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LABORATORY EVALUATION OF THE MIMIL, A RADON PROGENY INSTANT WORKING LEVEL METER

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by

J. Bigu*

ABSTRACT

A radon progeny instant working level meter, known as MIMIL. developed by the Centre de Radio Protections dans les Mines (CRPM), France, has been technically evaluated under laboratory controlled conditions. Radon progeny data by the MIMIL have been compared with grab-sampling data by the Thomas-Tsivoglou method. Within the range of radon progeny Working Levels (0.07 to 0.27) under which the tests were conducted, close agreement was found between readings by the MIMIL and grab-sampling data.

Key words: Radon progeny; Instrumentation; Working Level monitor.

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ÉVALUATION EN LABORATOIRE DU MIMIL, UN MONITEUR DU NIVEAU DE TRAVAIL INSTANTANÉ DES PRODUITS DE FILIATION DU RADON

par

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RÉSUMÉ

Un moniteur instantané du niveau de travail des produits de filiation du radon, connu sous le nom de MIMIL, mis au point par le Centre de radioprotection dans les mines (CRPM), en France, a fait l'objet d'une évaluation technique dans des conditions contrôlées de laboratoire. Les données relatives aux produits de filiation du radon obtenues grâce au MIMIL ont été comparées à des données recueillies par échantillonnage en vrac suivant la méthode de Thomas-Tsivoglou. Dans l'intervalle des niveaux de travail des produits de filiation du radon (0,07 à 0,27) utilisé pour les essais, on a constaté que les mesures fournies par le MIMIL et les données obtenues par échantillonnage en vrac concordaient étroitement.

Mots clés : Produits de filiation du radon; appareillage; moniteur de niveau de travail.

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INTRODUCTION

Man-made and natural radioactive environments pose potential occupational health hazards, hence, the need for adequate monitoring of radioactivity concentration levels in working areas. Monitoring of airborne radioactivity concentration levels is also important for engineering purposes such as the maintenance of reliable air quality control in working environments.

Miniaturized instrumentation for the measurement of α-particles from radon decay products found in uranium mines and mills, and in certain building materials, is of great practical value for monitoring radiation levels to which radiation workers and the general public alike are exposed. The measurement of radon progeny is particularly difficult because of the requirement for a portable unit with a high sensitivity capable of measuring radon progeny concentrations of the order of a few $pCiL^{-1}$.

Monitoring of radon progeny in uranium mines and mills for dose exposure purposes is mandatory in Canada. Radon progeny concentrations can be measured by means of a variety of instruments, mainly of the 'active type', using techniques which range from grab-sampling to time-integrating continuous monitoring employing different radioactivity counting methods. Instruments based on the quick determination of radon progeny Working Level, WL(Rn), are commonly referred to as Instant Working Level Meters (IWLM). These instruments are usually highly automated, requiring a minimum of manual intervention. Their operation is based on grab-sampling techniques.

This report presents experimental data on a laboratory technical evaluation of an IWLM, commercially known as MIMIL, developed and manufactured by the Centre de Radio Protection dans les Mines (CRPM), Commissariat à l'Energie Atomique (CEA), France. A technical evaluation of the same instrument in an underground uranium mine has also been reported elsewhere (1). The work reported here has been sponsored by the Atomic Energy Control Board (AECB), Ottawa (Canada) under financial encumbrance No. F.E. 86-2.

DESCRIPTION OF THE INSTRUMENT

A description of the MIMIL has been given elsewhere (1). This description is given again below for the benefit of the reader.

The MIMIL basically consists of a sample holder, where a suitable sampling filter is located, a sampling pump (~3 L min^{-1}), and a microprocessor-controlled timer/α-particle counter. The filter (28 mm in diameter, 1.2 μm pore size) is held in the sample holder by a specially designed tray.

Alpha-particle counting is done by means of a surface barrier silicon detector with a usable area of 250 mm^2, protected by a 3 μm Mylar membrane.

Air sampling is carried out manually by the sampling train, i.e., pump, filter holder, filter. After air sampling, the filter tray with the filter is removed from the sample holder and inserted in a rectangular slot where the active side of the filter faces the detector.

