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The EWLMII, A Measurement and Data-Acquisition System for Radon Daughters

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Introduction

Historical Background[1,2,3]

In 1972, the Radiological and Environmental Research Division of Argonne National Laboratory contracted with the United States Bureau of Mines for the development of three identical instruments to measure Rn-daughter concentrations and Working Level (WL), in uranium mine atmospheres. This project, under the direction of Dr. Peter Groer, led to the development of the Instant Working Level Meter (IWLM). The basic principles for the Groer method of measurement of Rn-daughter concentration were developed and proven with these instruments. These IWLM's were small portable units utilizing a calculator chip to automatically make the mathematical calculations required to compute the WL. CMOS circuitry and a small 12 liter/minute pump were used to permit battery powered operation.

This development led to another contract between the Electronics Division of Argonne National Laboratory and the Bureau of Mines for the development of the Remote Working Level Monitor (RWLM). The RWLM's electronics package was micro-processor based to provide automatic operation. The monitor was programmable via a keyboard to start and stop at selected times and to take measurements at desired time intervals, providing a fully automatic operation. This instrument differed from the IWLM in several ways:

It was a stationary unit with two remote monitoring stations automatically controlled from a central micro-processor. It was similiar in it's measurement sensitivity, (.01 WL) and utilized a flow rate of 12 liters per minute. The RWLM however, contained an automatic filter advance mechanism where the IWLM was manually operated. The data were printed out on a Texas Instruments Silent 700 terminal.

The Environmental Working Level Monitors (EWLM) were developed under a contract between the EPA and ANL. Under this contract, four instruments were built. Although the method of measurement was the same for all instruments developed, these units differed considerably

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from the previously constructed instruments. The first difference between the EWLM and the RWLM was measurement sensitivity. The EWLM had a sensitivity of (.001 WL) and a sampling flowrate of approximately 40 liters per minute compared to (.01 WL) and 12 liters per minute for the RWLM. The second significant difference was that each EWLM was self contained. That is, it contained a complete system, including the the micro-computer in one portable aluminum case. The EWLM's were designed for environmental measurements in non-mine atmospheres.

As experience with the field operation of the EWLM's accumulated, the ease with which these instruments automatically monitored environmental Rn-daughter concentrations and WL became more and more evident. This field experience led to the development of additional EWLM's for two of the scientific divisions at Argonne National Laboratory. The new EWLM's incorporated improvements designed to correct some maintenance problems which occurred in the original EWLM design. These new instruments (EWLMII) and their differences with the EWLM's is discussed in detail below.

Groer Method[1,2,3,4]

A brief review of the Groer method for the measurement of the Rn-daughter concentrations and the WL is beneficial in the understanding of the operation and principles of the EWLM and EWLMII.

The EWLM and the EWLMII use identical timing intervals to accumulate the data for the Groer method of Rn-daughter measurement. They first take a background count for three minutes. They then collect an air sample onto a filter membrane for three minutes and then move the filter membrane to a counting station. This air sample is then counted for three minutes starting 13 seconds after the end of the sampling period. The instrument has three counting channels; the lower-energy alpha channel, the upper-energy alpha channel, and a beta sensitive channel. The RaA counts observed are accumulated in the lower-energy alpha channel; the RaC' counts are stored in the upper-energy alpha channel, while the total beta counts from RaB and RaC are recorded in the beta channel. The counts in these three channels are functions of N_A, N_B, N_C, the unknown concentrations of RaA, RaB and RaC in the ambient air (units are atoms/liter). The following relationships hold:

$$\begin{aligned}
TA &= 1.023403\, E_1 V N_A \\
B + C &= (0.110393E_2 + 0.007653E_3)VN_A + (0.214298E_2 \\
&\quad + 0.023559)VN_B + 0.283042E_3 VN_C \\
TC' &= (0.007653N_A + 0.023559N_B + 0.283042N_C)E_1 V \qquad (1)
\end{aligned}$$

where:

TA = alpha counts from RaA accumulated during the 3 min counting period starting 13 sec after the end of sampling.

B + C = beta counts from RaB and RaC in beta channel accumulated during the same time interval as above.

TC' = alpha counts from RaC' (same period of accumulation as above).

V = flowrate (liters/min).

E_1 = detection efficiency for RaA and RaC'.

E_2 = detection efficiency for RaB.

E_3 = detection efficiency for RaC.

