

## Real-Time Transformer Oil Polychlorinated Biphenyl Sensor

- An innovative sensor technology for PCB detection is under development at Eltron Research & Development.
- Sensor provides quantitative measurement of PCB's in transformer oil.
- Small, field-portable system provides real-time analysis of transformer oil.
- Simple to operate, no sample handling necessary.
- Low cost per analysis.

### Problem Addressed

Polychlorinated biphenyls (PCBs) remain a significant environmental threat even though manufacturing of PCBs was discontinued in the U.S. 30 years ago. PCBs (manufactured under the name Aroclor) are toxic and suspected to be carcinogenic to humans and are therefore carefully monitored. Due to the chemical and thermal stability of PCBs in the environment and the continued use of transformers (>30 year lifetimes) that contained these chemicals, specific regulations are in place requiring the annual quantification of PCBs in *all* transformer oil, old and new. The Toxic Substance Control Act has mandated that the concentration of PCBs in transformer oil be less than 50 parts per million to be considered PCB-free.

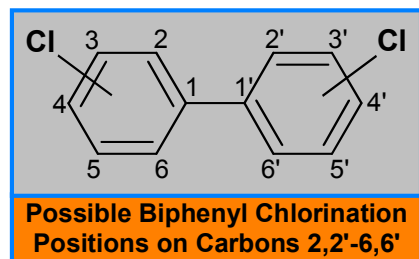


Detection and proper disposal of PCB's is a global problem. Thirty-five million oil-filled transformers are in service that may require on or off-site analysis for PCB's. EPA desires a sensor that can be used *in-situ* for real-time determination of PCB concentration in transformer oil.

### Current Solutions

There are only two options available for PCB analysis, qualitative on-site analysis or off-site analytical lab services based on ASTM or EPA SW-846 methods. Both require the removal and handling of transformer oil from its reservoir. On-site analysis is currently performed using disposable field kits that only indicate a PCB concentration range: less than 50 ppm (PCB-free), 50-500 ppm (PCB-contaminated), or >500 ppm (PCB-containing). Field test kits (Dexsil<sup>®</sup>) cost \$4-6 per sample, require 15-20 minutes per test, but cannot distinguish between different Aroclors, which have different levels of toxicity. Generated hazardous waste must also be properly disposed of. Therefore field kits are usually considered only a screening tool. Quantifying PCBs is extremely difficult without separating them from the parent oil as is done at an analytical lab.

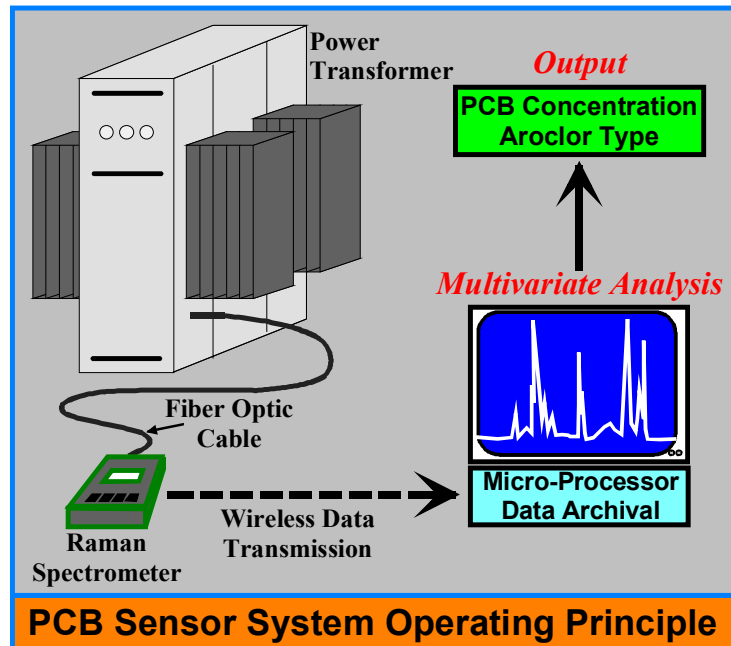
Analytical laboratories provide quantitative measurement of PCB concentration and identification of Aroclor type present (toxicity depends on Aroclor type) using gas chromatography. The cost of analysis is on the order of \$80-120 per sample with at least a one day turnaround. However, to provide this service, contaminated transformer oil must be removed and transported to the laboratory, increasing the possibility of environmental contamination or personnel



exposure. Laboratory determination of PCB concentration is time consuming and represents a significant financial obligation given the sheer number of oil containing transformers in service or being retired across the U.S.