The timer of the α-particle scaler (counter) is activated when the air sampling begins. After sampling, the sample is inserted in the slot facing the detector. The rest of the operation is done without manual intervention. The airborne radon progeny concentration level is given in $\mu J\ m^{-3}$, (1 WL(Rn) = 20.53 $\mu J\ m^{-3}$). The measuring range of the instrument is 0.1 to 199 $\mu J\ m^{-3}$.

The MIMIL makes use of the Rolle method (2,3) for determining WL(Rn). The accuracy of the method is of about 15% for normal mixtures of ^{218}Po, ^{214}Pb and ^{214}Bi found in underground uranium mines.

The sequence of events when using the instrument is as follows: 2-min sampling, 8-min waiting time, and 2-min α-particle counting.

Other specifications of interest regarding the MIMIL (scaler) are given below:

Display : liquid crystal

Electrical supply : NiCd batteries (8 h duration when fully charged)

Recharging time : 16 h

Dimensions : 180 x 130 x 80 mm

Weight : 1.85 kg.

The dimensions of the pump are 195 x 160 x 90 mm and it weighs 1.33 kg. A battery charger (24 V alternating current) is supplied with the scaler and pump to charge both simultaneously, if so desired.

EXPERIMENTAL PROCEDURE

The instrument was tested and evaluated in a Radon/Thoron Test Facility (4) under laboratory controlled conditions. Data obtained with the MIMIL were compared with grab-sampling data by the Thomas-Tsivoglou method (5).

The flow rate of the sampling pump was calibrated using a wet test gas meter (WTGM) and an automated 'bubble' flowmeter of the optical type known under the commercial name, Buck Calibrator, manufactured by Gilian (U.S.A.).

Three long series of flow rate measurements were conducted on different days with the following results: 3.39 ± 0.006 L min^{-1}, 3.37 ± 0.02 L min^{-1}, and 3.43 ± 0.1 L min^{-1} at 22.5 ^{o}C and 96.78 kPa.

The average of all the data was 3.40 L min^{-1} compared with the manufacturer's value of 3.56 ± 0.074 at 20 ^{o}C and 97.32 kPa.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the MIMIL evaluation in the RTTF are summarized in Tables 1 and 2. Table 1 shows radon progeny concentration data, i.e., [^{218}Po], [^{214}Pb], and [^{214}Bi], where square brackets are used to denote concentration, and radon progeny Working Level, WL(Rn), data. Data were obtained by grab-sampling using the Thomas-Tsivoglou method (5).

The WL(Rn) in the RTTF ranged from <0.08 to 0.27 depending on aerosol concentration. The WL(Rn) values in the RTTF were of the same order as those found in most underground uranium mines. The important radon progeny ratios $[^{214}Pb]/[^{218}Po]$ and $[^{214}Bi]/[^{218}Po]$ were ~0.47 and 0.31, approximately. These values agree with experimental data from reasonably well ventilated working areas of underground uranium mines.

Sodium chloride (NaCl) aerosols were continuously injected into the RTTF every morning at about 8:30. Aerosol concentration in the chamber before aerosol injection was $<3 \times 10^3$ cm^{-3}. Aerosol concentration in the RTTF was changed during the day between $<3 \times 10^3$ cm^{-3} and 8×10^3 cm^{-3}, a fact which is reflected in the steady increase in WL(Rn) and radon progeny with time. A threefold change in WL(Rn) was brought about by a change in aerosol concentration from $\sim 3 \times 10^3$ cm^{-3} to $\sim 8 \times 10^3$ cm^{-3}. The changes in radiation level in the RTTF were intended to study the response of the MIMIL under dynamic situations.

Table 2 shows data, μJ m^{-3}, obtained with the MIMIL. These data have been converted into WL(Rn) using the following relationship (6): WL(Rn) = MIMIL reading (μJ m^{-3})/20.53. Also shown in the table are the WL(Rn) values obtained by grab-sampling (G.S.), see Table 1, and the daily average values of WL obtained with the MIMIL and by grab-sampling. Figures 1 and 2 show a graphical display of the data of Tables 1 and 2.

The data of Table 2 and Figures 1 and 2 show a close agreement between the MIMIL and grab-sampling, i.e., within <3% for the daily averages under the flow rate conditions indicated above. However, some discrepancy was observed for individual samples (Figure 1) most likely because of pump resonance effects in the MIMIL.

