Test Report

Size and Concentration of Airborne Particulates in the Atmosphere of the Dental Office of Drs. Van Hale and Arima

June 20, 2008

Prepared by:

California Measurements, Inc.
150 East Montecito Avenue
Sierra Madre, CA 91024

Preface

On May 22, 2008, air particle size and concentration tests were conducted by William Chiang and Tom Chen of California Measurements at the dental offices of Drs. (D.D.S.) Gregory L. Van Hale and Cathleen T. Arima at 247 West Glenoaks Boulevard, Glendale, California. This report contains the data gathered during the tests and a summary of the test results.

Contents

1.0 OBJECTIVES

(1) To obtain aerosol size and concentration profiles in the ambient air at different parts of the dental suite.

(2) To obtain aerosol size and concentration data during dental procedures, with air samples drawn from a region close to the drilling site.

2.0 PROCEDURES

2.1 Test Sites

Figure 1-1 is a floor plan of the dental suite. A total of eight tests were made at different parts of the suite, including a test outside of the building. The sites are listed below in the order of their test sequence.

1. Room at west end.
2. Patient waiting room.
3. Room next to northeast corner (Dr. Van Hale root-canal preparation).
4. Room at the east end (teeth cleaning).
5. Front desk.
6. Sidewalk outside.
7. Room at northeast corner (Dr. Arima composite filling).
8. Room next to northeast corner (Dr. Van Hale crown preparation).

Tests 1, 2, and 5 were made to get data on background aerosols in the suite. Test 6 was made to get a data reference on the particles in the air outdoors. Tests 3 and 4 were made in the rooms where dental procedures took place. Tests 7 and 8 were done to get data when particle samples were collected near the drilling sites.

The time spent conducting the tests was 3 hours, from 10:30 a.m. to 1:30 p.m.

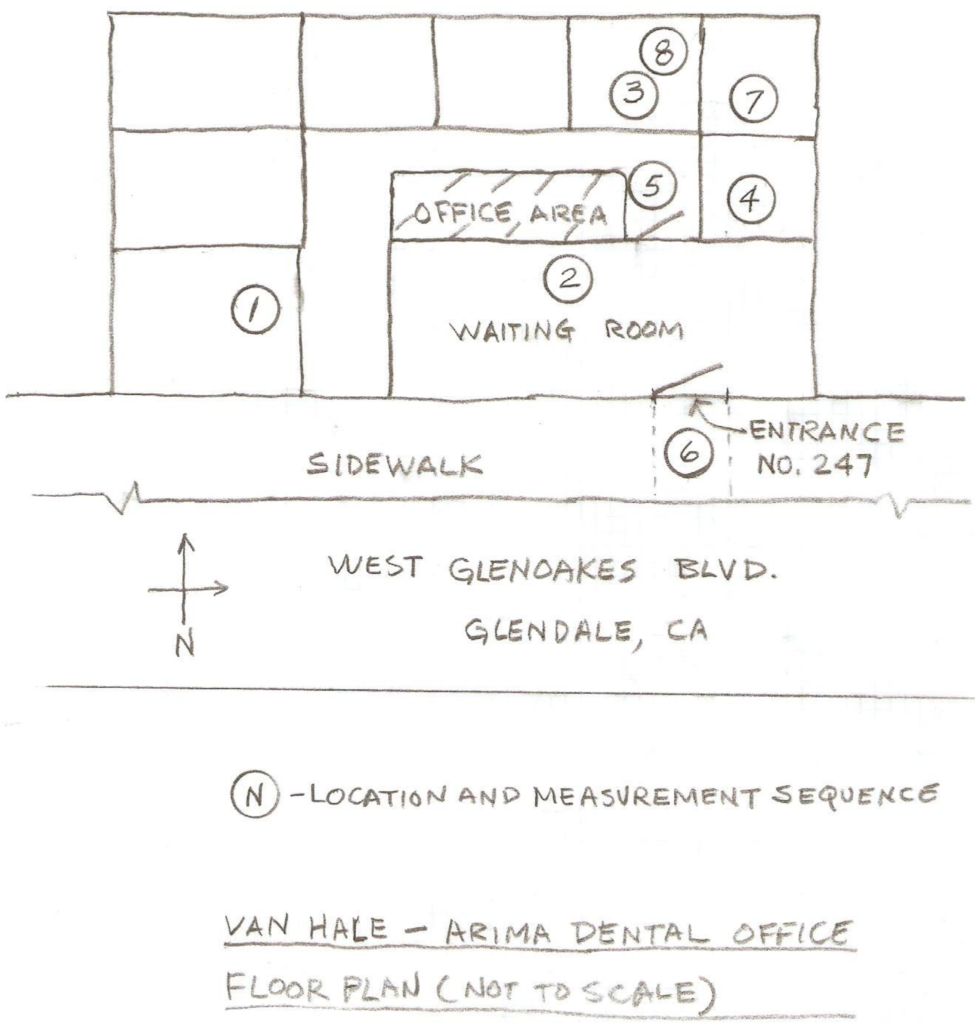

8
3
7
5
4
OFFICE AREA
2
1
WAITING ROOM
ENTRANCE
NO. 247
6
SIDEWALK
WEST GLENOAKES BLVD.
GLENDALE, CA
N
(N) - LOCATION AND MEASUREMENT SEQUENCE
VAN HALE - ARIMA DENTAL OFFICE
FLOOR PLAN (NOT TO SCALE)

Figure 1-1

2.2 Instrument

The instrument used was a California Measurements Model PC-2H 10-stage Quartz Crystal Microbalance (QCM) real-time aerosol analyzer. A description of this instrument is in the product brochure in the Appendix.

This instrument utilizes well-established inertial impaction principle to segregate air-suspended particles by size. It provides mass concentration data in ten size fractions, covering a range of 10 to 0.05 micron. The particle size cut-points of its 10-stage cascade impactor are:

STAGE	D50	EAD
1	>10 micron	>14 micron
2	5.6	7.9
3	3.0	4.2
4	2.0	2.8
5	1.0	1.4
6	0.5	0.7
7	0.3	0.4
8	0.2	0.3
9	0.1	0.14
10	0.05	0.07

The D50 is the stage cut-off particle diameter based on a particle density of 2 g/m^3 and the EAD is the Equivalent Aerodynamic Diameter based on a particle density of 1 g/m^3. Since the density of most particles in the ambient air is close to 2 g/m^3, D50 diameters are usually used for engineering purposes. When the aerodynamic behavior of particles is of more interest, such as in studying health effects of air-suspended particles, the EAD is used. The conversion factor between D50 based on density of 2 and EAD based on unit density is 1.414, or the square-root of the inverse ratio of the two densities.

