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TECHNICAL EVALUATION OF A RADON PROGENY INSTANT WORKING LEVEL METER IN AN UNDERGROUND URANIUM MINE

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by

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ABSTRACT

A radon progeny instant working level meter, known as MIMIL, developed by the Centre de Radio Protection dans les Mines (CRPM), France, has been technically evaluated in an underground uranium mine. Radon progeny data by the MIMIL has been compared with grab-sampling data by the Thomas-Tsivoglou, Kusnetz and Rock methods. The results show that the MIMIL systematically overestimated the radon progeny Working Level by about 13.5%, a figure which is in approximate accordance with theoretical expectations based on the thoron progeny/radon progeny Working Level ratios estimated at the mine.

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

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ÉVALUATION TECHNIQUE D'UN APPAREIL DE CONTRÔLE RAPIDE DU NIVEAU DE TRAVAIL DES PRODUITS DE FILIATION DU RADON DANS UNE MINE D'URANIUM SOUTERRAINE

par

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RÉSUMÉ

Une évaluation technique d'un appareil de contrôle rapide de la concentration volumique de l'énergie alpha potentielle des produits de filiation du radon dans l'air a été faite dans une mine d'uranium souterraine. Cet appareil est connu sous le nom de MIMIL et a été mis au point par le Centre de Radio Protection dans les Mines (CRPM), en France. Les données sur les produits de filiation du radon fournies par le MIMIL ont été comparées aux données d'échantillonnage pris au hasard selon les méthodes Thomas-Tsivoglou, Kusnetz et Rock. Les résultats montrent que les données obtenues à l'aide du MIMIL relativement au niveau de travail des produits de filiation du radon étaient systématiquement surestimées par environ 13,5 %, un pourcentage qui correspond à peu près aux attentes théoriques fondées sur les rapports de niveau de travail des produits de filiation du thoron/produits de filiation du radon qui ont été évalués à la mine.

Mots-clés : produits de filiation du radon, produits de filiation du thoron, instrumentation, moniteur du niveau de travail.

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INTRODUCTION

Radioactivity environments pose 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.

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.

The need for a simple, fast and reliable method for the routine determination of the radon progeny Working Level, WL(Rn), cannot be sufficiently emphasized. Instruments based on the quick determination of 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 data on the 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. 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

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 - 199 $\mu J\ m^{-3}$.

The MIMIL makes use of the Rolle method (1,2) 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:

<u>Display</u> : liquid crystal

<u>Electrical supply</u> : NiCd batteries (8 h duration when fully charged)

<u>Recharging time</u> : 16 h

<u>Dimensions</u> : 180 x 130 x 80 mm

<u>Weight</u> : 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. A picture of the instrument is shown in Figure 1.

EXPERIMENTAL PROCEDURE

The instrument was tested and evaluated in an underground uranium mine in conjunction with the evaluation of an exhaust fan/filtering system to reduce airborne radon and thoron progeny in working environments, and to supply 'fresh' air to production stopes (3). Because tests were conducted when the fan was on and off, and when the filtering system was in place or removed from the fan, illustrations and tabulated data may contain information regarding the operating conditions of the fan.

The underground test lasted 9 days. Data obtained with the MIMIL were compared with grab-sampling data by the Thomas-Tsivoglou and Kusnetz methods (4,5) and by continuous monitoring. Thoron progeny Working Levels, WL(Tn), were estimated using the Rock method (6).

Measurements were conducted at three different locations in the mine, namely, near a refuge station, in a production stope, and in a sill drivage.

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 $\pm$ 0.006 L min^{-1}, 3.37 $\pm$ 0.02 L min^{-1}, and 3.43 $\pm$ 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 $\pm$ 0.074 at 20^{o}C and 97.32 kPa.

EXPERIMENTAL RESULTS AND DISCUSSION

Grab-sampling data by the Thomas-Tsivoglou, Kusnetz and Rock methods for the underground sampling locations of interest are shown in Table 1.

Average values calculated for the daily shifts are shown in Table 2.

Table 3 shows data taken with the MIMIL and grab-sampling data obtained side-by-side. The Table shows the ratio WL(MIMIL)/WL(Rn), where WL(MIMIL) represents the Working Level values obtained with the instrument. Also shown in Table 3 are WL(Tn) and the ratio WL(Tn)/WL(Rn).