N_A = RaA concentration in units of atoms/liter.

N_B = RaB concentration in units of atoms/liter.

N_C = RaC concentration in units of atoms/liter.

The numerical coefficients in (1) follow from the laws of radioactive series decay. The half-lives used are:

Nuclide	Half-life
RaA(^{218}Po)	3.05 min
RaB(^{214}Pb)	26.8 min
RaC(^{214}Bi)	19.7 min

To show the principle of calculation of these numerical coefficients, a sample calculation is given below:

EXAMPLE: Calculate the numerical coefficient for the first of (1).

This coefficient is the product of three factors:

1) Buildup factor = $1 - \exp(^{-}\lambda_A t_B)$

t_B = buildup time = 3 min.

2) Delay factor = $\exp(^{-}\lambda_A D)$

D = Delay before start of the counting interval

= 13 sec or 13/60 min.

3) Decay factor = $[1 - \exp\,(^{-}\lambda_A t_D)]^{\lambda}/\ A$

t_D = decay time = 3 min.

λ_A = RaA decay constant = 0.2272614.

Multiplying all these factors one obtains:

$$[1 - \exp\,(-\lambda_A t_B)]\exp\,(-\lambda_A D)[1-\exp\,(-\lambda_A t_D)]/\lambda_A = 1.023403.$$

The derivations of the analogous coefficients for the other equations are more complex but easily obtainable by the computer programs. If all the efficiencies and the flow rate are known, (1) contains only numerical coefficients and the unknowns N_A, N_B and N_C. Inverting (1) results in another set of equations which give a N_A, N_B and N_C for every observed set of TA, (B+C) and TC'. The WL can be calculated easily from the resulting N_A, N_B and N_C.

The alpha efficiency E_1 is easily measured in the laboratory, but to determine the beta efficiencies, E_2 and E_3, a calibration run must first be made. Once E_1 is known, E_2 and E_3 can be determined by the following procedure. Knowledge of E_1 allows a complete analysis of any air sample by a method using total alpha counts. This method allows calculation of N_A, N_B and N_C for this particular air sample. N_A, N_B and N_C can then be used to calculate the beta disintegrations from RaB and RaC. By comparing the calculated beta disintegrations with the observed total beta counts, the values for E_2 and E_3 are obtained. The necessary calculations are all performed by the "EWLM CALIBRATION PROGRAM".

To calculate the beta efficiencies E_2 and E_3, the Rn-daughter concentrations (atoms liter) N_A, N_B and N_C must first be determined from the alpha counts during several counting periods using the following equations:

$$N_A = 0.711318*A_5/E_1*V$$

$$N_B = (-.689775*A_5 - 7.54536*C_5 + 1.86689*C_3)/E_1*V$$

$$N_C = (0.0441761*A_5 + 3.01566*C_5 - 0.203315*C_3)/E_1*V \qquad (2)$$

where:+

A_5 = RaA counts observed during 5 min starting 13 sec after the end of the 3 min sampling time.

C_5 = RaC' counts observed during the same time interval as above.

C_3 = RaC' counts observed during 30 min. starting at the same time as above.

+ The overlap corrections must be incorporated into the alpha counts (A_5, C_5 and C_3).

The numerical coefficients in (2) are again derived from the laws of radioactive-series decay. This derivation is straightforward but lengthy and will therefore be omitted.

With N_A, N_B and N_C known, E_2 and E_3 can be determined from the following equations:

$$\begin{aligned} Q_1 &= (0.212378*N_A + 0.348201*N_B)*V*E_2 + (0.019829*N_A \\ &\quad + 0.0496395*N_B + 0.455804*N_C*V*E_3 \\ Q_2 &= (1.482571*N_A + 1.549219*N_B)*V*E_2 + (0.599567*N_A \\ &\quad + 0.736276*N_B + 1.842208*N_C)*V*E_3 . \end{aligned} \tag{3}$$

where

Q_1 = total beta counts observed during 5 min starting 13 sec after the end of the 3 min sampling time.

Q_2 = total beta counts observed during 30 min same time as above.