Unless noted otherwise, the particle diameter referred to in this report is the D50 based on particle density of 2 g/cc.

A data printout was provided by the instrument within a few minutes after each measurement. The sampling time used was in the range of 60 seconds. The total time required to make a measurement and get a data printout was about 2 minutes. The instrument was placed on a dolly with wheels and pushed from site to site for test runs. Figure 1-2 is a picture of the instrument on the dolly.

This instrument was especially suitable for the tests, because researchers have used it in the past to study dental aerobiology and blood aerosols generated by surgical tools. Moreover, it has a 30-year history of reliable performance in different fields of aerosol research; see applications log in the Appendix on page 30.

2.3 Air Sample Inlet

The standard air sample inlet on the instrument was a short 0.187 inch inside diameter stainless tube, and the air sample was drawn into and through the cascade impactor at a flow rate of 2 std-liters/minute. With this inlet arrangement, particles in the air immediately surrounding the inlet were sampled.

A special setup was used to draw samples from a zone within 12 inches of the drilling site. For this arrangement, an extension tube of 6 feet was added to the impactor inlet. The inlet of the extension tube, was placed to a point that was within 12 inches of the breathing zone of the patient. With this arrangement, aerosol samples were captured soon after they were generated during the drilling process. The setup was used for collecting data during composite filling and crown preparation procedures; see Figure 1-3.

Sampling on Sidewalk at Entrance of Building

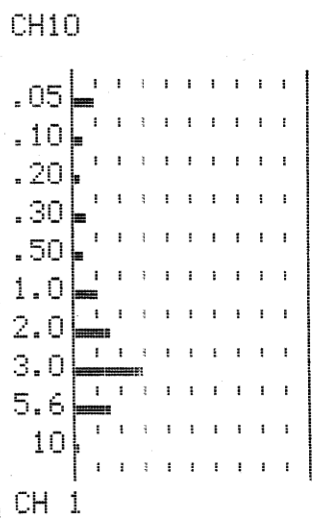
Figure 1-2

Sampling During Composite Filling Procedure by Dr. Arima

Figure 1-3

2.4 Data Printouts

Nineteen data printouts are were obtained during the 8 tests. They are shown in Figures 2-1 to 2-9 on the following pages.



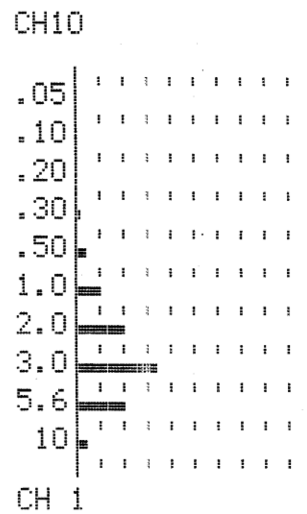
ΔT=060

RUN 01

TOTAL 0.03185

CH	ΔF	mg/m³
1	0001	0.00070
2	0008	0.00536
3	0021	0.00924
4	0015	0.00495
5	0011	0.00319
6	0005	0.00140
7	0007	0.00189
8	0003	0.00096
9	0004	0.00128
10	0009	0.00288

[A]



ΔT=060

RUN 02

TOTAL 0.03065

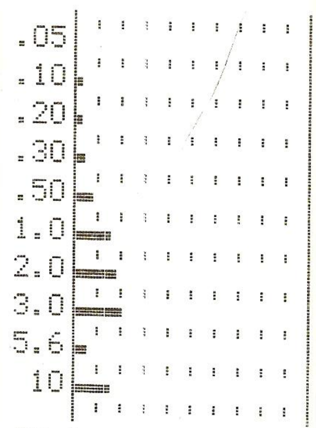
CH	ΔF	mg/m³
1	0002	0.00140
2	0010	0.00670
3	0024	0.01056
4	0019	0.00627
5	0011	0.00319
6	0005	0.00140
7	0003	0.00081
8	0001	0.00032
9	-0001-	0.00032
10	-0001-	0.00032

[B]

Figure 2-1

Data Set 1 – Room at West End of Suite; Fully Equipped but No Activity

CH10



CH 1

ΔT=066

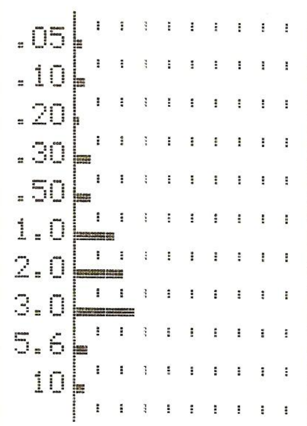
RUN 01

TOTAL 0.03215

CH	ΔF	mg/m³
1	0008	0.00509
2	0003	0.00182
3	0017	0.00680
4	0020	0.00600
5	0020	0.00527
6	0011	0.00280
7	0006	0.00147
8	0004	0.00116
9	0004	0.00116
10	0002	0.00058

[A]

CH10



CH 1

ΔT=066

RUN 03

TOTAL 0.03129

CH	ΔF	mg/m³
1	0002	0.00127
2	0003	0.00182
3	0021	0.00840
4	0021	0.00630
5	0021	0.00553
6	0009	0.00229
7	0009	0.00220
8	0003	0.00087
9	0005	0.00145
10	0004	0.00116

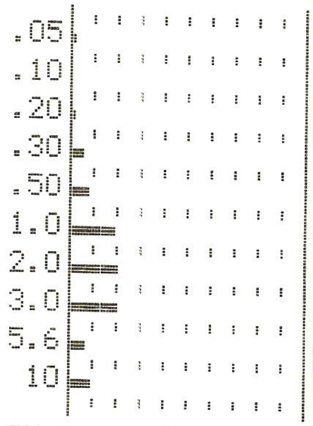
[B]

Figure 2-2

Data Set 2 – Center of Waiting Room Area

[A]

CH10



CH 1

ΔT=060

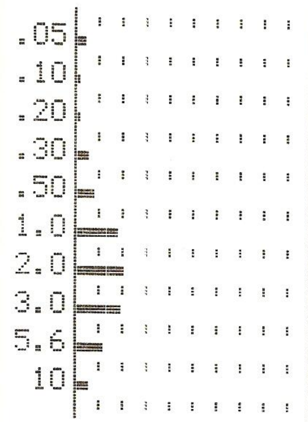
RUN 02

TOTAL 0.09105

CH	ΔF	mg/m³
1	0013	0.00910
2	0010	0.00670
3	0044	0.01936
4	0057	0.01881
5	0062	0.01798
6	0028	0.00784
7	0018	0.00486
8	0007	0.00224
9	0005	0.00160
10	0008	0.00256