Under the experimental conditions of the underground tests, i.e.,

$$WL(Tn)/WL(Rn) \sim 0.25 - 0.52,$$

$$[^{214}Pb]/[^{218}Po] \sim 0.56, \text{ and}$$

$$[^{214}Bi]/[^{218}Po] \sim 0.37.$$

the MIMIL systematically overestimated WL(Rn) by 12-15% with an average value of ~13.5%.

The WL(Rn) overestimation by the instrument is to be expected because of the presence of thoron progeny in mine air, counted as radon progeny by the MIMIL which cannot discriminate thoron progeny from radon progeny.

It should be noted that an increase in the ratio WL(MIMIL)/WL(Rn) with increasing WL(Tn)/WL(Rn), with the same WL(Rn), was observed which is consistent with theory. Typical thoron progeny α-counting rates measured on the MIMIL filters 7-9 h after the end of sampling was in the order of 1.5 to 3.0 counts min^{-1} (cpm).

Agreement between the instrument and grab-sampling is expected to improve in radon/radon progeny atmospheres only. Since these conditions are rarely met in underground uranium mines, an evaluation of the instrument in radon/radon progeny atmospheres only will be carried out in the near future in a Radon/Thoron Test Facility (RTTF) at the Elliot Lake Laboratory (CANMET).

SUGGESTIONS FOR IMPROVING THE INSTRUMENT

Two serious design defects were noticed in the instrument, one in the pump, and the other in the sample holder.

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 substituted 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, 3-5 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.

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Table 1 - Radon progeny and thoron progeny data by grab-sampling

Date	Time	Location	$[^{218}Po]$ pCiL^{-1}	$[^{214}Pb]$ pCiL^{-1}	$[^{214}Bi]$ pCiL^{-1}	$\frac{[^{214}Pb]}{[^{218}Po]}$	$\frac{[^{214}Bi]}{[^{218}Po]}$	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	Remarks
June 15/87	10:20	Intake	49.3	31.3	21.9	0.634	0.444	0.291	0.062	0.212	
	11:00	"	55.6	35.4	29.6	0.636	0.532	0.347	0.068	0.197	
	11:40	"	50.8	34.8	22.9	0.685	0.451	0.315	0.070	0.222	Fan on, no filters
	12:20	"	38.2	24.8	21.2	0.649	0.555	0.245	0.065	0.263	
	13:00	"	34.6	22.36	15.6	0.646	0.451	0.207	0.069	0.332	
	13:40	"	33.6	21.21	14.08	0.631	0.419	0.195	0.065	0.335	
June 16/87	9:00	Intake	47.1	23.78	14.66	0.505	0.311	0.224	0.082	0.365	Fan on, no filters
	10:00	"	39.88	20.67	13.32	0.518	0.334	0.196	0.076	0.390	
	10:40	"	39.22	20.61	12.82	0.525	0.327	0.193	0.073	0.379	
	11:20	"	32.8	16.57	10.49	0.505	0.319	0.157	0.069	0.438	Fan off, no filters
	12:00	"	28.1	14.67	8.22	0.522	0.292	0.134	0.057	0.426	
	12:40	"	26.3	14.6	11.4	0.555	0.433	0.144	0.050	0.346	
	13:20	"	29.1	14.1	8.16	0.485	0.280	0.132	0.059	0.448	
June 17/87	9:20	Intake	43.0	21.6	10.39	0.502	0.241	0.193	0.073	0.380	Fan off, filters in place
	10:00	"	39.8	16.8	5.8	0.422	0.146	0.148	0.047	0.319	
	10:40	"	34.9	14.8	6.13	0.424	0.176	0.134	0.058	0.433	
	11:20	"	21.77	10.4	11.97	0.477	0.549	0.120	0.051	0.425	Fan on, filters in place
	12:00	"	26.3	11.55	7.44	0.439	0.283	0.114	0.057	0.498	
	12:40	"	29.5	14.04	8.19	0.475	0.278	0.132	0.051	0.389	
	13:20	"	28.19	13.6	9.66	0.482	0.343	0.134	0.066	0.493	
June 18/87	9:21	Intake	33.5	27.5	24.7	0.821	0.737	0.267	0.080	0.301	
	10:00	"	29.6	20.6	17.4	0.696	0.587	0.201	0.074	0.371	
	10:40	"	29.2	15.8	7.41	0.541	0.254	0.138	0.061	0.439	
	11:20	"	-	-	-	-	-	0.126	0.061	0.482	Fan on, filters in place
	12:00	"	22.1	12.2	10.2	0.552	0.461	0.123	0.061	0.494	
	12:40	"	36.8	17.19	3.76	0.467	0.102	0.139	0.052	0.376	
	13:00	"	32.19	15.6	7.25	0.484	0.225	0.140	0.055	0.391	
June 19/87	8:59	Intake	42.9	23.4	14.2	0.545	0.331	0.216	0.084	0.390	
	9:40	"	25.1	14.86	10.05	0.589	0.400	0.139	0.071	0.515	Fan off, filters in place
	10:40	"	33.8	14.6	4.73	0.432	0.139	0.127	0.069	0.548	
	11:20	"	26.6	12.5	6.98	0.470	0.262	0.117	0.061	0.523	
	12:00	"	33.6	15.3	5.25	0.455	0.156	0.132	0.058	0.441	
	12:40	"	29.8	12.8	6.79	0.429	0.228	0.121	0.075	0.623	Fan on, filters in place
	13:20	"	26.1	12.6	8.71	0.482	0.333	0.102	0.072	0.703	

