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Regional Air Pollution Study

Dichotomous Aerosol Sampling System

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REGIONAL AIR POLLUTION STUDY

Dichotomous Aerosol Sampling System

by

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ABSTRACT

Ten of twenty-five stations making up the Regional Air Monitoring System (RAMS) in St. Louis were equipped with dichotomous samplers and high volume filter samplers for aerosol measurements. The dichotomous samplers, built by Lawrence Berkeley Laboratories (LBL), were designed for automatic operation and were capable of collecting up to 36 samples in each of two size fractions before filter stacks must be changed. Most of the time, the samplers operated to collect 12-hour samples (0000-1200, and 1200-2400), except that at two stations with high aerosol loadings, the sampling intervals were split into two 6-hour intervals. Sample filters were pre-weighed by beta gauging before exposure in St. Louis and subsequently returned to LBL for determination of aerosol mass in each size fraction, as well as determination by x-ray flourescence of the concentrations of the following elements: Al, Si, P, Cl, K, Cr, Mn, Ga, Rb, Sr, Sn, Sb, Ba, Hg, S, Ca, Ti, V, Fe, Ni, Co, Zn, As, Se, Br, Cd, and Pb. Approximately 33,000 samples were collected between March 1975 and March 1977. Analytic data are stored in the RAPS Data Bank at Research Triangle Park, N.C.

The operation of the samplers in the RAMS network is described along with problems encountered and procedures used for preventive maintenance and quality control. Also described are two streaker samplers specially installed for continuous aerosol measurements and a silicon cell pyranometer.

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TABLES

1.0 SUMMARY AND CONCLUSIONS

Aerosols, due to the diversity of their sources, physical and chemical properties, present a special challenge to air monitoring technology. The bimodal particle size distribution in the urban aerosol suggests the use of a dichotomous sampling method with a cut point near two microns. A sampler of this nature was constructed by Lawrence Berkeley Laboratory, University of California at Berkeley.

In support of the aerosol modeling studies as part of the St. Louis Regional Air Pollution Study (RAPS), a network of ten automatic dichotomous samplers was set up and operated to collect particulate pollutant data. To facilitate analysis and data handling, the samples were collected on a filter with computer readable digital labels. Information on trace elements together with concurrent chemical and meteorological data will serve to define the air quality in the St. Louis Region and relate atmospheric composition to various emission sources. In addition, it will provide needed input for defining aerosol growth, transport and decay equations.

During the period covered by this task order the RAPS LBL Dichotomous Aerosol Filter Sampling System was established. Ten samplers were installed and operated in the St. Louis Regional Air Monitoring System (RAMS) network. An elaborate system for filter validation and sampler monitoring was developed and proved to be invaluable and time saving (see Appendix B). Thirty-three thousand six hundred ninety-five filters were collected and there were nine hundred thirty-four filter failures for an overall efficiency of 97.25%. Failures caused by sampler malfunctions accounted for 0.67% of the total failures with overload failures accounting for 0.37%. Failures from miscellaneous causes accounted for 1.73% (see Table 1). It appears that the virtual impactor, with its inherent advantages, has fulfilled the need for an instrument to collect aerosols in two distinct size ranges.

Upon termination of the LBL Dichotomous Aerosol Filter Sampler System, all samplers were returned to the warehouse where eight of them were carefully inspected, cleaned and crated for shipment. Samplers with serial numbers 3, 6, 7, 8, 9, 10 and 12 were shipped back to Lawrence Berkeley Laboratory. Sampler number 5 was placed in station 105 to be shipped out with the station and sampler number 2 was installed in station 111 for a continuing sampling program. The samplers with serial numbers 4 and 11 were previously shipped back to Lawrence Berkeley Laboratory for modifications. All of the maintenance log books remain with each sampler, wherever they may go, as a historical record.

The LBL Automatic Dichotomous Air Sampler (ADAS) is a very well engineered piece of equipment. The instrument is capable of monitoring and displaying most of the conceivable failures encountered by this type of instrument, e.g., a.c. power, insert, withdraw, no sample, flow control valve and valve out of range. The status monitor and display located on the flow controller instrument panel in combination with the failure display provided a valuable tool in analyzing instrument malfunction at a glance. Proper interpretation of the panel display provided for faster repair and reduced sampler downtime.