Inverting equations (3), the beta efficiencies E_2 and E_3 can be determined, then (1) can be inverted and properly scaled. When properly scaled, this yields a set of equations which gives the Rn-daughter concentrations in pCi/liter. The WL can also be expressed as a linear combination of A, (B + C) and C'. These counts are net counts, i.e., the background has been subtracted. The equations are of the following form:

$$\begin{aligned} \text{WL} &= C_1(A) + C_2(B + C) + C_3(C') \\ \text{RaA(pCi/liter)} &= C_4(A) + C_5(B + C) + C_6(C') \\ \text{RaB(pCi/liter)} &= C_7(A) + C_8(B + C) + C_9(C') \\ \text{RaC(pCi/liter)} &= C_{10}(A) + C_{11}(B + C) + C_{12}(C') \end{aligned} \tag{4}$$

C_1 through C_{12} are the derived weighting coefficients which are stored in the memory of the EWLM. It is clear from this description of the calibration, that N_A, N_B and N_C are treated as independent unknowns (i.e., no a priori relationship between these quantities other than radioactive series decay is assumed). The EWLM determines, therefore, the Rn-daughter concentrations and WL, without any assumptions about the Rn-daughter equilibrium.

The EWLMII

Calibration^{5,6}

To be able to measure the WL and the Rn-daughter concentrations, the coefficients C1 through C12 of equations (4) must be contained in the EWLMII's permanent memory. A calibration program automates the solution of the equations for radioactive-series decay, as applied to the EWLMII, and calculates the required efficiencies and coefficients. However, to provide this external program with input data, a calibration run by the EWLMII is required first.

An internal calibration program is requested via the keyboard which automatically takes a series of 20 - forty one minute calibration runs. In each 41 minute run a normal measurement is made using a single 3 minute sample but the counting time is not terminated after 3 minutes as in a regular run. Data is stored in memory and printed out on the printer for several time periods. The data printed out is the WL followed by the Rn-daughter concentrations for a standard run as well as the counts for all the counting channels for 3 minutes, 5 minutes, 30 minutes, 35 minutes and the counts during the time interval between 39 and 41 minutes after sampling.

This data can then be used as input for a "Calibration Program" running on a seperate microcomputer. After entering the data generated by the calibration runs of the EWLMII into this external program, it will perform the following functions:

1) It calculates the Rn-daughter concentrations by three different methods and the WL by four different methods from the input data of each individual run. The four different methods are, the alpha-spectroscopic method, the total-alpha method, The Kusnetz method and the Groer method.

2) It calculates the RaB and RaC efficiencies using the Rn-daughter concentrations calculated by the total-alpha method, and the beta counts at two different periods of time.

3) It calculates the 12 coefficients needed for the Groer method.

4) It calculates the Rn-daughter concentrations from 9 of these calculated coefficients, in units of atoms/liter.

5) It calculates the WL from the Rn-daughter concentrations, and with the use of the three remaining coefficients it also determines the WL directly from the measured counts.

This calibration program has two branches, one which calculates the beta efficiencies from the input data, and another which uses the mean value of the beta efficiencies previously calculated to derive the final weighted coefficients. A tabulation of the beta efficiency values calculated in 20 seperate calibration runs and the final weighted coefficients are shown in the Table of Efficiencies and Coefficients.

Inputting the mean value of the beta efficiencies into the second branch of this program, as well as the input count data asked for by the program, results in the calculated values of the Rn-daughter concentrations and WL. The calculated concentrations and WL's are for a single 3 minute sample of air.

A summary of the calculated values is shown in the Table of Calibration Data. The units used in this table for the Rn-daughters are Atoms/Liter. The constants used in these calculations for the specific Unit calibrated are also shown, with, EA the alpha efficiency, EB and EC the RaB and RaC beta efficiencies respectively, V the flow-rate in liters/minute and OL the overlap correction factor. You will notice good agreement between the values of the Rn-daughter concentrations and the WL's calculated by the various independent methods for each individual run.

Electronic and Mechanical Improvements

After extended use of the EWLM's in the field, certain areas of high maintenance began to appear. To eliminate these problems modifications were incorporated into the EWLMII and are listed below:

The Bomar printer suffered from excessive mechanical failures because its plastic parts were apparently too fragile for continuous operation. Therefore, the printer and its interface card were replaced with a more reliable system. A Texas Instruments model EPN 9120 thermal printer and a standardized RS-232 serial interface card were substituted.

The take-up gear assembly on the automatic filter advance mechanism required proper lubrication and adjustment and was prone to failure if not maintained properly. This caused failures in the filter advance cycle. To solve this problem, a torque motor was substituted for the take-up gears to provide the desired filter advance operation.