Table 1 cont. overleaf

Table 1 Cont.

Date	Time	Location	$[^{218}Po]$ $pCiL^{-1}$	$[^{214}Pb]$ $pCiL^{-1}$	$[^{214}Bi]$ $pCiL^{-1}$	$\frac{[^{214}Pb]}{[^{218}Po]}$	$\frac{[^{214}Bi]}{[^{218}Po]}$	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	Remarks
June 15/87	9:37	Exhaust	90.6	60.6	50.9	0.669	0.562	0.591	0.090	0.153	
	10:20	"	43.0	28.8	28.8	0.669	0.669	0.308	0.070	0.230	
	11:00	"	56.1	34.5	27.1	0.615	0.483	0.334	0.068	0.203	
	11:40	"	48.7	29.8	25.4	0.612	0.522	0.297	0.063	0.213	Fan on, no filters
	12:20	"	61.6	35.5	13.2	0.576	0.214	0.308	0.066	0.221	
	13:00	"	35.9	21.0	15.1	0.585	0.420	0.200	0.065	0.322	
	13:40	"	26.2	18.4	15.6	0.702	0.595	0.180	0.070	0.389	
June 16/87	9:02	Exhaust	41.8	24.6	16.1	0.588	0.385	0.228	0.082	0.357	Fan on, no filters
	10:00	"	46.0	33.6	24.2	0.730	0.526	0.309	0.085	0.276	
	10:40	"	44.5	37.2	33.3	0.836	0.748	0.359	0.082	0.229	
	11:20	"	59.6	41.1	29.1	0.689	0.488	0.379	0.086	0.227	Fan off, no filters
	12:00	"	61.5	46.9	33.2	0.762	0.540	0.426	0.089	0.210	
	12:40	"	50.3	41.0	35.0	0.815	0.696	0.391	0.096	0.246	
	13:20	"	54.2	36.7	24.8	0.677	0.458	0.335	0.069	0.207	
June 17/87	9:00	Exhaust	79.2	56.1	44.9	0.708	0.567	0.534	0.087	0.163	Fan off, filters in place
	10:00	"	30.4	13.9	9.41	0.457	0.309	0.137	0.069	0.501	
	10:40	"	25.7	11.29	9.18	0.439	0.357	0.118	0.059	0.502	
	11:20	"	22.2	12.5	9.43	0.563	0.425	0.122	0.053	0.433	Fan on, filters in place
	12:00	"	27.0	11.8	6.57	0.437	0.243	0.112	0.049	0.436	
	12:40	"	23.7	13.96	8.45	0.589	0.356	0.127	0.053	0.417	
	13:20	"	30.4	14.6	7.35	0.480	0.242	0.133	0.052	0.389	
June 18/87	9:20	Exhaust	36.7	22.8	18.3	0.621	0.499	0.222	0.081	0.365	
	10:00	"	30.8	20.1	14.5	0.652	0.471	0.188	0.063	0.335	
	10:40	"	23.6	12.0	10.0	0.508	0.423	0.123	0.054	0.441	
	11:20	"	23.5	12.1	7.8	0.515	0.332	0.115	0.060	0.518	Fan on, filters in place
	12:00	"	24.1	12.72	8.2	0.528	0.340	0.120	0.052	0.434	
	12:40	"	27.4	11.7	8.1	0.427	0.296	0.118	0.048	0.410	
	13:20	"	27.2	13.3	7.59	0.489	0.279	0.124	0.048	0.385	
June 19/87	9:26	Exhaust	47.5	37.3	27.9	0.816	0.611	0.350	0.074	0.211	
	10:05	"	41.1	27.9	19.4	0.679	0.472	0.260	0.087	0.335	Fan off, filters in place
	10:42	"	27.7	16.9	11.2	0.610	0.404	0.160	0.075	0.469	
	11:26	"	23.6	11.9	7.5	0.504	0.318	0.120	0.061	0.508	
	12:01	"	25.5	9.6	8.5	0.376	0.333	0.110	0.061	0.554	Fan on filters in place
	12:40	"	27.6	13.7	5.3	0.496	0.192	0.120	0.049	0.408	
	13:20	"	25.5	12.2	6.9	0.478	0.271	0.120	0.074	0.617	