2.0 SCOPE OF WORK

Aerosol samples were collected on filters in size ranges greater than and less than two microns at ten RAMS stations. Two separate filters sampled simultaneously from two air streams, depositing particulates of 2 microns or less on one filter and those larger than 2 microns with a cut point around 10 microns. Sample mass was determined by beta gauge and the samples were analyzed for trace elements (atomic number 13 and above) by X-ray fluorescence. Temporal resolution was as fine as two hours. The extent of this task order was for the collection of filters, maintenance and operation of the Automatic Dichotomous Air Samplers. Mass measurements and analyses of the samples were performed under a separate contract between the Environmental Protection Agency and the Lawrence Berkeley Laboratory (LBL), University of California at Berkeley. The data produced from this sampling network were to become part of the aerometric data base of the Regional Air Pollution Study.

Government Furnished Equipment (GFE) were eleven LBL Automatic Dichotomous Air Samplers, filter trays and membrane filters to be periodically supplied by Lawrence Berkeley Laboratory. A comprehensive quality assurance plan was submitted to the EPA Task Coordinator. This report dealt with the calibration, maintenance, operation of the sampling units; collection, identification, and delivery of exposed samples; and sampling procedure validation. In addition, monthly progress reports were made which included descriptions of quality assurance activities, status of filter samples, operational performance of each sampler, major problems and planned corrective action and plans for future efforts (see Appendix B).

Task Order No. 102 is a continuation of effort previously performed under Task Order No. 27, under Contract DU 68-02-1081. Under Task Order No. 27, the ten Automatic Dichotomous Air Samplers of the Regional Air Monitoring System (RAMS) were operated and maintained from 2 January 1975 to 29 August 1975.

3.0 OPERATIONS

In November 1974 eleven Lawrence Berkeley Laboratory Automatic Dichotomous Air Samplers were received at the Regional Air Pollution Study (RAPS) facility. The samplers were stored in the warehouse area and when uncrated, each sampler was thoroughly inspected for possible damage during shipment, then cleaned for a test run with sample filters. Dr. B. W. Loo from Lawrence Berkeley Laboratory arrived in January 1975 with calibration equipment and tests revealed no variances in the calibration set-point adjustments.

Ten of the samplers were scheduled for installation in the Regional Air Monitoring System (RAMS) stations. The eleventh sampler would be used as a backup unit in case of an emergency. Before the samplers were installed, two modifications were made on each sampler: (1) the virtual impactor was extended four inches, and (2) the failure mode circuitry was modified. Modifications were also made in the RAMS stations. The RAMS modifications consisted of the installation of an isokinetic intake manifold, installation of a larger manifold blower and an electronic interface to the computer control system. The modifications required for the isokinetic manifold were completed in January 1975 and the computer interfacing was completed in February. The RAMS stations chosen for sampler installation were 103, 105, 106, 108, 112, 115, 118, 120, 122 and 124. A detailed description of the theory of the sampler operation is given in Appendix A.

In February 1975, initial operation of the network was devoted to "debugging" the samplers and the computer interface, and to the development of operational procedures. The dichotomous sampler was engineered to be kept under surveillance by the RAMS central computer facility. However, because of the large number of failure mode indicators provided by the sampler, all output modes were tied together (logical or) to reduce the number of signal lines required. A failure in any mode would be flagged at the central facility, notifying the computer operator, who in turn notified operating personnel for corrective action.

Originally the normal sampling schedule for each of the ten samplers was to be one 24 hour sample per day, beginning and ending at midnight, except during periods of "intensive study". During the "debugging" period it became apparent very early that this sample frequency was too long, as many filter samples failed from particulate overloading. The samplers at stations 103, 105, 108 and 115 were changed to 12 hour sampling periods, and the samplers at station 106, 112, 118, 120, 122 and 124 were left on the 24 hour sampling period. The "debugging" period used 700 filter samples.

Formal operations began on 17 March 1975. All samplers were loaded with matched pairs of filter trays and were synchronized by the central facility computer. Station visitation occurred routinely every three days. Weekend maintenance occurred only during periods of intensive study. During regular sampling periods, when a malfunction was detected by the computer surveillance system, maintenance personnel were immediately dispatched to get the malfunctioning equipment back on line. The frequency of sample filter overload required another evaluation and the samplers at 103 and 105 had their sample frequencies further reduced from 12 hours to 6 hours on 21 April 1975 and 14 May 1975 respectively. Subsequently, reductions from 24 to 12 hour sampling frequency were made at station 120 on 18 May, 106 on 19 May, 112 on 22 May, 118 on 3 June, 122 on 24 June, and 124 on 25 June 1975. The 6 hour sampling frequency at stations 103 and 105 had starting times at 0000, 0600, 1200 and 1800 CST and the 12 hour sampling stations had starting times at 0000 and 1200 CST.