The paper position fiber-optic sensor caused failures in the filter advance cycle because the optical sensitivity of the sensor was too great. This occasionally caused the filter advance to prematurely stop due to light reflections received 180 degrees out of phase with the positioning mechanism. The solution to this problem was to use a different optical sensing method which eliminated the fiber-optics and used a less expensive, less sensitive, directly coupled optical sensor.

The solenoid clutch-brake occasionally failed due to binding of its cylindrical shaft which prevented full closure of the brake assembly. To eliminate this problem a complete redesign of the clutch-brake assembly was made. This included a longer cylindrical shaft on the clutch assembly and additional windings in the coil assembly.

The scotch yoke assembly of the filter transport mechanism showed excessive wear do to the lack of proper lubrication. The solution was to install a sealed bearing on the driver shaft.

To adjust the length of movement for precise filter membrane positioning in the EWLM's, shimming of the top plate of the filter transport mechanism was required. A more flexible positioning method was needed. Therefore, we redesigned the upper roller arm of the paper drive assembly incorporating a locked cam adjustment in order to more conveniently adjust the filter membrane positioning.

In the process of servicing the EWLM's, we found that they frequently needed to be removed from the outer case. This process was found to be time consuming and costly as all sub-assemblies were bolted separately to the outer case. Therefore, we decided to repackage the EWLMII to provide easy access to all parts without requiring disassembly. An inner mounting frame was designed to which all components could be fastened and which could easily be removed from the outer case. This allowed easy access to components for troubleshooting and repair.

On extended monitoring periods we found that the printer paper was occasionally blocking the airflow into the sample port. Therefore, the filter advance mechanism was repositioned with respect to the printer so as to eliminate any possibility of obstruction of the air sampling port.

In addition to the modifications for the EWLMII listed above, certain other improvements were incorporated. The standard (STD) bus was selected to implement the electronics package. This allowed us to purchase commercially most of the required micro-processor cards such as the CPU, the serial and parallel I/O cards and the memory card. We updated our CPU from the 8080 to the 8085 which reduced power requirements and doubled the processing speed. The PROM memory capacity was doubled by using 2k memory chips rather than the original 1k memory chips.

A 16 channel analog to digital converter card has been incorporated in order to be able to measure additional parameters. This card, along with the addition of a digital data recorder allows us to transfer data more efficiently from the EWLMII to external computers for data analysis.

Software Changes

The original operating programs for the RWLM and EWLM were written in PL/M, a high level language developed by the Intel corporation. At that time, Intel's software consisted of a compiler and cross assembler residing externally to their development system. This meant that the compiling and loading of the hex files had to be made via a phone linked into TSO, a time sharing program used by our central computer facility. Although the compiler allowed structured programming it had no capability to link assembly language programs and provided non-relocatable addressing. With these restrictions we were forced to resort to tricks to use assembly language modules such as a floating point mathematics package. To make a small change in the program, the entire program had to be recompiled. This was time consuming both in the compiling operation as well as the resulting debugging that was often required.

However, with the introduction of a resident software PL/M the Intel package now provides linking and locating capabilities. This allowed us to modularize the programming of the EWLMII, linking and locating modules in our local development systems. By building libraries of these modules linking was further simplified. Now minor changes to the program can be made at the module level, and only those modules changed required recompiling. This also means that new modules could quickly be written and linked into the main program. With the use of this new software package, the new or modified modules could then be linked and located in minutes rather that the days taken in the past to recompile and debug the program.

Updated PROM programmers further reduced the time required to change memory. These new instruments and software allow us to down line load several modules at a time into the EWLMII's RAM memory for debugging. After all modules have been thoroughly checked out, the entire program is re-linked and loaded into the PROM programmers buffer. Each PROM for the EWLMII's operating system is then programmed and inserted into the memory board. This process greatly accelerates the time needed to debug, check out and program a new operating program.

MEASUREMENT OF ADDITIONAL PARAMETERS

The increased memory capacity and the addition of an Analog I/O subsystem in the EWLMII allows us to measure additional parameters. An Analog Devices Model RT-1225 STD bus compatible card was used. It provides the system with 16 channels of analog input and 2 channels of analog output. It contains a standard sample and hold amplifier with a monolithic 10 bit A/D converter with the flexibility of 16 single ended or 8 differential inputs. It operates off a single +5 volt power supply and contains a memory mapped I/O.