Table 1 cont. overleaf

Table 1 Cont.

Date	Time	Location	$[^{218}Po]$ $pCiL^{-1}$	$[^{214}Pb]$ $pCiL^{-1}$	$[^{214}Bi]$ $pCiL^{-1}$	$\frac{[^{214}Pb]}{[^{218}Po]}$	$\frac{[^{214}Bi]}{[^{218}Po]}$	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	Remarks
June 15/87	11:00	Sill drift	49.9	30.7	25.4	0.615	0.510	0.310	0.074	0.239	
	11:40	" "	49.6	28.7	25.2	0.578	0.508	0.300	0.072	0.240	
	12:20	" "	53.9	27.7	16.1	0.514	0.298	0.260	0.060	0.231	Fan on, no filters
	13:00	" "	47.1	21.8	11.0	0.463	0.233	0.210	0.051	0.243	
	13:40	" "	39.3	20.9	10.4	0.532	0.264	0.190	0.064	0.337	
June 16/87	9:10	Sill drift	18.3	15.3	22.1	0.836	1.208	0.180	0.061	0.339	Fan on, no filters
	10:00	" "	35.7	21.5	13.9	0.602	0.389	0.200	0.067	0.335	
	10:40	" "	40.6	19.0	14.2	0.468	0.350	0.200	0.094	0.470	
	11:20	" "	22.9	16.0	13.7	0.699	0.598	0.160	0.071	0.441	Fan off, no filters
	12:00	" "	24.1	15.8	10.6	0.656	0.439	0.150	0.073	0.487	
	12:40	" "	38.0	16.7	8.7	0.439	0.229	0.160	0.068	0.425	
	13:20	" "	25.9	14.4	9.7	0.556	0.374	0.140	0.086	0.614	
June 17/87	9:10	Sill drift	46.5	23.1	9.30	0.497	0.200	0.210	0.054	0.257	Fan off, filters in place
	10:00	" "	39.8	16.7	5.03	0.419	0.126	0.150	0.065	0.433	
	10:40	" "	28.6	13.0	7.27	0.454	0.254	0.130	0.053	0.408	
	11:20	" "	31.7	13.3	7.59	0.419	0.239	0.130	0.056	0.431	Fan on, filters in place
	12:00	" "	31.5	12.4	5.68	0.394	0.180	0.120	0.061	0.508	
	12:40	" "	24.9	13.7	9.13	0.550	0.367	0.130	0.079	0.608	
	13:20	" "	29.1	14.2	7.66	0.488	0.263	0.130	0.056	0.431	
June 18/87	9:20	Sill drift						0.220			
	10:00	" "						0.220			
	10:40	" "						0.140			
	11:20	" "						0.140			Fan on, filters in place
	12:00	" "						0.130			
	12:40	" "						0.120			
	13:20	" "						0.150			
June 19/87	9:00	Sill drift						0.270			
	10:00	" "						0.170			Fan off, filters in place
	11:00	" "						0.160	------------	------------	
	12:00	" "						0.150			Fan on, filters in place
	13:00	" "						0.130			

Table 2 - Radon progeny and thoron progeny data by grab-sampling.
(Average values under 'steady-state' conditions.)