As previously pointed out (1), the instrument requires some modifications in the mechanical configuration to improve its performance. The following defects were noticed.

1. The pump often exhibited a resonance effect which induced strong vibrations in the tubing between the pump and the sample holder, and in the sampling filter. The sampling pump is provided with a 'damper' at the exhaust side of the pump inside the pump casing to minimize these vibrations. However, the two ends of the damper were connected to plastic tubing of different diameters resulting in potential air leaks. In order to eliminate this problem, the damper was removed from inside to outside the pump casing and the two lengths of plastic tubing of different diameters were replaced by two lengths which fitted leak-free to the pump exhaust and the pump casing exhaust port, respectively.
2. The filter tray sample holder was not provided with any physical support (e.g., metal or plastic mesh) for the filter. Hence, the filter was supported at the rim and bulged markedly when the pump was operated. On the average, 3 to 5 times out of 10, the filter was either damaged around the rim causing considerable leakage, or it was broken (cut) completely and sucked right into the exhaust side of the sampling holder. Because of this design flaw it was not possible to sample reliably and a circular disc of fine mesh had to be cemented to one of the flaps of the filter tray.

CONCLUSIONS

The MIMIL performed well in the laboratory controlled tests and technical evaluation. Agreement with grab-sampling data (daily averages) was quite good. As the instrument was previously evaluated in an underground uranium mine extensively, it is suggested that no more tests should be conducted on the instrument apart from the usual periodic calibration and maintenance.

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Table 1 - Grab-sampling data in the RTTF by the Thomas-Tsivoglou method

Date	Time	WL(Rn)	[^{218}Po] pCi/L	[^{214}Pb] pCi/L	[^{214}Bi] pCi/L	[^{214}Pb]/[^{218}Po]	[^{214}Bi]/[^{218}Po]
Sept 23/87	8:32	0.092	31.10	9.26	3.55		
"	9:22	0.135	36.89	13.64	7.37		
"	10:22	0.154	36.96	14.62	11.20		
"	11:22	0.184	39.97	18.36	13.26		
"	12:24	0.204	44.63	21.00	13.88	0.47	0.31
"	13:22	0.213	48.47	21.00	15.26		
"	14:20	0.231	43.11	24.23	17.02		
"	15:20	0.246	48.97	25.56	17.69		
Sept 24/87	8:24	0.075	32.76	6.64	2.04		
"	9:18	0.141	33.02	14.33	9.09		
"	10:33	0.186	42.50	18.87	12.46		
"	11:15	0.192	40.78	18.30	15.19		
"	12:38	0.221	48.77	22.41	15.38	0.46	0.31
"	13:24	0.228	44.44	21.99	18.88		
"	14:22	0.256	53.28	25.60	19.14		
"	15:27	0.270	60.57	28.22	17.27		

Table 2 - MIMIL data and grab-sampling data (Thomas-Tsivoglou) in the RTTF

Date	$(Time)_M$	PAEC* $\mu J/m^3$	$WL(Rn)_M$	$(Time)_{GS}$	$WL(Rn)_{GS}$
Sept. 23/87	8:50	1.978	0.096	8:30	0.092
"	9:35	2.594	0.126	9:22	0.135
"	10:35	2.743	0.134	10:22	0.154
"	11:35	3.445	0.168	11:22	0.184
"	12:36	3.232	0.157	12:24	0.204
"	13:37	3.849	0.187	13:22	0.213
"	14:02	4.360	0.213	14:20	0.231
"	14:16	5.040	0.245	15:20	0.246
"	14:32	4.636	0.226		
"	15:32	5.232	0.255		
Average:			0.181±0.05		0.182±0.05
Sept. 24/87	8:36	1.701	0.083	8:24	0.075
"	9:12	2.772	0.135	9:18	0.141
"	9:30	2.999	0.146	10:33	0.186
"	10:29	3.445	0.167	11:15	0.196
"	10:46	3.998	0.195	12:38	0.221
"	11:11	3.956	0.193	13:24	0.228
"	12:34	4.105	0.200	14:22	0.256
"	12:48	4.317	0.210		
"	13:20	5.232	0.255		
"	13:36	4.572	0.223		
"	14:18	4.764	0.232		
"	14:31	5.083	0.248		
Average			0.191±0.05		0.186±0.06

*PAEC stands for Potential Alpha Energy Concentration in air.
The indices M and GS stand for MIMIL and grab-sampling, respectively.