Early in the program it was noted that the samplers were not remaining synchronized and this was somewhat of a mystery because there were no apparent reasons for loss of synchronism. However, the mystery began to unravel when it was discovered that reprogramming the station computer caused the sampler to abort and remain in standby with no failure flags back at central. Activating the station CPU inhibit button would also cause a sampler to abort. Operating the station teletype would sometimes cause a sampler to abort. In an attempt to solve the problem of sampling abortions, when for any reason the station computer had to be disturbed, the signal cable connecting the computer and the sampler was to be removed and replaced when the attending technician completed his task. In many instances however, the technician would forget to replace the plug, thereby causing the loss of command and surveillance control at the central facility. In order to eliminate the problem completely the decision was made to disconnect the command lines and manually synchronize the samplers whenever the need arose. The surveillance lines would remain connected to the computer. The problem of unexplained abortions was solved when the command lines were disconnected. Manually synchronizing each sampler required more effort but was well worth the price because the string of uninterrupted samples was greatly increased.

During the first week in July 1975 all samplers were throughly inspected, cleaned, lubricated and calibrated in preparation for the summer intensive operation. Samplers at stations 103, 105 and 112 were scheduled to operate on a 2 hour sampling frequency. Samplers at stations 106, 108, 115, 118, 120, 122 and 124 were operated on a 6 hour sampling frequency. At the end of the summer intensive all the samplers were returned to their original sampling schedules except the samplers at stations 106 and 124 which were used in support of a special study initiated by Dr. T. Dzubay, from EPA, Research Triangle Park, North Carolina. Dr. Dzubay's study ended the first week in September and the samplers were returned to their regular sampling schedules.

During the month of October 1975 all the carbon vanes were changed in the vacuum pumps. The sampler at station 108 was damaged by gunfire and required extensive repair. The electronic controller had to be returned to Lawrence Berkeley Laboratory for repairs and the controller was taken from the spare unit at the warehouse and installed in the sampler at 108.

For the rest of the sampling program the samplers were held to their regular sampling schedules except for the samplers at stations 108 and 115 during the month of July 1976 when both sampling frequencies were changed to 6 hours as a precaution against particulate overloading. These samplers were returned to their regular sampling frequencies at the end of August. The samplers at 106 and 124 were returned to Lawrence Berkeley Laboratory in August 1976 for modifications and were never returned.

3.1 CORRECTIVE MAINTENANCE

Regular maintenance is described in detail in the Quality Assurance

TABLE 1. LAWRENCE BERKELEY LABORATORIES (LBL) DICHOTOMOUS SAMPLER OPERATION 1975-1977

	RAMS STATIONS										
	103	105	106*	108	112	115	118	120	122	124*	TOTALS
Total Samples Collected	5874	6023	2214	2802	3492	3098	2706	2808	2666	2012	33,695
Total Samples Failed	116	126	89	105	82	65	112	98	84	57	934
Total Uninterrupted Synchronized Samples	5758	5897	2125	2697	3410	3033	2594	2710	2582	1955	32,761
Total Failures Due to Sampler Malfunction	52	46	14	18	6	30	25	7	16	13	227
Total Failures Due to Filter Overload	18	6	12	20	16	6	22	13	9	1	123
Total Miscellaneous Failures	46	74	63	67	60	29	65	78	59	43	584
Percent Failures Due to Sampler Malfunction	0.885	0.764	0.632	0.642	0.172	0.968	0.924	0.249	0.600	0.646	
Percent Failures Due to Filter Overload	0.306	0.100	0.542	0.714	0.458	0.194	0.813	0.463	0.337	0.050	
Percent Failures Due to Miscellaneous Causes	0.783	1.229	2.845	2.391	1.718	0.936	2.402	2.778	2.213	2.137	
Percent Uninterrupted Synchronized Samples	98.025	97.908	95.980	96.252	97.652	97.902	95.861	96.510	96.849	97.167	

* The samplers at these stations were removed in August 1976 and returned to the Lawrence Berkeley Laboratories for electronic and mechanical modifications.