Date	Location	$[^{214}Pb]/[^{218}Po]$	$[^{214}Bi]/[^{218}Po]$	$\overline{WL(Rn)}$	$\overline{WL(Tn)}$	$\frac{\overline{WL(Tn)}}{\overline{WL(Rn)}}$	Remarks
June 15/87	Intake	0.65	0.47	0.267	0.066	0.247	Fan on;
	Exhaust	0.63	0.49	0.268	0.067	0.250	no filter
	Sill drift	0.54	0.36	0.254	0.064	0.252	
June 16/87	Intake	0.52	0.33	0.168	0.066	0.393	Fan off;
	Exhaust	0.73	0.55	0.347	0.084	0.242	no filter
	Sill drift	0.57	0.40	0.170	0.074	0.435	
June 17/87	Intake	0.46	0.29	0.139	0.058	0.417	Fan on;
	Exhaust	0.52	0.36	0.125	0.056	0.448	filter in place
	Sill drift	0.46	0.23	0.143	0.061	0.426	
June 18/87	Intake	0.59	0.39	0.156	0.063	0.404	Fan on;
	Exhaust	0.53	0.38	0.144	0.058	0.403	filter in place
	Sill drift	-	-	0.160	-	-	
June 19/87	Intake	0.49	0.26	0.136	0.070	0.515	Fan off until ∿11:20;
	Exhaust	0.56	0.37	0.177	0.069	0.390	fan on at ∿11:20;
	Sill drift	-	-	0.176	-	-	filter in place

Table 3 - Radon progeny data obtained with the MIMIL and radon and thoron progeny measurements by grab-sampling.

Date	Time	Location	$\mu J/m^3$	WL(MIMIL)	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	$\frac{WL(MIMIL)}{WL(Rn)}$
June 15/87	11:00	Exhaust	8.358	0.407	0.334	0.068	0.20	1.217
	11:40	"	7.593	0.370	0.297	0.063	0.21	1.246
	12:20	"	6.402	0.312	0.298	0.066	0.22	1.045
	13:00	"	4.190	0.204	0.200	0.065	0.32	1.019
	13:40	"	4.253	0.207	0.179	0.070	0.39	1.157
								1.137±0.102
June 16/87	8:40	Exhaust	7.274	0.354	0.228	0.082	0.36	-
	10:00	"	7.423	0.362	0.309	0.085	0.28	1.171
	10:40	"	8.848	0.431	0.359	0.082	0.23	1.200
	11:20	"	8.465	0.412	0.379	0.086	0.23	1.088
	12:00	"	8.826	0.430	0.426	0.089	0.21	1.010
	12:40	"	8.975	0.437	0.391	0.096	0.25	1.118
	13:20	"	8.061	0.393	0.335	0.069	0.21	1.171
								1.126±0.070
June 17/87	8:43	Intake	5.147	0.251	-	-	-	-
	8:58	Exhaust	12.370	0.602	0.534	0.087	0.16	1.128
	9:15	Sill drivage	5.721	0.279	0.210	0.054	0.26	1.327
	10:00	Intake	3.169	0.154	0.148	0.047	0.32	1.040
	10:40	Exhaust	2.786	0.136	0.118	0.059	0.50	1.150
	11:20	Sill drivage	2.509	0.122	0.130	0.056	0.43	0.940
	12:00	Intake	2.807	0.137	0.114	0.057	0.50	1.203
	12:40	Exhaust	3.084	0.150	0.127	0.053	0.42	1.184
	13:20	Sill drivage	3.190	0.155	0.130	0.056	0.43	1.195
								1.146±0.116

cont. overleaf

Table 3 - Cont.