[B]

CH10



CH 1

ΔT=060

RUN 03

TOTAL 0.08830

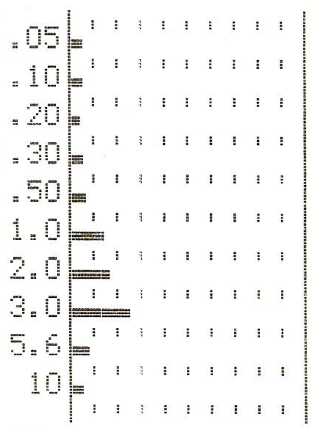
CH	ΔF	mg/m³
1	0008	0.00560
2	0016	0.01072
3	0039	0.01716
4	0054	0.01782
5	0057	0.01653
6	0027	0.00756
7	0017	0.00459
8	0006	0.00192
9	0008	0.00256
10	0012	0.00384

Figure 2-3

Data Set 3 – During Root-Canal Access Procedure (Dr. Van Hale); Second Room from NE Corner

[A]

CH10



CH 1

ΔT=060

RUN 02

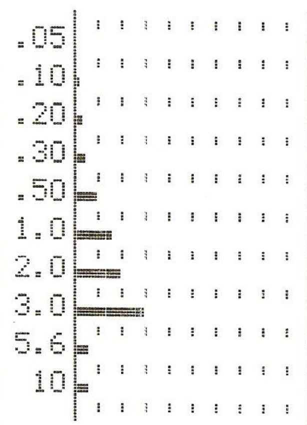
TOTAL 0.03966

CH	ΔF	mg/m³
1	0003	0.00210
2	0005	0.00335
3	0023	0.01012
4	0021	0.00693
5	0020	0.00580
6	0010	0.00280
7	0008	0.00216
8	0005	0.00160
9	0007	0.00224
10	0008	0.00256

[A]

[B]

CH10



CH 1

ΔT=060

RUN 03

TOTAL 0.03086

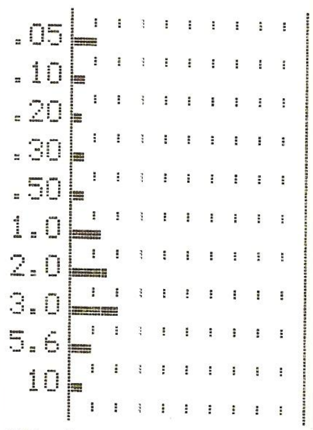
CH	ΔF	mg/m³
1	0003	0.00210
2	0003	0.00201
3	0021	0.00924
4	0018	0.00594
5	0018	0.00522
6	0011	0.00308
7	0005	0.00135
8	0003	0.00096
9	0002	0.00064
10	0001	0.00032

[B]

Figure 2-4

Data Set 4 – Teeth Cleaning in Progress; Room at East End of Suite

CH10



CH 1

ΔT=065

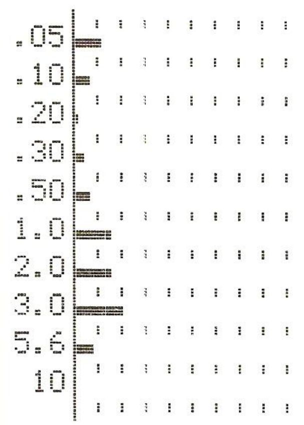
RUN 01

TOTAL 0.03829

CH	ΔF	mg/m³
1	0003	0.00193
2	0006	0.00371
3	0020	0.00812
4	0019	0.00578
5	0019	0.00508
6	0010	0.00258
7	0009	0.00224
8	0006	0.00177
9	0009	0.00265
10	0015	0.00443

[A]

CH10



CH 1

ΔT=065

RUN 02

TOTAL 0.03538

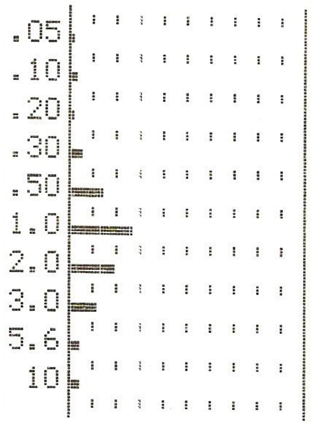
CH	ΔF	mg/m³
1	0001	0.00064
2	0005	0.00309
3	0019	0.00771
4	0019	0.00578
5	0022	0.00588
6	0010	0.00258
7	0007	0.00174
8	0003	0.00088
9	0009	0.00265
10	0015	0.00443

[B]

Figure 2-5

Data Set 5 – Front Desk Area; East End of Suite at Door to Waiting Room

CH10



CH 1

ΔT=065

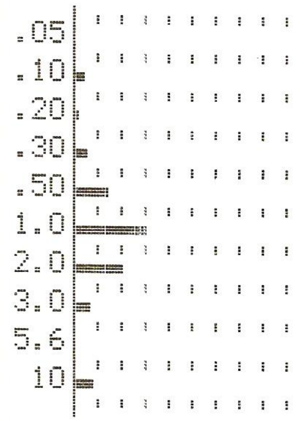
RUN 02

TOTAL 0.03975

CH	ΔF	mg/m³
1	0003	0.00193
2	0003	0.00185
3	0012	0.00487
4	0026	0.00792
5	0041	0.01097
6	0023	0.00594
7	0011	0.00274
8	0003	0.00088
9	0005	0.00147
10	0004	0.00118

[A]

CH10



CH 1

ΔT=065

RUN 03

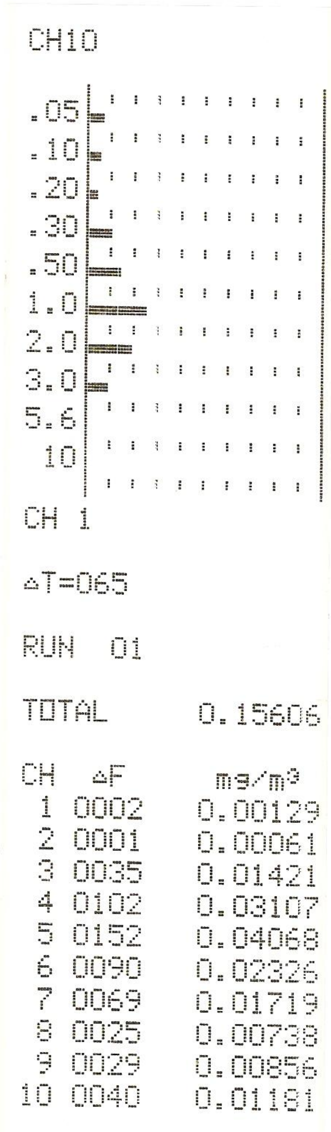
TOTAL 0.03640

CH	ΔF	mg/m³
1	0005	0.00323
2	0001	0.00061
3	0007	0.00284
4	0025	0.00761
5	0043	0.01151
6	0021	0.00542
7	0009	0.00224
8	0003	0.00088
9	0005	0.00147
10	0002	0.00059

