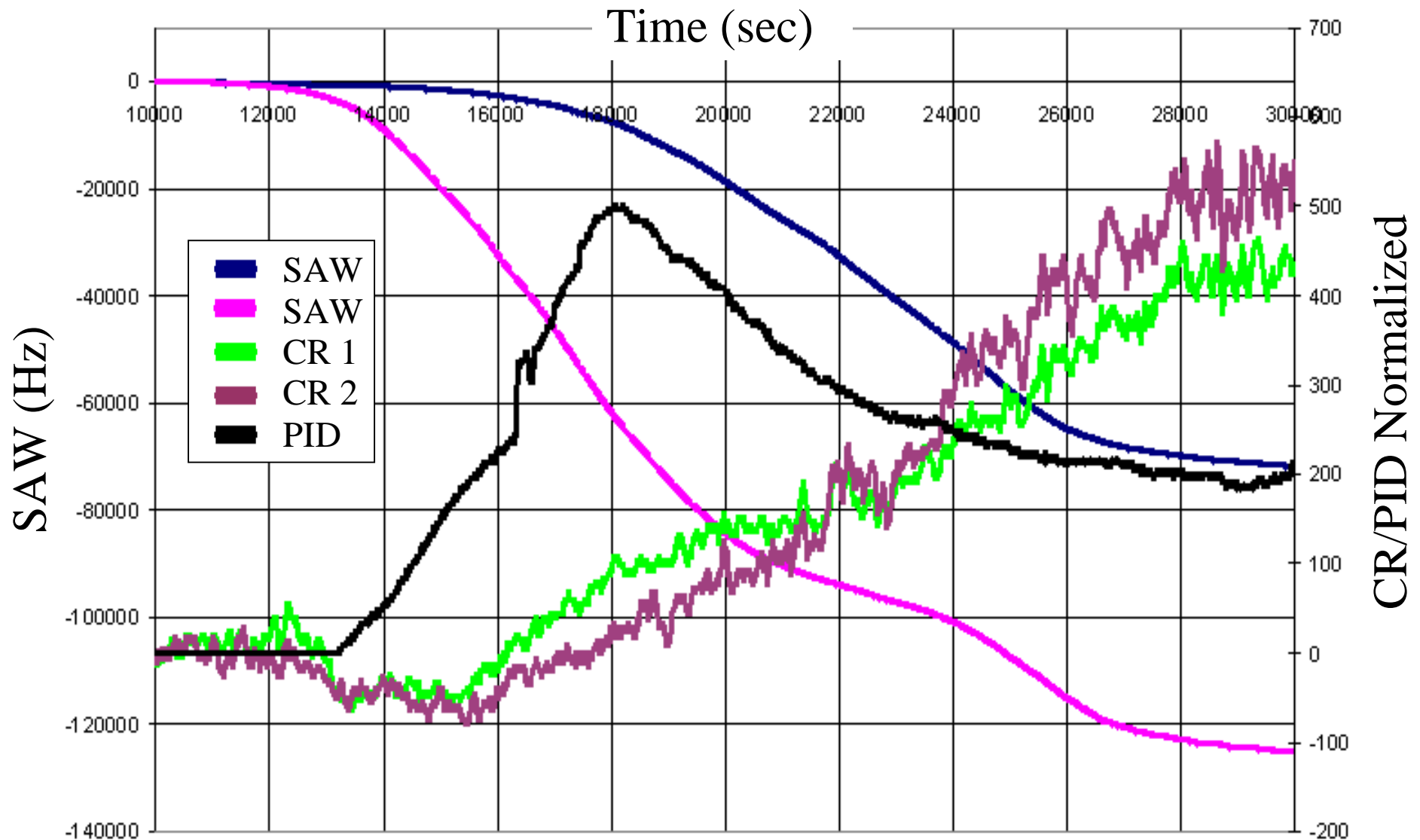
Frequency (SAW) and resistance (Chemiresistor) change upon DMMP breakthrough.

DMMP concentration =  $1500 \text{ mg/m}^3$ . Flow rate = 10 lpm.  $T = 21^\circ\text{C}$ , %RH = 25%. Sensors position = middle of 5 cm bed (2.5 cm from the bottom), flush mounted. Breakthrough time = 10000 sec.



**Both SAW and Chemiresistor Sensors  
Provide Similar Results**

# RESULTS: SAMPLE SIDE-BY-SIDE DATA WITH DMMP CHALLENGE



# SUMMARY

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- ➔ **SAW & Chemiresistor sensors can monitor the entire breakthrough process and from low to high humidities**
- ➔ **Humidity and temperature signal effects can be safely factored out**
- ➔ **Placement of sensors parallel and flush to the wall of filter or at end of filter provides effective results and simple implementation**
- ➔ **Operation of SAW sensors is effective for ColPro and gas mask filter beds**
- ➔ **From preliminary data, CR & PID sensors provide similar information as SAW sensors**