## Eltron's Approach

A convenient, hand held, field-portable system for identifying and quantifying PCB content in transformer oil is being developed at Eltron R&D. This system provides essentially real-time analysis without removing transformer oil from its reservoir using a submersible probe. The analysis cost will be based almost completely on capital investment (e.g., \$2 per sample for 10,000 analyses and \$20K capital) while analysis time is estimated to require 1-5 minutes. The minimal cleaning waste generated from wiping down the probe after use can be immediately categorized for the appropriate disposal method from the analysis results. An additional benefit of this system is that the analysis data is easily archived for documentation and can be reanalyzed if necessary.

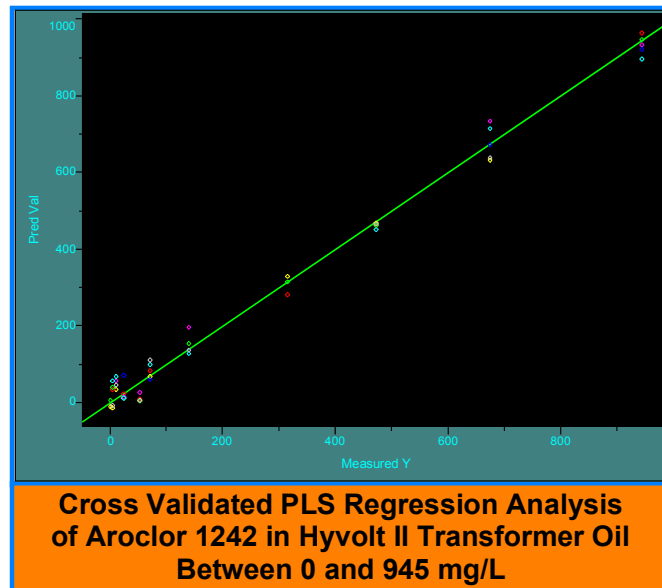
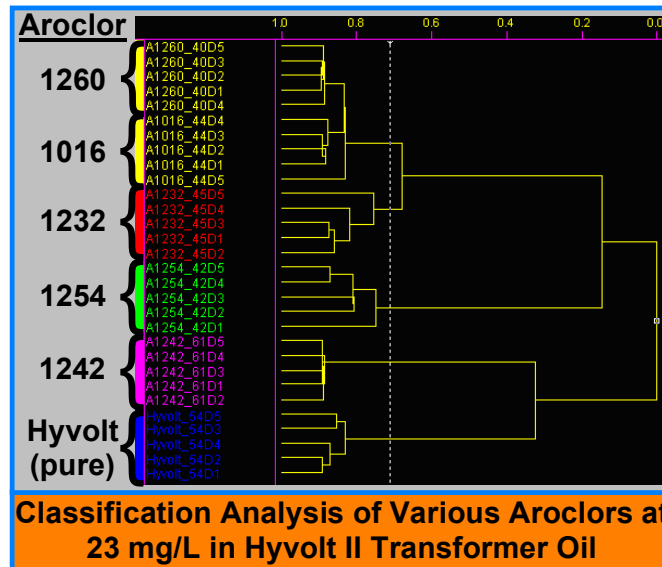


The technological approach is to use a Raman spectroscopy method combined with multivariate data analysis for spectral evaluation. This combined measurement and analysis method provides the sensitivity necessary for quantitative, in-situ analysis. The operating principal for the PCB sensor system is shown schematically in the figure above. Fiber optics and a submersible probe allow the analysis to be made without removal of contaminated samples from transformers.

Raman spectra of the transformer oil are measured using a small portable or hand-held spectrometer with submersible fiber optic probe. The data is stored and analyzed by multivariate analysis automatically by a programmed microprocessor or laptop computer. Results are displayed and recorded with the associated data set.

The multivariate analysis first predicts the type of Aroclor present. This **Classification Analysis** is illustrated below for several transformer oil samples containing low concentrations of PCBs analyzed with Eltron's sensor technology. With the Aroclor type identified, the concentration can then be determined by **Regression Analysis**. A cross validated partial-least-squares analysis is illustrated below for different PCB concentrations measured for a single Aroclor type. The detection limit is presently near 5 mg/L.

This technology is expected to be readily developed into a comprehensive transformer oil health sensor that would not only determine PCB type and concentration, but also viscosity, water content, TAN (total acid number), dielectric constant, and other variables related to transformer oil health.



**Advantages of Eltron's PCB Detection Technology:**

- Real-time identification of Aroclor type and determination of PCB concentration.
- Easy to operate field-portable system.
- Low cost per test (\$2 estimated).
- PCB-contaminated sample handling can be eliminated.
- Detection limit below PCB-free concentration limit (<50 mg/L).
- Technology is applicable to detection of organic contaminants in aqueous and non-aqueous media.

**For more information, please contact:** Carl R. Evenson, Ph.D., Senior Chemist

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