[B]

Figure 2-6

Data Set 6 – Sidewalk (Outdoor); at Main Entrance to Building



CH10

.05 .10 .20 .30 .50 1.0 2.0 3.0 5.6 10

CH 1

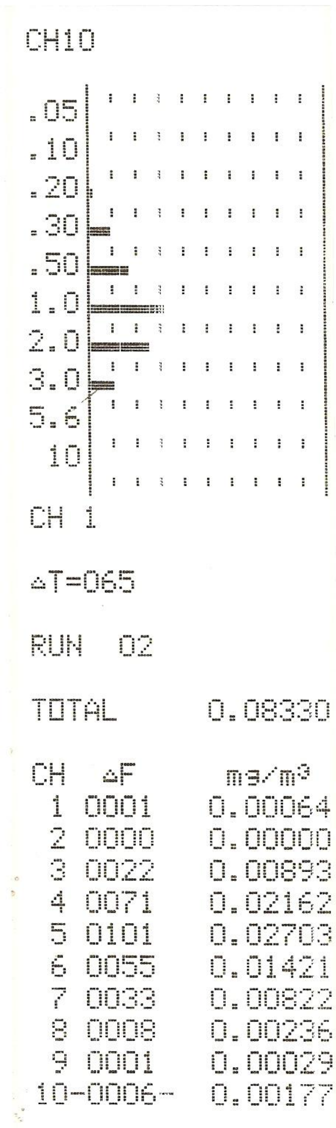
ΔT=065

RUN 01

TOTAL 0.15606

CH	ΔF	mg/m³
1	0002	0.00129
2	0001	0.00061
3	0035	0.01421
4	0102	0.03107
5	0152	0.04068
6	0090	0.02326
7	0069	0.01719
8	0025	0.00738
9	0029	0.00856
10	0040	0.01181

[A]



CH10

.05 .10 .20 .30 .50 1.0 2.0 3.0 5.6 10

CH 1

ΔT=065

RUN 02

TOTAL 0.08330

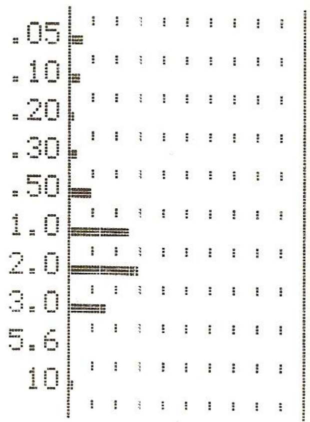
CH	ΔF	mg/m³
1	0001	0.00064
2	0000	0.00000
3	0022	0.00893
4	0071	0.02162
5	0101	0.02703
6	0055	0.01421
7	0033	0.00822
8	0008	0.00236
9	0001	0.00029
10	-0006-	0.00177

[B]

Figure 2-7

Data Set 7 – During Composite Filling Procedure (Dr. Arima); NE Corner Room

CH10



CH 1

ΔT=065

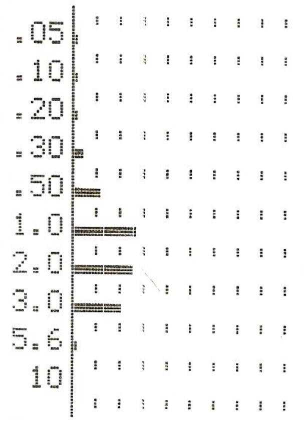
RUN 03

TOTAL 0.04662

CH	ΔF	mg/m³
1	0002	0.00129
2	0000	0.00000
3	0018	0.00731
4	0045	0.01370
5	0045	0.01204
6	0018	0.00465
7	0007	0.00174
8	0004	0.00118
9	0007	0.00206
10	0009	0.00265

[C]

CH10



CH 1

ΔT=065

RUN 04

TOTAL 0.02746

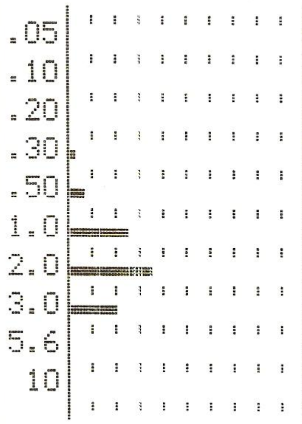
CH	ΔF	mg/m³
1	0000	0.00000
2	0001	0.00061
3	0014	0.00568
4	0024	0.00731
5	0028	0.00749
6	0013	0.00336
7	0005	0.00124
8	0002	0.00059
9	0002	0.00059
10	0002	0.00059

[D]

Figure 2-8

Data Set 7 (continued) – During Composite Filling Procedure (Dr. Arima); NE Corner Room

CH10



CH 1

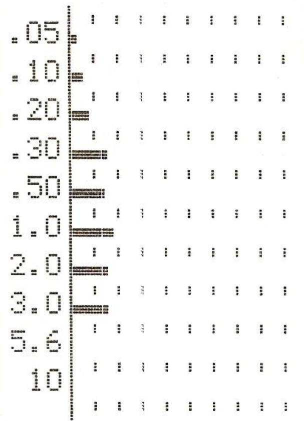
ΔT=065

RUN 01

TOTAL 1.89634

CH	ΔF	mg/m³
1	0054	0.03489
2	0010	0.00618
3	0974■	0.39559
4	2293■	0.69848
5	1811■	0.48479
6	0585■	0.15120
7	0237	0.05906
8	0103	0.03042
9	0081	0.02392
10	0040	0.01181

CH10



CH 1

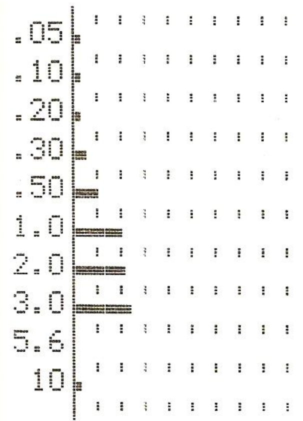
ΔT=065

RUN 02

TOTAL 0.16639

CH	ΔF	mg/m³
1	0001	0.00064
2	-0001-	0.00061
3	0065■	0.02640
4	0092■	0.02802
5	0115■	0.03078
6	0095■	0.02455
7	0111	0.02766
8	0046	0.01358
9	0032	0.00945
10	0018	0.00531

