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SPECTROSCOPIC ANALYSIS OF RADON AND THORON WORKING LEVEL: AN OVERVIEW OF THE WLx WORKING LEVEL MEASUREMENT SYSTEM

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ABSTRACT

The purpose of this paper is to address the technology on which the new WLx Working Level Measurement System (WLx) is based. The WLx is a complete system for the accurate and simple measurement of radon and thoron decay products, offering both scientific and professional users the versatility of continuous or grab sampling; it is also an effective tool for distinguishing other alpha emitting isotopes in a sample. The WLx is defined from a design and operations point of view and its performance and capabilities are discussed and demonstrated. The paper also attempts to provide a means whereby the WLx's methodologies and software reporting capabilities can be evaluated.

INTRODUCTION

Exposure to elevated radon (Rn-222), thoron (Th-220), and their decay products in our natural living and occupational environments are believed to elevate the incidence of lung cancer. Surveys performed to investigate the impact of indoor radon concentration conclude that radon is the major contributor of radiation exposure to the general public. There is limited survey data available on the effect of thoron concentration. Studies suggest that the thoron progeny can sometimes be an important contributor to total radon concentrations, and thus contributing an effective dose, comparable to that of radon.

Concerns over the potential health effects of inhaled radon and thoron decay products prompted the development of an advanced working level measurement system. The WLx, developed and manufactured by Pylon Electronics Inc., detects, measures, and discriminates radon and thoron decay products using an alpha spectroscopic analysis to provide a detailed study of the various radioisotopes in a sample.

Radon decay products consist of a series of short lived isotopes emitting alpha, beta, and gamma radiation. Useful alpha emitting isotopes for the determination of working level from the radium decay chain include Po-218(6.00 MeV) and Po-214(7.69 MeV), and for the thoron decay chain include Bi-212(6.04, 6.08 MeV) and Po-212(8.78 MeV). Potential alpha emitters for radon include Po-218, Pb-214, Bi-214, and Po-214 and for thoron include Pb-212, Bi-212, and Po-212.

The working level unit is a measure of the exposure rate to radon and radon decay products and is defined as the unit of measure consisting of any combination of short lived decay products of radon and thoron which will result in the ultimate emission of 1.3×10^5 MeV of alpha energy per litre of air. Cumulative human exposure to radon and thoron decay products is measured in working level months (WLM). The WLM may be given as an exposure to 1 WL for 1 working month (170 hours).

It is hoped that a study of this paper will aid in the technical enrichment of readers and provide a means for evaluating the WLx as a simple and versatile tool for the accurate measurement of radon and thoron decay products and their associated potential health risk.

MATERIALS AND METHODS

Technical Overview

The portable WLx is a fully integrated, compact powerful tool for radon and thoron working level measurements. The WLx operates by drawing air samples through a standard 0.8 µm pore size (25 mm diameter)[1] using an internal servo controlled pump to compensate for filter loading. The programmable air flow is measured via an air mass flow sensor and converted to a volumetric air flow by an algorithm, which compensates for the air temperature and barometric pressure. The radon and thoron progeny deposited on the filter decay and emit alpha particles which are detected by a silicon semiconductor particle detector. Particles that penetrate the depletion window of the detector cause a current flow that is proportional to the alpha energy. This current is processed by circuitry which performs integration and pulse shaping. The shaped pulse is then fed to a multichannel analyzer for further processing. (Refer to Figures 1 and 2 for Photograph and Block Diagram of WLx).

The multichannel analyzer identifies a valid pulse by comparing the incoming signal to a low level detection threshold. As a valid pulse is detected, it triggers a sample and hold circuit that stores the peak value of the pulse. An analog to digital converter then discriminates the various pulses into 256 energy channels.

The PC software provides the operator with various file management tools and also allows the uploaded data to be displayed and manipulated on a typical PC. The software also allows the operator to modify various constants and routines in the instrument itself. Data may be presented in various forms such as a graph, raw data print out, or as a spectrum. (Refer to Figure 3 for sample of spectrum showing energy peaks). A Detachable printer is also included with the system.