Date	Time	Location	μJ/m³	WL(MIMIL)	WL(Rn)	WL(Tn)	WL(Tn)/WR(Rn)	WL(MIMIL)/WL(Rn)
June 18/87	8:44	Intake	2.339	0.114	-	-	-	-
	9:00	Exhaust	2.212	0.108	-	-	-	-
	9:20	Sill drivage	4.509	0.220	-	-	-	-
	10:00	" "	4.509	0.220	-	-	-	-
	10:40	" "	2.828	0.138	-	-	-	-
	11:20	" "	2.786	0.136	-	-	-	-
	12:00	" "	2.679	0.130	-	-	-	-
	12:40	" "	2.552	0.124	-	-	-	-
	13:20	" "	3.084	0.150	-	-	-	-
June 19/87	8:28	Intake	3.913	0.191	-	-	-	-
	8:43	Exhaust	9.103	0.443	-	-	-	-
	9:00	Sill drivage	5.593	0.272	-	-	-	-
	9:27	Exhaust	9.762	0.475	0.350	0.074	0.21	1.359
	10:00	Sill drivage	3.403	0.165	-	-	-	-
	10:30	Exhaust	4.700	0.229	0.160	0.075	0.47	1.431
	11:00	Sill drivage	3.275	0.159	-	-	-	-
	11:30	Exhaust	2.871	0.140	0.120	0.061	0.51	1.165
	12:00	Sill drivage	3.190	0.155	-	-	-	-
	12:30	Exhaust	1.722	0.084	0.120	0.049	0.41	0.699
	13:00	Sill drivage	2.616	0.127	-	-	-	-
	13:30	Exhaust	2.679	0.130	0.120	0.074	0.62	1.087
								1.148±0.287
June 23/87	8:35	Intake	3.424	0.167	-	-	-	-
	9:30	"	3.764	0.183	0.161	-	-	1.136
	9:55	Exhaust	3.190	0.155	0.152	-	-	1.022
	10:22	Intake	3.190	0.155	0.123	-	-	1.258
	10:48	Exhaust	2.360	0.115	0.105	-	-	1.099
	11:10	Intake	2.999	0.146	0.132	-	-	1.106
	11:35	Exhaust	3.211	0.156	0.132	-	-	1.185
	12:00	Intake	2.679	0.130	0.117	-	-	1.118
	12:25	Exhaust	2.488	0.121	0.105	-	-	1.152
	12:50	Intake	2.445	0.119	0.115	-	-	1.032
	13:15	Exhaust	2.679	0.130	0.102	-	-	1.278
								1.139±0.084

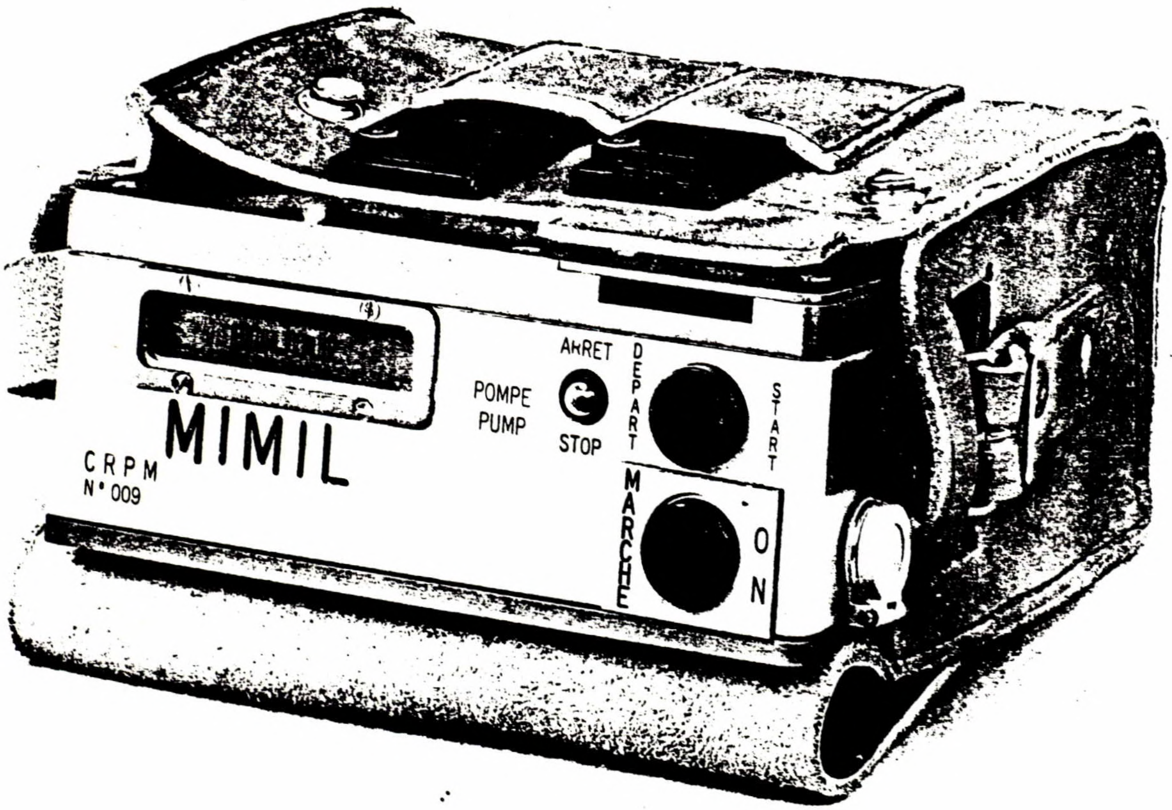

Fig. 1 - View of the MIMIL.