CH10



CH 1

ΔT=065

RUN 03

TOTAL 0.05464

CH	ΔF	mg/m³
1	0003	0.00193
2	0000	0.00000
3	0033■	0.01340
4	0041■	0.01248
5	0042■	0.01124
6	0025■	0.00646
7	0013	0.00324
8	0006	0.00177
9	0007	0.00206
10	0007	0.00206

Figure 2-9

Data Set 8 – During Crown Preparation Procedure (Dr. Van Hale); Second Room from NE Corner

3.0 SAMPLE CALCULATIONS

3.1 Mass Median Diameter (MMD)

An aerosol is composed of particles of many sizes, and the size distribution of those particles is usually log-normal. When aerosols have different size distributions, it is difficult to compare their distribution profiles. A more convenient and meaningful way is to compare the average size of each distribution. For a mass-based particle size distribution, the average size of a polydisperse aerosol is the Mass Median Diameter (MMD). Half of the total mass of the particles in the size range smaller than this value, and half of the mass is in the size range larger than this value.

Since the size distribution is usually log-normal for man-made and naturally formed particles, the MMD can be obtained using a graphical plot of cumulative concentrations versus the particle size on log-probability paper. This is a standard procedure in aerosol science and in the evaluation aerosol medicine. When plotted on log-probability paper, the curve is close to a straight line if the distribution is truly log-normal. The intersection of the plotted curve with the 50% cumulative percentage weight point is the MMD.

The MMD value of each size distribution was obtained using this procedure. A sample on this procedure is shown below using the data from Data Set 1 (Run 01) in Figure 2.

(1) Calculate percent of concentration (C/CT) for each stage. For example, for stage 1, it was 00070 mg/m^3 divided by the total concentration of 03185 mg/m^3 to get 2.2%.
(2) Calculate the cumulative percent starting with stage 10 and continue upward to stage 1. The cumulative percent of a stage is be plotted against the particle size cut-point of the stage immediately above.
(3) A 2-cycle log-probability paper is used. The ordinate is labeled as the particle size in microns and the abscissa is labeled as the "Percent Weight Less Than Stated Size."

STAGE	D50	C/CT	CUM
1	10 micron	2.2 %	99.8%
2	5.6	16.8	80.8
3	3.0	29	51.8

4	2.0	15.5	36.3
5	1.0	10.0	26.3
6	0.5	4.4	21.9
7	0.3	5.9	16.0
8	0.2	3.0	13.0
9	0.1	4.0	9.0
10	0.05	9.0	--

(4) Plot points and obtain curve. The intercept at the 50% point on the curve is the MMD. In this case, it is 3.2 micron.

(5) The Geometric Standard Deviation (GSD) is the particle size corresponding to 84.1% divided by the MMD. In this case, it was 6.2/3.2 = 1.94. (The GSD is an indication of the spread of the distribution.)

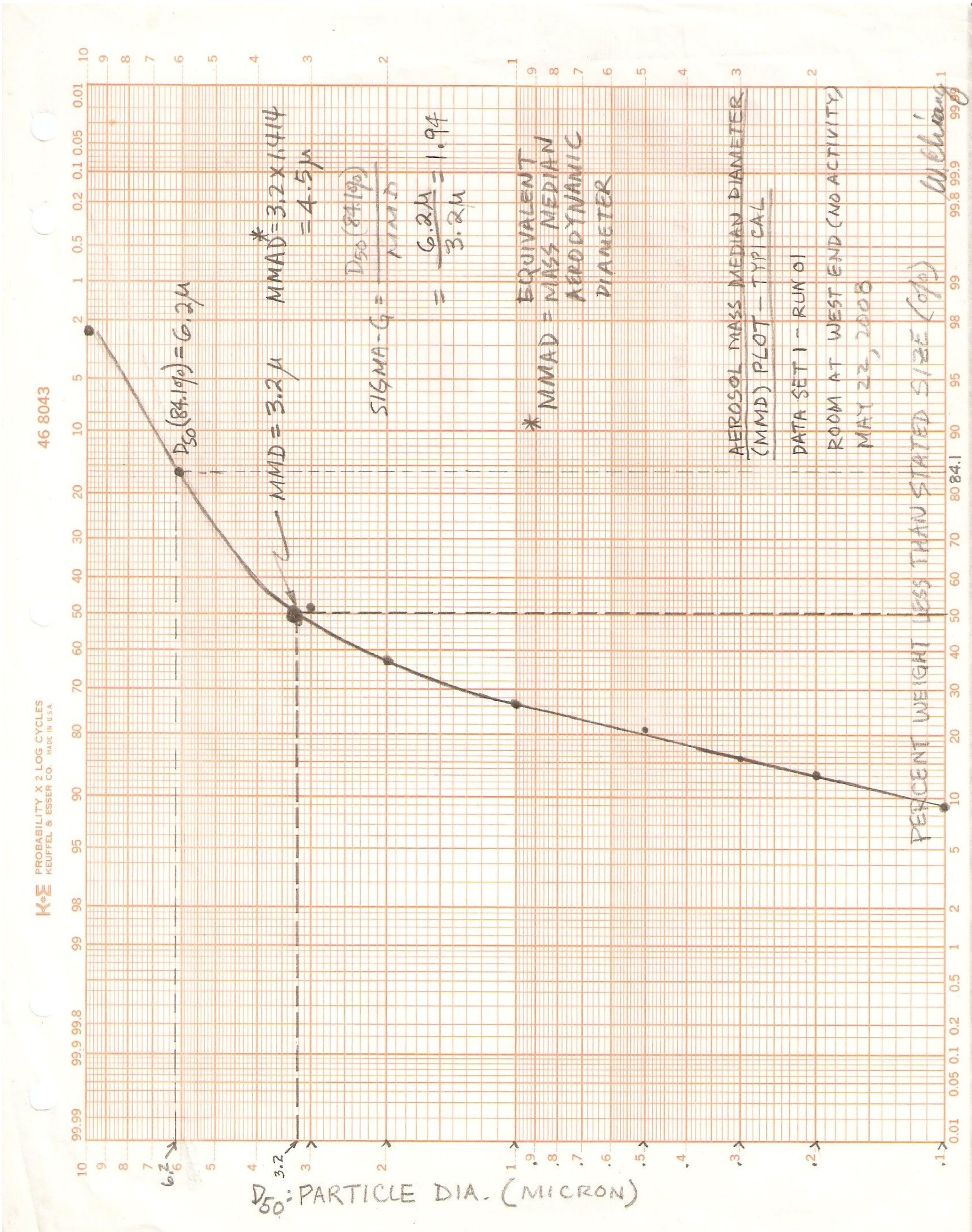
(6) The Mass Median Aerodynamic Diameter (MMAD) based on a particle density of 1 g/m^3 was obtained by multiplying MMD by a factor of 1.414 as explained in Section 2.2. In this case, the MMAD = 3.2 x 1.414 = 4.5 micron.