Various pre-set continuous or quasi-grab analysis techniques enable the determination of the WL. Analysis techniques include Continuous and various versions of the Alpha Spec, Kuznetz and Tsivoglou methodologies. These methods of measurement may be modified via the field unit keyboard or PC software. Each measurement value is supported by an approximate relative uncertainty based on some system inherent uncertainty (flowrate, efficiency, overlap factors and K factors, as well as the true count and background rates statistic uncertainty).

The **Continuous** method is a flexible method which measures both radon and thoron, having both the pump and the counter in continuous operation. Parameters such as flowrate, loop and interval length can be edited. The **Alpha Spec** method is a flexible routine used to measure high or low radon and thoron working levels. The **Tsivoglou** method only determines radon WL following a series of wait and count intervals. Even though it only measures for radon, it also discriminates against thoron. The modified **Kuznetz** method is used to calculate both radon and thoron WL following 3 fixed counting phases. The **Background** method is also flexible. Separate background rates are determined for each region of interest and will be automatically saved and used in the WL calculations. These values can also be directly edited.

User programmable parameters include: 1) Regions of Interest (ROI) which allow the discrimination of the radon and thoron progeny. 2) Method Events such as start, stop, loop and calculate commands; an 3) Alarm events which produce an audible tone when the WL exceeds a selected level (a external alarm can also be connected to the unit).

The WLx also features a graphics display that shows the 256 channel wide alpha energy spectrum (at half resolution) during collection. In the spectrum display mode, the monitor displays the maximum channel counts and autoscales the display during the collection process. WLx highlights include:

- a servo controlled pump
- pre-programmed method files with programmable options
- a programmable alarm with external alarm capability
- pulse input design for simultaneous radon and WL measurement

- a multichannel analyzer- AC/battery operation
- temperature and humidity sensors- a detachable printer
- remote operation capability.

Equilibrium ratio, relative uncertainty measurement, and decay product ratio calculations are performed by the internal software. The WLx has the unique capability of simultaneous gas and WL studies when used with the AB-5 Radon Gas instrument[2] to form a complete system.

To prevent tampering a key pad access pass word for factory and user set-up operational factors is used. A locking control arm filter holder design prevents the displacement of the filter during sampling. Decay product ratio calculations serve as an additional indicator of tampering by indicating variations in the decay product ratios as a function of time.

METHODOLOGY

The WLx performance in radon and thoron atmospheres was intercompared against various industry standards at the Environmental Measurement Laboratory (EML, NY), Pylon Electronics Inc. (Ottawa) and the CANMET Laboratory (Elliot Lake).

The EML intercomparison consisted of a WLx operating continuously in a radon atmosphere against an EML WL independent method. A Pylon intercomparison consisted of 4 WLxs, each programmed to perform various methods including Continuous, Alpha Spec and Kuznetz, as well as an AB-5/AEP[3] Detector operating continuously over a 150 hour duration. The CANMET intercomparison studied the response of a WLx utilizing the Alpha Spec and Kuznetz methods in a pure thoron atmosphere against a CANMET independent method. The flow rate for all instruments were preset at 2.0 l/min. for the Grab Sampling method and at 0.5 l/min. for Continuous method.

The resulting radon and thoron WL concentrations were plotted as a function of time and a spectrum of the resulting energy peaks generated (Refer to Figure 4, 5, and 6 for Graphs of EML, Pylon, and CANMET Intercomparison Data.

The decay product ratios were also calculated to determine the potential for plate out and to ensure a normal progeny particulate concentration in the chamber.

RESULTS AND DISCUSSION

The intercomparison results obtained at the EML, CANMET, and Pylon Laboratories show the WLx to be in agreement with experimental values in both low and elevated radon and thoron atmospheres.

The CANMET intercomparison using the Alpha Spec method reported an error in measuring the WL(Th). This error was later determined to be due to misalignment of the energy windows. Additional work is being scheduled with the CANMET Laboratory to repeat the WL(Th) measurements.

Overall, the WLx field evaluation results and user feedback regarding performance, design, methodologies, and applications have been incorporated into production units of the WLx. WLM calculation and Plutonium-239 measurement capabilities are among the envisioned future features of the WLx.