Program, Appendix B. The following paragraphs describe additional measures that were found to be very helpful in maintaining a smoother operation. As shown in Tables 1 and 2, the failures caused by sampler malfunctions were of a low order of magnitude. Experience has shown that samplers should be cleaned immediately after any nearby major farming or earth moving activities. During the 30 day cleaning schedule two preventative operations were found very helpful in enhancing valid filter capture and these were: (1) check the adjustment of the micrometer clutch, and (2) check adjustment of the Geneva wheel.

TABLE 2. SAMPLER RELATED FAILURES (TOTAL FAILURES - 227)

	NUMBER	BY PERCENT
Flow Control Valve	45	19.82
Failed on Insert	23	10.13
Geneva Wheel Assembly	68	29.95
Improper Seal	8	3.52
Micrometer Valve Assembly	24	10.57
Null Switch	14	6.17
Vacuum Pump	10	4.41
Failed on Withdraw	6	2.64
Other Various Infrequent Causes	9	3.96
Unknown	20	8.81

Before filter trays are placed in the sampler the trays should be held two or three inches above a tabletop and turned so that the open side of the tray is turned towards the tabletop. The tray should be agitated slightly so as to cause any loosely held filters to drop to the tabletop. The filter retainer springs can then be adjusted to hold the filters properly. The filters should be tested by manually inserting and withdrawing them.
A filter retainer spring adjusted too tightly can cause the stackloader to malfunction because the exposed filters cannot be fully tucked back in the tray and will protrude, causing the stackloader to jam as the mechanism

travels upward. A filter retainer spring adjusted too loose will allow filters to creep outward as other filters are inserted and withdrawn, and also may cause jamming of the stackloader. Filters should also be inspected for cracks that may occur during shipment. Filters are checked before shipment but may be damaged in transit. Such transit damaged filters will often fail causing an interruption in the sampling schedule. Another useful check on new filters is one in which the backside of the filter is inspected for extrusions probably left over when the plastic filter holder is molded. A larger than normal extrusion can also cause sampler failure. The sampler checks each inserted filter before allowing the filter to actually start sampling, and when a filter does not pass the filter seal test the sampler automatically shuts down until corrective action is taken by operating personnel. An extension on the back of the filter holder may cause a failure when the filter pusher inserts the filter fully forward and then slips under the extrusion causing the rear end of the filter to be lifted, thus destroying the filter seal.

Samplers are normally given a visual inspection on each station visitation for filter and time synchronization and any obvious malfunctions. Other checks found to be useful were: (1) check the knurled knob holding the pusher for looseness; (2) check the cooling fan for proper operation by touching the panels in the area of the vacuum pump and feeling beneath the sampler for exhaust air; (3) check stackloader for partially protruding filters that may cause the stackloader to jam; (4) check intake sample air manifold for fully mated sections; and (5) disconnect tubing that checks pressure for constant sample air flow. A momentary change in equalization pressure should cause the instrument to send out a corrective signal to the micrometer drive motor indicating proper null region adjustment. When the tubing is replaced the micrometer drive motor should return the micrometer to its original setting.

Maintenance logs were kept at each station where all corrective measures were entered into the logbook thus giving a complete history of each sampler. Calibration data entered in the logbooks were checked by noting the micrometer calibration set-point when a clean filter was inserted in the sampling position. The samplers were found to be extremely reliable in maintaining their set-points. Periodic checks with calibration equipment also proved the stability of the sampler in maintaining calibration.

3.2 FAILURE ANALYSIS

A list of the most prevalent failures other than sampler related failures is given in Table 3. The computer related failures were completely eliminated once the command lines were disconnected. Most of the a.c. power failures were caused by adverse weather conditions interrupting the power from the electric utilities except at station 112. The a.c. power for station 112 was supplied by the power station at Washington University. Occasionally a sampler was found in a standby mode with no failure lights indicated on the panel. It is thought at this time that spurious signals getting into the system caused the sampler to interpret them as withdraw commands.