The MMD, MMAD, and GSD values for all the data sets are in tabular form in Table 1 that follows.

3.2 Percent of Particle Concentration <0.5 Micron

The particle size distributions of the 19 sets of data obtained showed that most the particles were in the size ranges of 1.0 to 3.0 micron. The amounts of particles smaller than the 0.5 micron range varied. In order to have a better visibility of the amounts of the smaller particles, the fractional concentrations of particles in each set of data were found and listed in Table 2 in the next section.

The procedure was to add the concentrations of stages 7, 8, 9, and 10 and divide the sum by the total concentration to get a percentage. (Note: the sum started with stage 7, which collected particles between 0.3 and 0.5 micron. Stage 6, with a cut-point of 0.5 micron, collected particles larger than 0.5 micron and smaller than 1.0 micron in stage 5.) For Data Set -1, Run 01 in Figure 2-1, the sum of the concentrations in stages 7, 8, 9, and 10 was 7.1 micrograms/m^3. That sum divided by the total concentration of 31.85 micrograms/m^3 yielded 22%. Table 2 is a listing of the other values.


K+E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8043
D50 (84.1%) = 6.2µ
MMD = 3.2µ
MMAD* = 3.2 X 1.414
= 4.5µ
SIGMA-G = D50 (84.1%) / MMD
= 6.2µ / 3.2µ = 1.94
* MMAD = EQUIVALENT MASS MEDIAN AERODYNAMIC DIAMETER
AEROSOL MASS MEDIAN DIAMETER (MMD) PLOT – TYPICAL
DATA SET 1 – RUN 01
ROOM AT WEST END (NO ACTIVITY)
MAY 22, 2008
PERCENT WEIGHT LESS THAN STATED SIZE (%)
84.1
6.2
3.2
D50: PARTICLE DIA. (MICRON)

4.0 TABULATED DATA

TABLE-1

C = Aerosol Total Mass Concentration ($\mu g/m^3$)
MMD = Mass Median Diameter (particle density = 2 g/cc)
MMAD = Mass Median Aerodynamic Diameter (particle density = 1 g/cc)
GSD = geometric standard deviation or Sigma-G

Data Set	Location/Activity	C ($\mu g/m^3$)	MMD (μ)	MMAD(μ)	GSD
1	West Room	31	3.2	4.5	1.94
2	Waiting Room	32	2.1	3.0	2.48
3	Root Canal	90	3.1	4.4	2.19
4	Teeth Cleaning	35	2.3	3.3	2.61
5	Front Desk	37	1.7	2.4	3.24
6	Outdoor Sidewalk	38	1.4	2.0	3.57
7 (1)*	Composite Filling	156	1.2	1.7	2.50
7 (2)	-ditto-	83	1.5	2.1	2.87
7 (3)	-ditto-	47	1.8	2.6	1.94
7 (4)	-ditto-	28	2.0	2.8	1.95
8 (1)*	Crown Preparation	1,900	2.3	3.3	1.74
8 (2)	-ditto-	166	1.1	1.6	2.82
8 (3)	-ditto-	55	2.0	2.8	1.90

MMAD = 1.414 x MMD. The conversion factor of 1.414 is the square-root of the inverse ratio of the two particle densities: square-root of 2 g/cc divided by 1 g/cc, or $[2/1]^{1/2}$.

*Series of consecutive measurements made 65 seconds apart.

TABLE 2

Percent of Total Concentration [C] of Particles < 0.5 micron

Data Set	Location/Activity	% of Total C	C<0.5μ
1	West End Room	22%	6.8 $\mu g/m^3$
2	Waiting Room	17	5.4
3	Root Canal	14	13.0
4	Teeth Cleaning	16	5.6
5	Front Desk	28	10.3
6	Outdoor Sidewalk	15	5.7
7 (1)*	Composite Filling	33	52.0
7 (2)	-ditto-	13	10.8
7 (3)	-ditto-	16	7.5
7 (4)	-ditto-	11	3.1
8 (1)*	Crown Preparation	7	133.0
8 (2)	-ditto-	34	56.0
8 (3)	-ditto-	17	9.4

*Series of consecutive measurements made 65 seconds apart.

5.0 ANALYSIS AND DISCUSSION

The aerosol concentrations of the sampled air at the West Room, the Waiting Room, and the Front Desk were 31, 32, 37 $\mu g/m^3$ respectively; see Table 1. The average concentration of background aerosols in the suite was 35$\mu g/m^3$. That concentration was relatively low and was comparable to the average value of 38 $\mu g/m^3$ in the air outside of the building as shown in the data in Figure 2-6.

The particle size distribution profiles at those locations were quite similar. Most of the particles were in the range of 1.0 to 5.6 microns. Within that band, the peak size range was 2.0 to 3.0 microns.

The level of particle concentration in the outdoor air was about the same as that in the indoor air. But, the size distribution of the particles in outdoor air was different from the distribution of the indoor air. The peak size of the outdoor air was at 1.0μ whereas the peak size of the indoor air was at 3.0μ.

This difference in size distribution was most likely caused by two factors. One factor was the presence of a strong breeze that caused more smaller particles to be airborne in the outdoor air. The second factor was that inside the building there were more man-made particles from dental procedures and other activities that produced more particles in the 2.0 to 3.0μ ranges.

The average aerosol concentration in the room during a root canal procedure was 90$\mu g/m^3$ as shown in Figure 2-3. Compared to the concentration in the air outside of that room, it was three times higher. Even though the concentration in that room was higher, the size distribution profile in that room was about the same as that in the air outside of that room; most of the particles were concentrated in the 1.0 to 3.0μ range. For this test, about 14% of the total concentration was in the <0.5 micron range.

The average concentration in the teeth cleaning room was 35 $\mu g/m^3$; see Table 1 and Figure 2-4. This concentration was the same as that in the air outside of that room. Compared to the concentration in the root canal case, it was less by a factor of three, which indicated that teeth cleaning generated much less particles. The size distribution was very similar with the other ones discussed, except that in this case, there were fewer particles in the 5.6 and 10μ ranges.