Through the use of this card additional parameters such as, inside and outside temperatures, atmospheric pressure, wind velocity and direction, humidity and control switches are interfaced to the EWLMII, making this instrument a true data acquisition system. These external DC inputs and others can be added to the system to output additional parameters on either a predetermined or programmable schedule. Additional program modules for this added capability can easily be linked into the main EWLMII program. This relinked program can then be burned into the PROM's to provide this additional monitoring ability.

Data Storage, Display and Analysis

The EWLM and EWLMII temporarily store their data in active memory (RAM) and this information is then transferred to the printer at the completion of the measurement cycle. Subsequent measurements use the same data area causing the loss of previous data. The only storage media used in the EWLM was the printed data stored on a continuous paper tape. This method of data readout required that these recorded values be entered into an external computer for analysis.

To streamline the data processing, a TEAC MT-2 digital data recorder was added to the EWLMII. Immediately after the data has been printed out, it is then recorded on the digital cassette recorder. The EWLM's print out a short report onto the 20 character per line printer. There is additional data stored in memory which is not printed out in this short report. The digital cassette records the complete memory image, therefore all data is permanently stored on the cassette. This allows us to use any part of or all of this data for our analysis. The data from each sample is contiguously stored on the tape. When the series of runs are complete an "E" is entered into the keyboard which will close out the file and rewind the tape. The cassette is then removed from the EWLMII and is ready for a data transfer.

To display and analyze this data stored on the cassette, we used a micro-computer with 32k of memory configured with an identical digital data recorder, an eight inch floppy disk and a dual serial port.

Software was written which loads the tape, transfers the cassette tape's data into the micro-computers memory and then rewinds the tape. After the data has been transferred to the computer's memory the cassette can be removed for reuse in the EWLMII. Another program was written to display a complete report of the data on the terminal or line printer. Additional programs are to be written for data analysis. This stored data can be transferred to the floppy disk and data from additional tapes can be added to this extended data file. This library of data can then be used for data analysis. Programs can be written to either tabulate or plot the WL and Rn-daughter concentrations verses time. Other manipulations of the data can be printed such as Rn-daughter ratios, statistical evaluations and comparisons of the daughter concentrations with; barometric pressure, humidity, temperature, inside-outside temperature differences, air circulation rates, air filter effects with air flow-rates and time and other parameters.

Conclusion

Development of new methods and instruments for the measurement of WL and Rn-daughter concentrations has been in progress for several years. However, efficient methods of data acquisition has not been the primary thrust of this research. If large volumes of data from automated instruments are to be efficiently analyzed, a built in data acquisition system is needed. One such an instrument, the EWLMII, has been described in this paper. The need for accelerated research for the understanding and control of Rn-daughters can be enhanced by such an instrument.

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TABLE OF EFFICIENCIES and COEFFICIENTS

EWLMII UNIT 2
2-9-81, TWILIGHT MINE URAVAN,COLORADO

RUN	EB	EC
1	.2020	.2887
2	.1799	.3129
3	.1769	.3167
4	.2146	.2772
5	.1954	.2983
6	.1574	.3374
7	.1835	.3017
8	.1949	.2850
9	.1565	.3345
10	.1784	.3053
11	.1663	.3177
12	.2076	.2746
13	.1915	.2874
14	.2247	.2455
15	.1684	.3116
16	.1565	.3230
17	.2203	.2505
18	.1676	.3078
19	.1703	.3147
20	.1914	.2771

AVERAGE EB = .1852 STANDARD DEVIATION = .0211

AVERAGE EC = .2984 STANDARD DEVIATION = .0250

COEFFICIENTS

4.7095478359E-06	3.49815313024E-05	-1.71403658529E-05	WL
6.36590042261E-03	0.00	-1.65513410988E-03	RaA
-3.73206192398E-04	7.52498502545E-03	-6.92698319685E-03	RaB
1.5610219182E-05	-8.52066462292E-04	5.28141146336E-03	RaC