CONCLUSION

The WLx has successfully demonstrated its potential for the accurate and reliable measurement, detection and discrimination of radon and thoron decay products. The WLx is thus a simple and effective tool for assessing the true potential health risk associated with exposure to natural radiation.

ACKNOWLEDGEMENT

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1. Millipore Co., P.O. Box 255, Bedford, MA 01730.

2. Pylon Electronics Inc., AB-5 Radiation Detector and Radon Gas Accessory.

3. Pylon Electronics Inc., AB-5 Radiation Detector and Working Level Accessory.

Figure 1 Photograph of WLx Working Level Measurement System

Figure 2 Block Diagram of WLx Working Level Measurement System

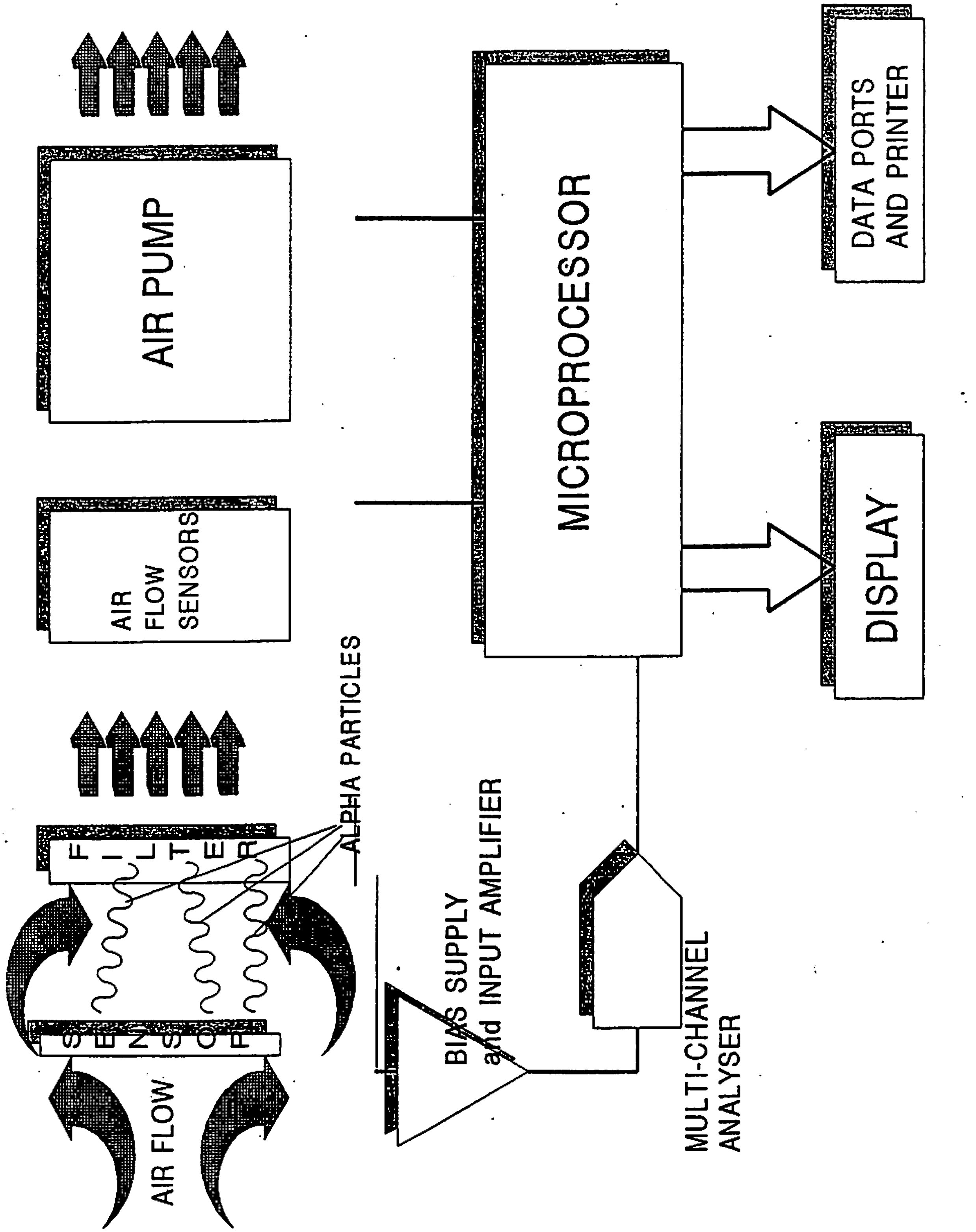