TABLE 3. MISCELLANEOUS FAILURES (TOTAL FAILURES - 584)

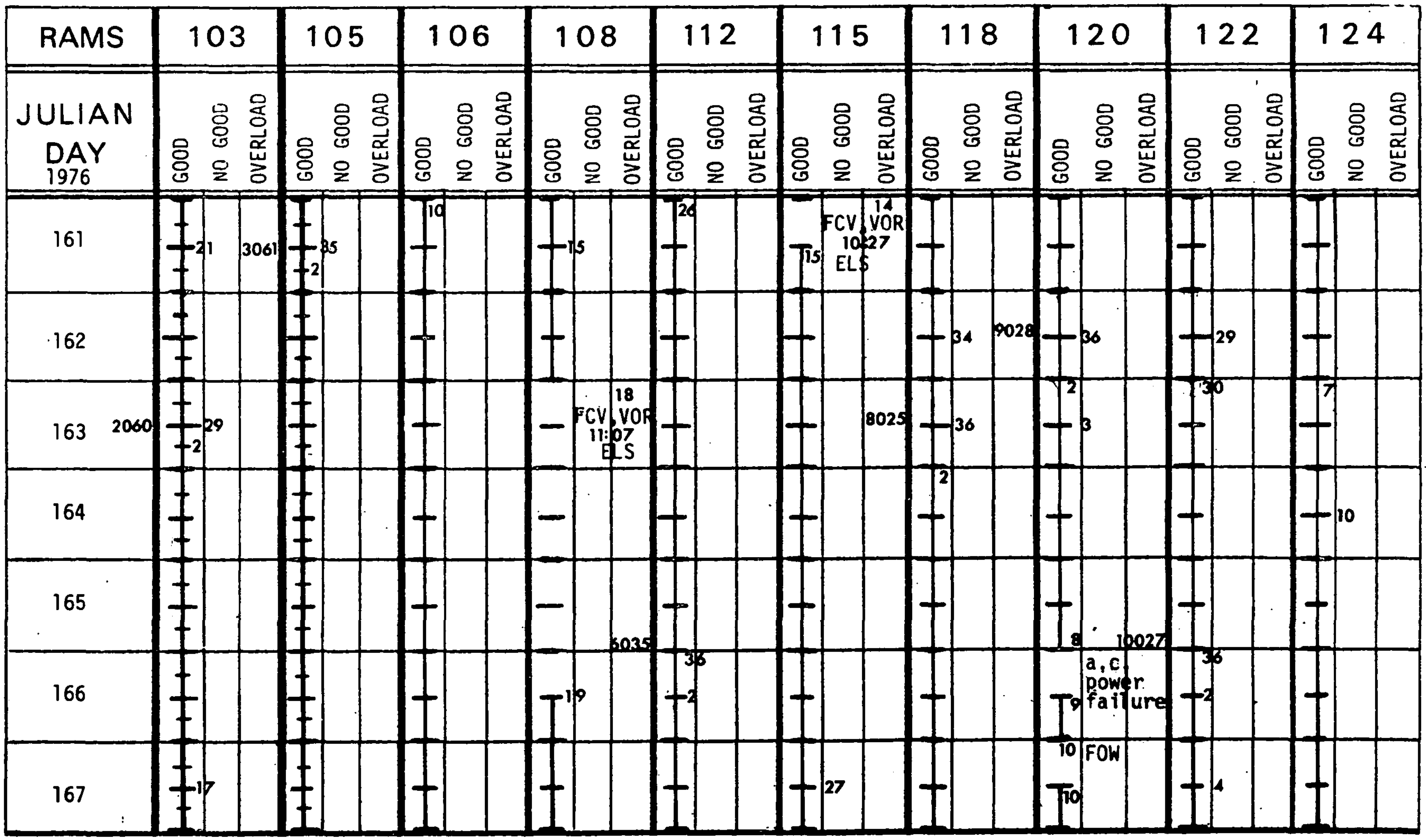
	NUMBER	BY PERCENT
A.C. Power Related Causes	79	13.53
Computer Related Causes	334	57.19
Filter Related Causes	24	4.11
Filter Tray Retainer Springs	100	17.12
Other Various Infrequent Causes	47	8.05

Failures resulting from overloads occurred early in the program, mainly from sampling frequencies that were too long. Shorter sampling frequencies solved most of the overload failures. The occasional overload failures occurring after the shorter sampling frequencies were mainly caused by farmers harvesting grains or plowing nearby fields. A very few overload failures were actually caused by unusually heavy particulate loading resulting from high pollution activity after the sampling frequencies were shortened.