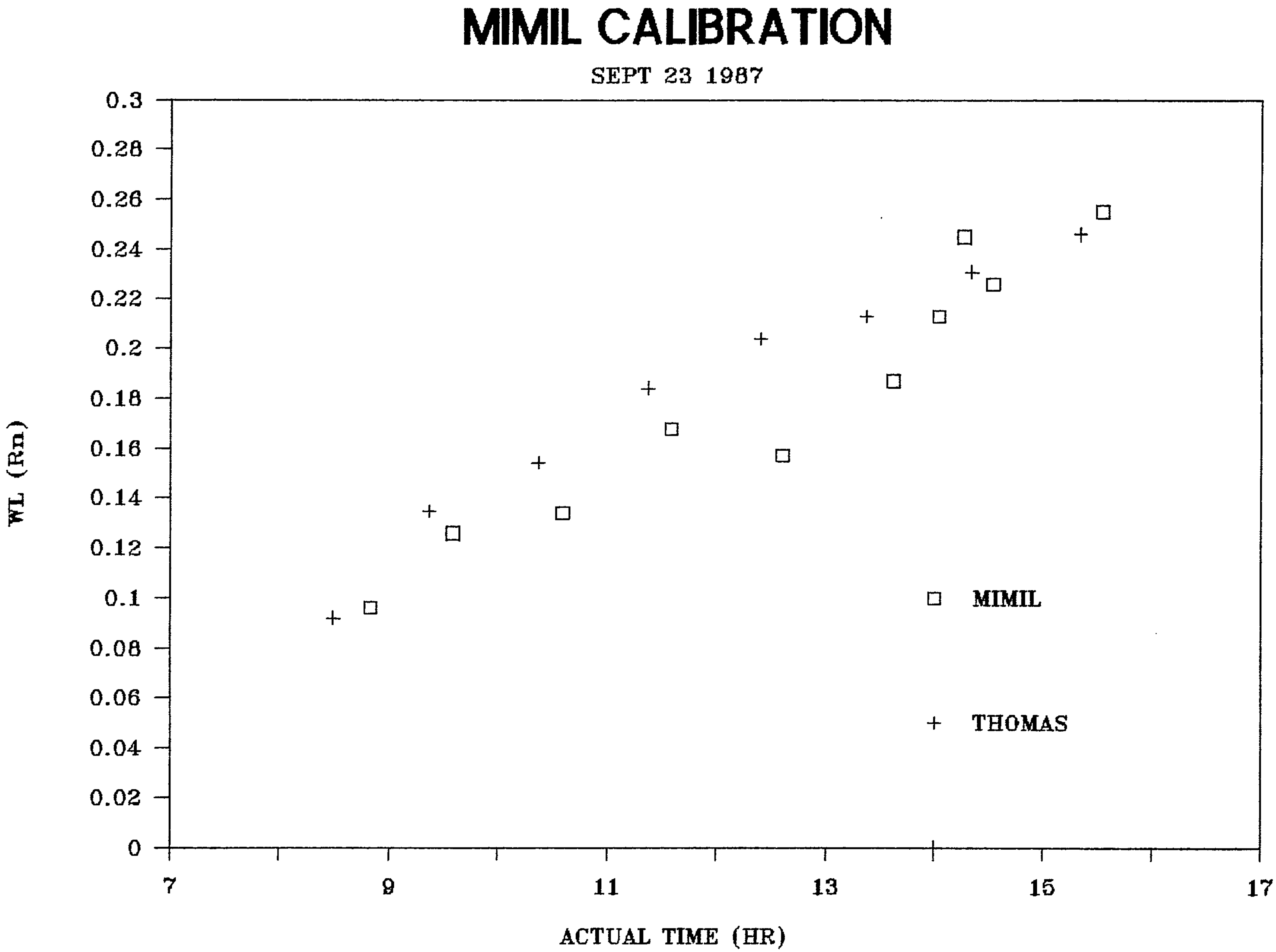

Fig. 1 - Comparison of MIMIL data and grab-sampling data by the Thomas-Tsivoglou method.