Figure 3 Sample of Spectrum

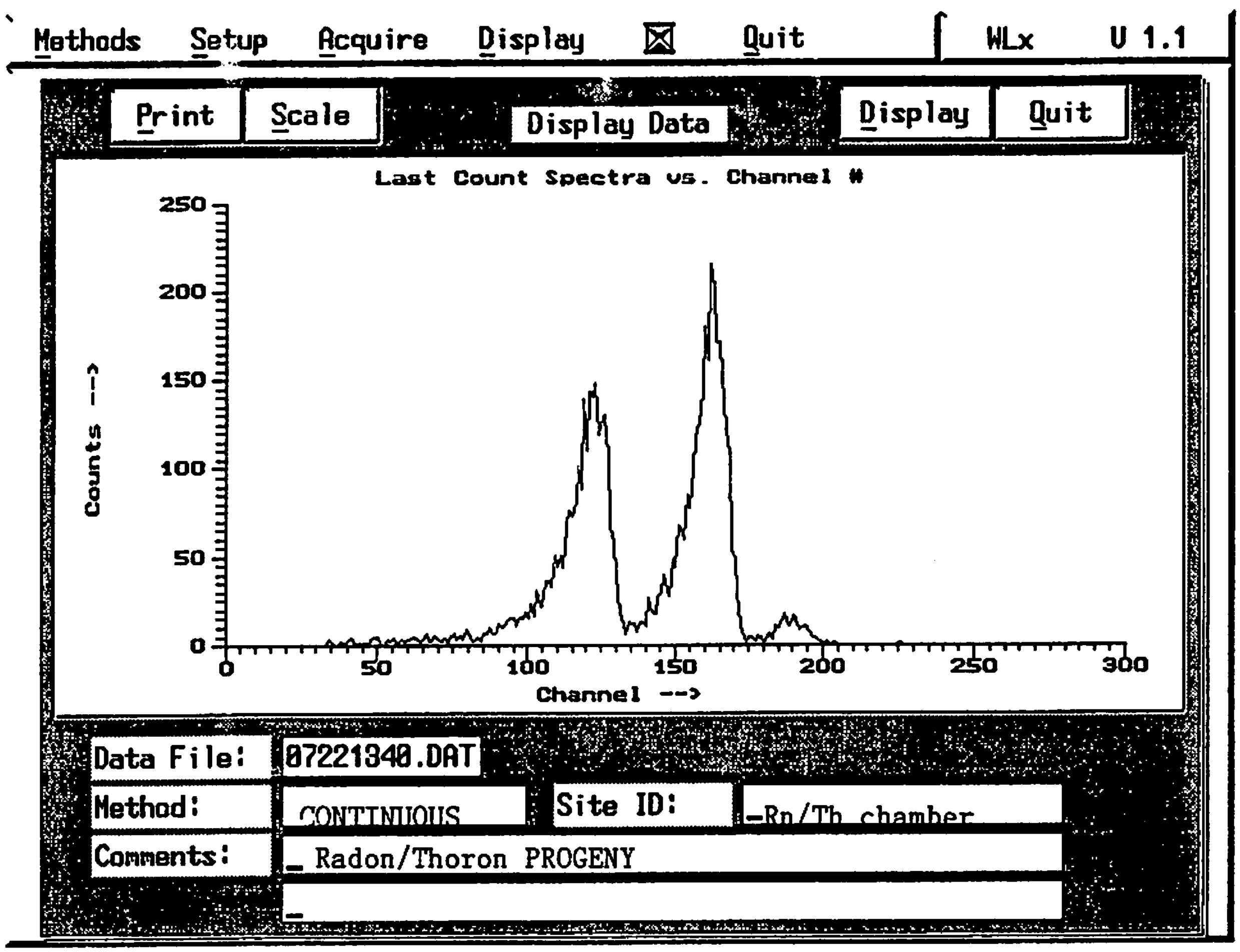

Figure 4 EML Intercomparison Data

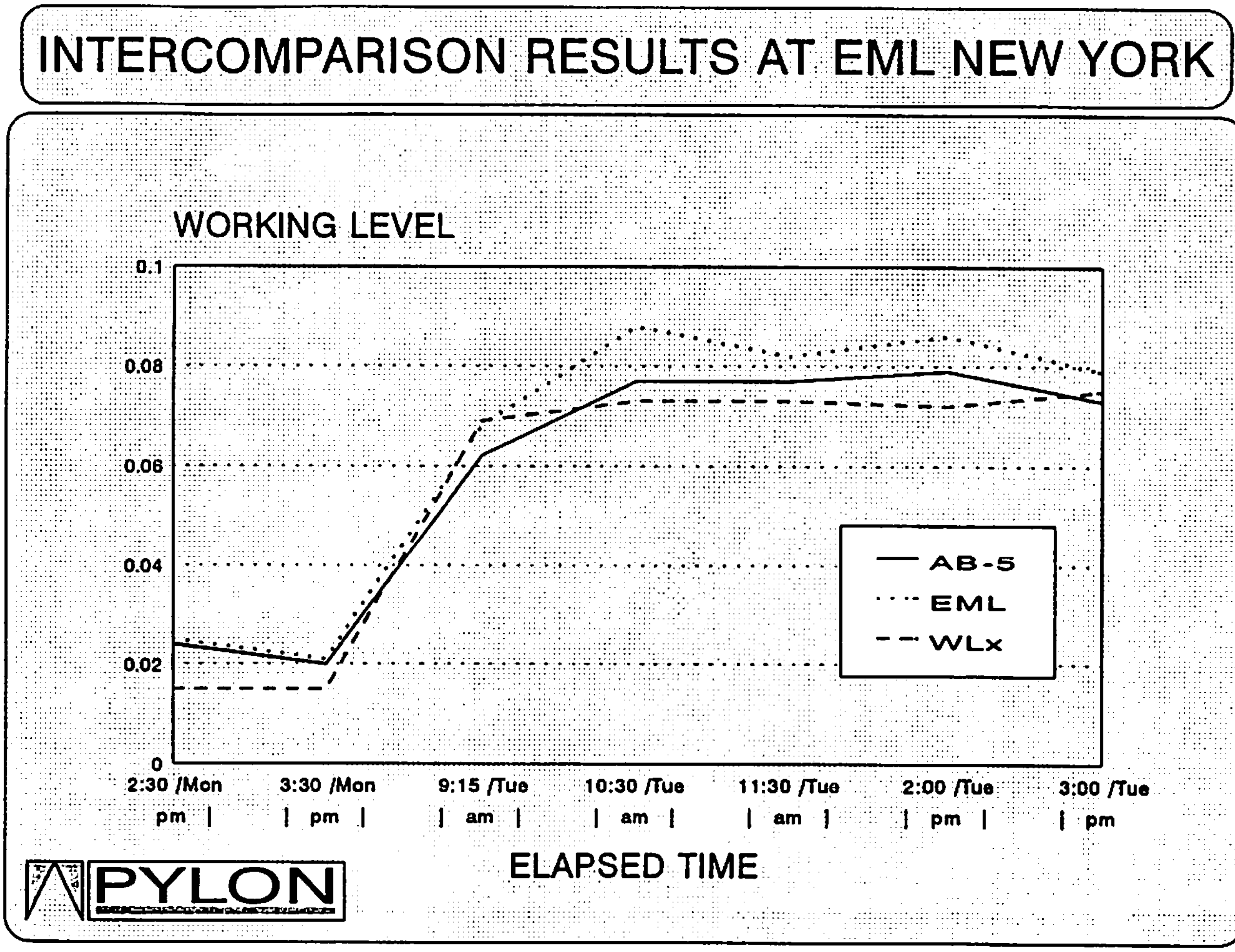

Figure 5 Pylon Intercomparison Data

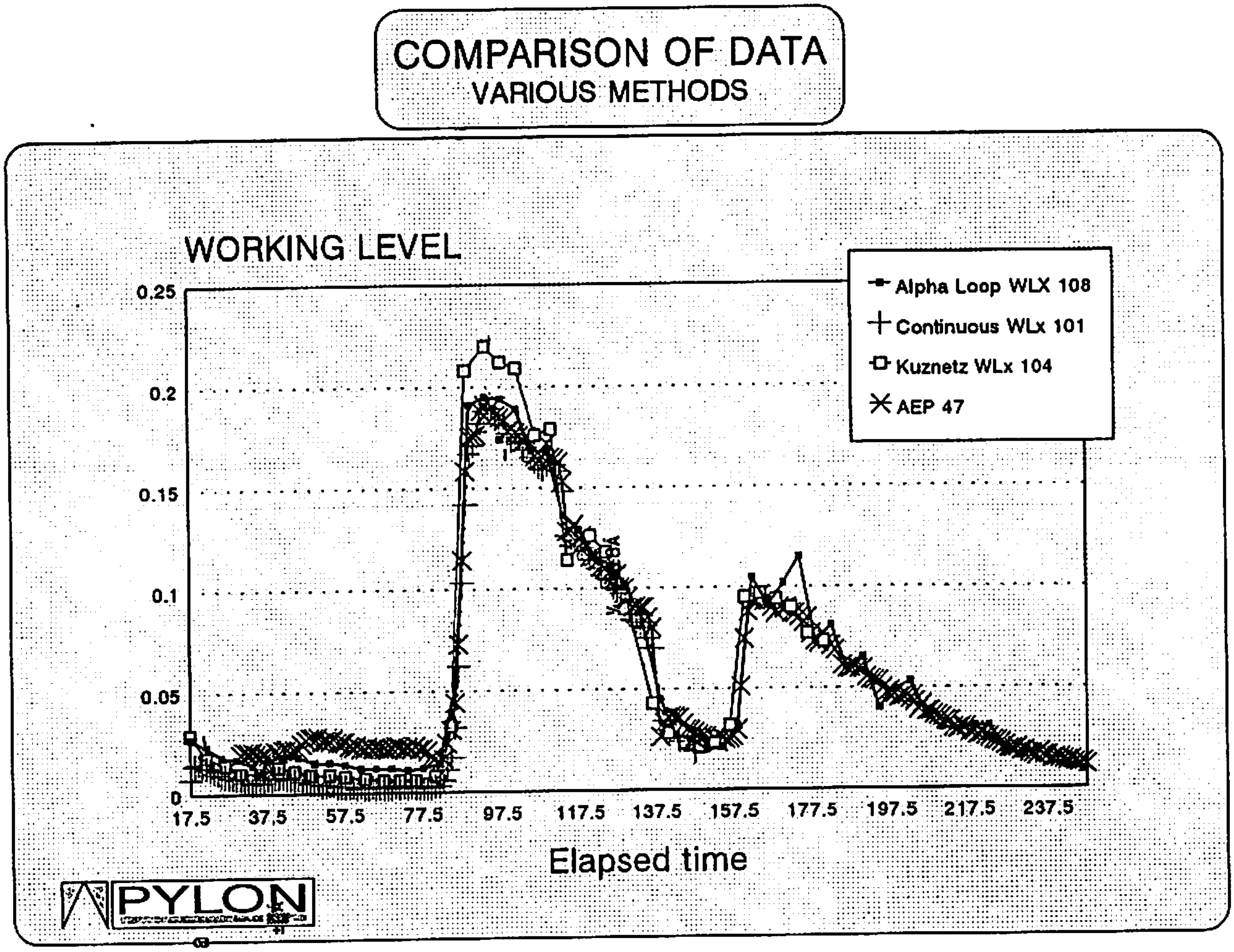

Figure 6 CANMET Intercomparison Data