TABLE OF CALIBRATION DATA

EWLMII UNIT 2
2-9-81, TWILIGHT MINE URAVAN,COLORADO
EA=.4028 EB=.1852 EC=.2984 V=39.01 OL=.26

	ALPHA SPEC.	TOT.ALPHA	GROER	KUZ
RUN 1				
RaA	531.62	541.23	525.06	
RaB	2234.72	2490.50	2511.20	
RaC	1339.34	1281.56	1320.23	
WL	.2671	.2798	.2816	.2759
RUN 2				
RaA	502.94	509.71	502.62	
RaB	2051.15	2237.05	2290.43	
RaC	1280.54	1239.21	1259.60	
WL	.2498	.2590	.2626	.2554
RUN 3				
RaA	483.36	486.49	478.96	
RaB	2032.74	2159.80	2143.99	
RaC	1278.29	1254.74	1278.34	
WL	.2465	.2529	.2526	.2544
RUN 4				
RaA	476.93	489.85	474.01	
RaB	1911.69	2077.52	2125.45	
RaC	1225.43	1167.08	1226.23	
WL	.2355	.2432	.2479	.2435
RUN 5				
RaA	477.68	491.56	471.09	
RaB	1877.39	2046.68	2084.18	
RaC	1259.92	1198.17	1245.89	
WL	.2356	.2434	.2463	.2527
RUN 6				
RaA	476.76	466.71	461.54	
RaB	1824.90	1885.25	1949.83	
RaC	1176.87	1173.69	1156.76	
WL	.2266	.2298	.2321	.2353
RUN 7				
RaA	464.27	495.65	462.13	
RaB	1853.58	2116.37	1951.37	
RaC	1190.79	1064.14	1194.29	
WL	.2287	.2401	.2345	.2355

EWLMII UNIT 2

	ALPHA SPEC.	TOT. ALPHA	GROER	KUZ
RUN 16				
RaA	447.41	455.23	445.48	
RaB	1694.11	1756.25	1479.86	
RaC	1059.00	1027.87	1105.09	
WL	.2097	.2124	.1996	.2126
RUN 17				
RaA	414.10	453.60	413.15	
RaB	1525.72	1751.83	1499.24	
RaC	1013.70	865.62	1020.21	
WL	.1936	.2023	.1923	.1917
RUN 18				
RaA	358.36	382.94	355.56	
RaB	1298.76	1396.09	1169.06	
RaC	817.77	730.37	840.17	
WL	.1627	.1659	.1561	.1607
RUN 19				
RaA	354.76	372.17	353.07	
RaB	1069.26	1143.29	957.81	
RaC	776.95	714.51	802.29	
WL	.1464	.1489	.1411	.1462
RUN 20				
RaA	358.06	378.46	358.52	
RaB	1145.07	1239.90	1044.75	
RaC	744.27	670.21	764.88	
WL	.1493	.1527	.1446	.1560

EWLMII UNIT 2

	ALPHA SPEC.	TOT. ALPHA	GROER	KUZ
RUN 8				
RaA	496.75	511.94	496.25	
RaB	2071.82	2224.76	2062.23	
RaC	1219.44	1155.39	1238.82	
WL	.2467	.2536	.2472	.2563
RUN 9				
RaA	492.43	483.54	487.69	
RaB	1947.77	1984.61	1980.26	
RaC	1244.22	1268.14	1264.01	
WL	.2404	.2430	.2430	.2459
RUN 10				
RaA	507.79	516.76	504.65	
RaB	2092.49	2255.62	2126.36	
RaC	1264.74	1219.06	1275.75	
WL	.2518	.2597	.2541	.2582
RUN 11				
RaA	514.50	523.17	517.78	
RaB	2092.66	2186.74	2058.15	
RaC	1249.48	1212.22	1263.51	
WL	.2516	.2559	.2507	.2525
RUN 12				
RaA	448.05	475.11	444.87	
RaB	1814.10	2016.33	1836.98	
RaC	1207.58	1101.00	1204.95	
WL	.2256	.2342	.2265	.2231
RUN 13				
RaA	493.76	528.21	492.39	
RaB	1727.60	1955.32	1647.76	
RaC	1175.96	1043.48	1214.78	
WL	.2235	.2327	.2209	.2249
RUN 14				
RaA	514.95	584.07	512.50	
RaB	1700.60	2115.32	1774.62	
RaC	1216.51	955.24	1218.41	
WL	.2265	.2429	.2308	.2366
RUN 15				
RaA	496.12	511.36	495.36	
RaB	1813.69	1904.92	1703.11	
RaC	1186.01	1128.48	1210.38	
WL	.2294	.2330	.2242	.2317