As described in Section 2.2, for measurements during the composite filling and crown preparation procedures, a 6-foot extension sampling tube was added to the instrument inlet .This allowed the capture of aerosol samples soon after they were generated during the drilling process, within a distance of about 12 inches from the patient's mouth.

With this modified sampling setup, four consecutive measurements were made in 65-second intervals during the composite filling procedure conducted by Dr. Arima. The concentrations were 156, 83, 47, and 28 $\mu g/m^3$ respectively for runs 1, 2, 3, and 4. The data printouts for these four runs are in Figures 2-7 and 2-8. There was a burst of high concentration aerosols at the start of the drilling followed by steady decreases of concentration levels over the ensuing four minutes.

The size distribution characteristics showed a distinct shift towards the smaller size range. The peak size was 1.0μ, instead of the typically 3.0μ seen before. There also was a higher abundance of smaller particles; see Table 2. For the first run, the amount of particles in the <0.5 micron range was 33%.

With a same setup in another room, measurements were made during a crown preparation procedure by Dr. Van Hale. The concentration levels were 1,900, 166, and 55 $\mu g/m^3$ respectively for runs 1, 2, and 3. Once again, there a burst of very high concentration aerosols at the start of the procedure and the concentration decreased steadily in the subsequent test runs; see data in Figure 2-9.

The size distribution characteristics were noticeably different from those observed before. At the start of the procedure, the peak size was 2.0μ with an MMD of 2.3μ. A minute later, there was a significant broadening of the distribution with higher concentrations in many more stages. There were a higher population of smaller particles less than 1.0μ. In Run 02, the amount of particles in the <0.5 micron range was 34%. By the third run, the distribution profile shifted back to having the majority of the size being clustered around 1.0 to 3.0 microns.

A summary of the data discussed above is as follows:

(1) A burst of high concentration aerosols was generated near the site of drilling at the start of dental procedures; the interaction between the tool and the high-speed dental tool can be viewed as an aerosol generator system. The concentration during a short burst reached a high level of almost 2,000μg/m^3, almost 60 times higher than the concentration of background aerosols in the suite.

(2) The size distribution characteristics were all similar with most of the particles, 75 to 80% of the concentration, clustered in the 1.0 to 3.0 micron range. Smaller particles in the <0.5 micron ranges were present and were 10 to 15% of total concentrations. During bursts of high concentration aerosols, the amount of the smaller particles was as high as 33% of the total concentration.

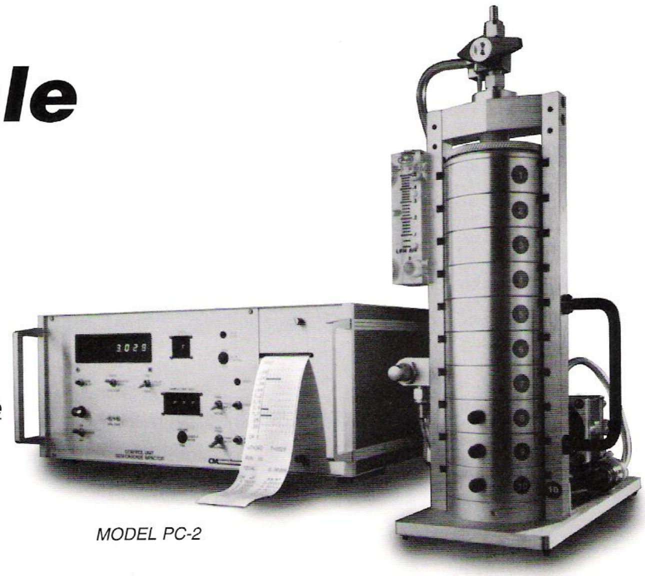
(3) After the particles were generated in high concentrations, they diffused into the ambient air. Particles larger particles than 10 microns settled out of the air in a relatively short time and did not travel too far.

(4) The smaller particles remained airborne for long periods of time and mixed with the ambient air in the suite to form a quiescent background aerosols in the suite at a relatively lower overall concentration of 35μg/m^3.

APPENDIX

Air Particle Analyzer

Provides <u>mass-based</u> concentration and size distribution data in <u>real-time</u> and saves samples for microanalysis.



MODEL PC-2

A QCM Real-Time Cascade Impactor

The PC-2 is a 10-stage cascade impactor with quartz crystal microbalance (QCM) mass sensors in the impactor stages to provide ***mass-based*** data in real-time. It samples a small volume of particle-laden air during a measurement and collects particles in size-segregated groups. Within seconds after sampling, it provides mass concentration and size distribution data in a printout.

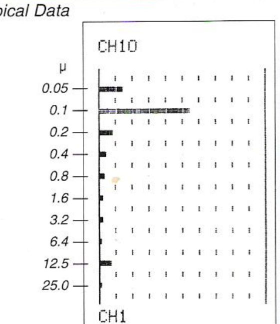
Simple to Operate

The PC-2 is a complete system for turnkey operation. Getting a set of data is simple: just initialize the instrument by pressing a push-button switch, turn the impactor inlet valve to briefly let particle-laden air to enter, and then press the switch again. A set of data will be printed out automatically. No need to clean crystals after each measurement if the valve sampling time is properly controlled to avoid prematurely overloading.

Wide Dynamic Range

This instrument handles mass concentrations over a range of four decades, from tens of mg/m³ to a few μg/m³. It also covers a broad size range of 25 to 0.05 microns in ten size fractions.

Typical Data



Sampling Time (seconds) — ΔT=060

Concentration — TOTAL 0.56090

Concentration per stage

CH	ΔF	mg/m³
1	0001	0.00770
2	0007	0.03990
3	0001	0.00570
4	0004	0.01480
5	0004	0.01280
6	0007	0.02170
7	0009	0.02790
8	0016	0.04640
9	0082	0.30340
10	0026	0.08060

Size distribution and mass concentration of person smoking filtered cigerette within 3 feet of instrument. Total time required to get this data: 90 seconds.

Portability

The instrument can be conveniently moved around to get on-the-spot data at different parts of a building or factory. It can also be easily transported to the field with the impactor stack detached from the control unit and set up for operation quickly.

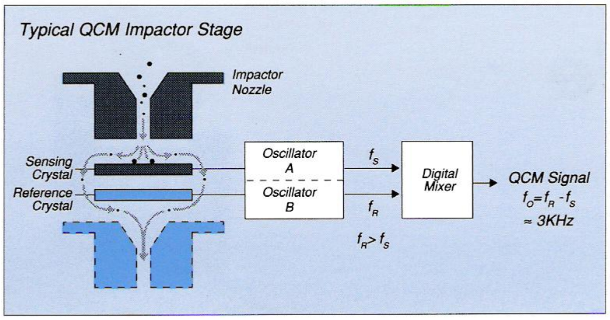
Samples are Available for Microanalysis

Particles collected in the impactor stages in size-segregated groups can be saved for post-sampling speciation analysis using Scanning Electron Microscopy, Energy Dispersive X-Ray Spectroscopy, or other microanalytical techniques. Samples retained on a crystal can be analyzed directly without disturbance; sample preparation in the laboratory is minimized or even eliminated, reducing analysis costs significantly.