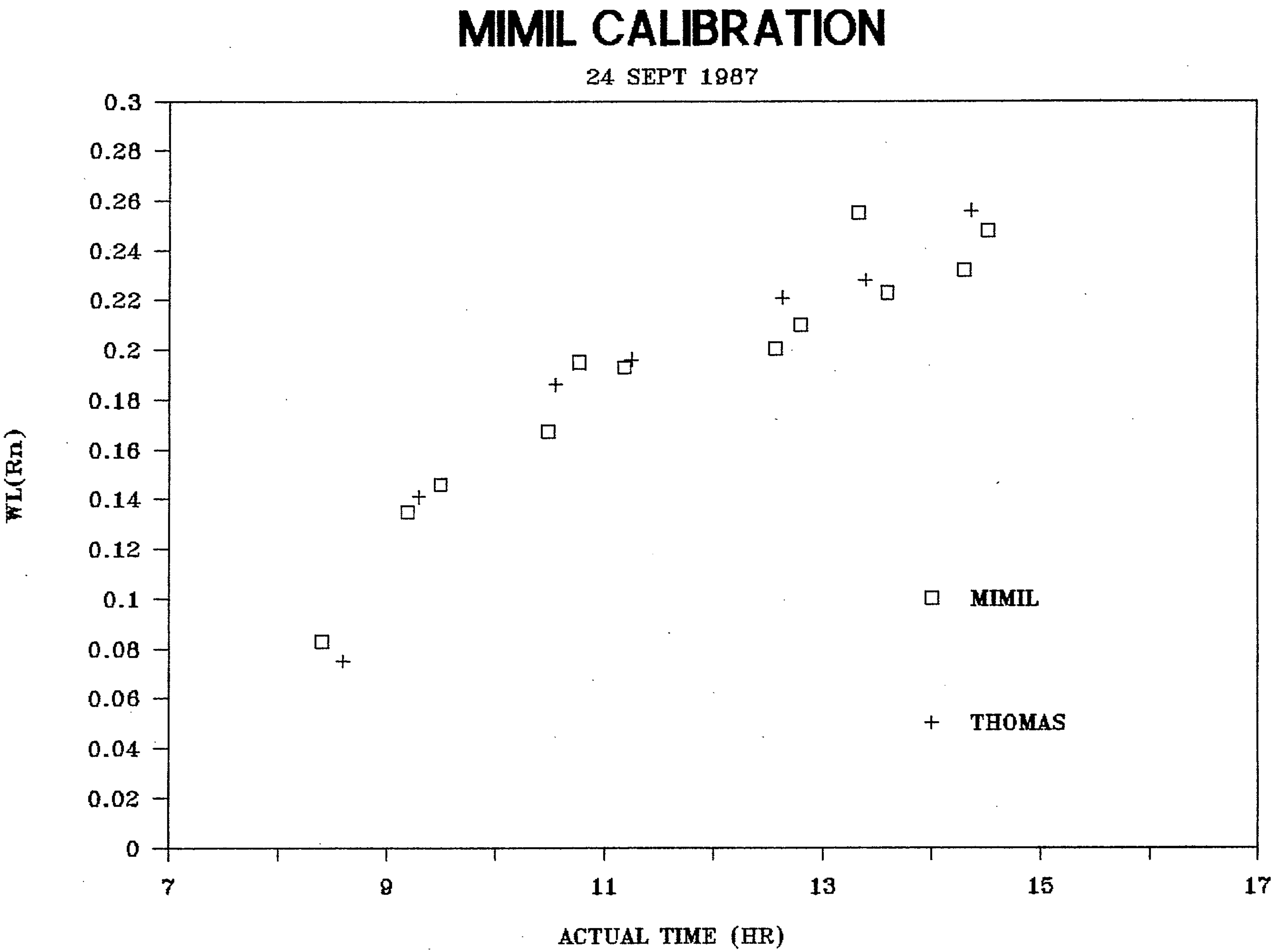

Fig 2 - Comparison of MIMIL data and grab-sampling data by the Thomas-Tsivoglou method.