Long Successful Record and Versatile Applications

For two decades researchers around the world have relied on the PC-2 to gather data, often under demanding circumstances: from the Antarctic to Alaska, inside sub-

CM California Measurements, Inc.



marines, on board high altitude aircraft, and even in volcano craters. Whatever the circumstances, the PC-2 performed well. The instrument is suitable for various applications, such as:

- **Inhalation toxicology research**
- **Pharmaceutical aerosol size analysis**
- **Product safety evaluation**
- **Industrial process emission studies**
- **Clean room contamination analysis**
- **Air cleaner and filter efficiency tests**
- **Indoor and outdoor air quality studies**
- **Industrial hygiene measurements**

NASA/JPL Developed QCM Sensor

Originally developed by NASA's Jet Propulsion Laboratory for space applications, the dual-crystal QCM sensor used in this instrument is so sensitive a mass-to-frequency transducer that only a 1 nanogram of particle deposition on its sensing crystal will produce an output frequency change of 1 Hz. To get valid data during a measurement, it is only necessary to collect enough particles to cause about 20 to 30 Hz frequency change in the most concentrated stage. Controlling sampling time to limit particle collection to this amount allows making up to 25 measurements before overloading the crystal.

Two Models to Choose From

For applications where the aerosol concentration is usually high, up to many milligrams/m^3, the lower flow rate (0.24 lpm) model PC-2 is more suitable. For applications where the concentration is generally much lower, less than a few hundred micrograms/m^3, the higher flow rate (2 lpm) PC-2H model is more suitable.

Specifications:

Flow Rate:

PC-2 0.24 SLPM
PC-2H 2 SLPM

Diameters (D_{50}):
(Based on Particle Density of 2 g/cm^3).

STAGE	PC-2 D_{50} (micron)	PC-2H D_{50} (micron)
1	>25	>10
2	12.5	5.6
3	6.4	3.0
4	3.2	2.0
5	1.6	1.0
6	0.8	0.5
7	0.4	0.3
8	0.2	0.2
9	0.1	0.1
10	0.05	0.05

Total Concentration Range (Nominal):

	Max. (mg/m^3)	Min. (µg/m^3)
PC-2	50	10
PC-2H	5	1

Warm-up Time:
10 minutes, max.

Operating Temperature:
-20° to +65°C for aerosol gas.
-10° to +40°C for instrument.

QCM Stability:
±2 Hz/minute max. after warm-up, noncumulative.

Crystal:
AT-Cut, 10 MHZ, optically polished.

Display:
8-digit LED.

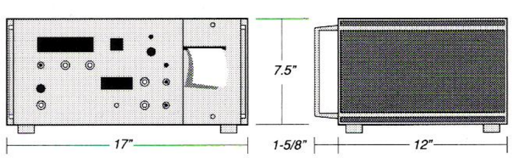
Printer:
Thermal dot-matrix.

Saturation Warning:
Built-in microprocessor controlled black dot printed next to channel that has more than 500 Hz cumulative loading.

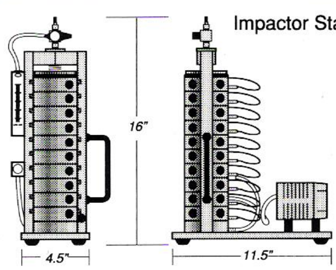
Power:
120V, 50/60 Hz, 50 watts
(240V 50 Hz version available).

Weight:
Impactor with pump - 11 lbs.
Control unit - 22 lbs.

Control Unit



Impactor Stack



CM California Measurements, Inc.
150 E. Montecito Ave., Sierra Madre, CA 91024
Tel 626/355-3361; Fax 626/355-5320
www.californiameasurements.com

What's in the air?...

California Measurements Real-Time Air Particle Analyzers at work...

When doctors and scientists at the University of California, San Francisco, Medical Center, needed information on blood aerosols generated by surgical tools during orthopedic surgery, they used our PC-2H 10-stage *quartz crystal microbalance (QCM) real-time cascade impactor* to find out. The instrument provided them particle size distribution and mass concentration data rapidly and accurately *in real-time.* They found that the surgical tools did generate blood-containing aerosols small enough to be inhaled by operating room personnel.

For many years the U.S. Navy has used our PC-2 real-time cascade impactors to monitor the air inside nuclear submarines. Naval Research Laboratory engineers were able to use the instrument to gather long-term data on the nature of airborne particulates in the closed environment and on the efficiency of ship-borne air cleaners for the removal of oil vapor particles. The data enabled the Navy to improve the performance of new air cleaners.

Whenever there is a major volcanic eruption, chances are that a California Measurements multistage QCM *real-time* cascade impactor is at work on board a NASA research aircraft to track the particle plume in the upper atmospheres. Our instruments have seen service on many types of research aircraft, including NASA's U-2 and ER-2, over the volcanoes at Mt. St. Helens in Washington, and Mt. Erebus in the Antarctic.

Environmental health scientists in Hawaii will soon be able to "gain a better understanding of the nature of Volcanic Smog (VOG) on the Big Island of Hawaii caused by the continuous eruption of the Kilauea Volcano. VOG has produced a natural air pollution with discernible visual impact and anecdotal evidence of health effects. The state of Hawaii is using three of our PC-2 instruments to collect particle samples for speciation and gather size distribution and concentration data continuously, *in real-time,* at several locations.

The DOE/Los Alamos National Laboratory Micro-Atmospheric Measurement System utilizes one of our multistage QCM *real-time* cascade impactors to monitor airborne particle size distribution and mass concentrations. It weighs only 13 pounds and can be deployed on a remotely piloted vehicle (RPV), or another mobile platform, to measure particle emission plumes from diffuse sources, such as, hazardous-waste sites or land undergoing environmental remediation.

When the Taiwan Power Company needed to conduct dose assessments of radioactive aerosols inhaled by workers at its nuclear power plant, our PC-2 real-time air particle analyzer and our MPS-4G 1 Microanalysis Air particle Sampler were used to get the data needed. The PC-2 provided size distribution and mass concentration data *in real-time* at various locations and the MPS-4G 1 collected samples *directly on SEM stubs* for speciation analyses in a scanning electron microscope.