3.3 DICHOTOMOUS SAMPLING NETWORK MASTER LOG

A Dichotomous Sampling Network Master Log was developed which gave, at a glance, the past history of each sampler and the anticipated operation in the future. By knowing the future of each sampler, tray changes and optimum maintenance routes could be planned in advance of each day's operation (see Table 4). The Dichotomous Sampling Network Master Log was maintained on a daily basis and provides at a glance, the status of each sampler and expected positions of each filter. During each station visit, the Dichotomous Sampler Check Sheet (see Appendix B) was filled out, and upon return to the main office, the information was transferred to the Dichotomous Sampling Network Master Log. A completed log will show periods of uninterrupted data, interrupted data and causes for failure, tray identification and period of exposure time. Table 4 represents a period of actual sampling history for Julian day 161 through 167, and it shows that station 103 for this period had an uninterrupted train of samples as represented by the continuous line through the good section. The number 21 on Julian day 161 shows that the station was visited and number 21, the expected filter position, was in its correct place. There was a tray change on Julian day 163 before 1200 hours. The dichotomous sampler is constructed so that a tray may be changed without interrupting the sampling filter. The first filter position in an unexposed tray is always left empty. When the last filter in a sampled tray is reached the filter pusher may be removed, the old tray lifted out and the new tray installed. The last filter in the old tray can now be withdrawn into the empty space in the new tray, thus the last filter in the old tray now becomes the first filter in the new tray. The tray change also identifies the tray as 2060. The numeral 2 identifies the sampler serial number and 60 the number of sampled trays that this sampler has exposed since the network was established. Station 106 shows an uninterrupted train of samples with a station visit on Julian day 161. Station 108 shows a station visit on Julian day 161, and the sampling tray had an interruption as shown by the broken line on Julian day 163 with a filter overload on filter number 18 after 11:07 elapsed time. The sampler was synchronized on Julian day 166 with filter number 19. Station 120 shows an interruption on Julian day 166 on filter number 8 when there was an a.c. power failure at the station. Filter number

TABLE 4. DICHOTOMOUS SAMPLING NETWORK MASTER LOG



9 failed on withdraw at midnight causing another interruption as indicated by the broken line. The filter numbers displayed represent actual station visits and can be used as direct evidence to prove that the filters may be verified as valid filters. Two filter trays are sampled simultaneously in the Automatic Dichotomous Air Sampler (ADAS). One filter tray samples for the small particles and the other tray samples for the large particles. One vertical line represents both trays because a failure in either sample stream will cause the sampler to shutdown and signal a failure back at the central computer facility. The crosslines on the vertical line indicate sampled filters and when the crosslines are counted for one Julian date the sampling frequency of that sampler can be determined.

All of the accumulated check sheets, filter tray record sheets and the master log sheets will be turned over to EPA. Copies of the sheets and master log are on file at LBL for use in validating filters for analyses. When a number of samplers are operated in a network, the Dichotomous Sampling Network Master Log is an invaluable aid in validating filters and determining sampler operation.

4.0 RECOMMENDATIONS

The sampler was designed to either operate under control of a central computer facility or from its own internal system. When synchronization problems arose, as experienced in the RAMS network, manual synchronization became necessary requiring operating personnel to actually be present at the sampling station. When a number of these samplers are active in a network it would be advantageous to have a countdown circuit to activate the sampler automatically. Overloads cause the sampler to shutdown and hold the elapsed time on the clock until the sampler is again manually synchronized. A circuit to store the elapsed time and automatically restart the sampler on the next scheduled filter would cause the sampler to maintain synchronization.

5.0 STREAKER AND RADIOMETER OPERATION

The Jensen-Nelson streakers and the silicon cell pyronometer originally operated under Task Order No. 117. Task Order No. 117 had a period of performance commencing on 1 July 1976 and terminating on 30 November 1976. Continued maintenance of the Jensen-Nelson streakers and the silicon cell pyronometer were incorporated in Change 3 to Task Order No. 102. The following paragraphs provide a summary of the effort expended toward streaker and radiometer installation and maintenance.

The two Jensen-Nelson streakers were installed, one each on the towers at the 10 meter level, at stations 120 and 124 in the spring of 1976 by representatives from Florida State University. The streaker pumps were Sierra constant flow pumps located on the roof of the shelters. Power and vacuum lines were already in place, being left over from the 1975 summer intensive study. Filter frames were supplied by Mr. W. W. Berg, Jr. of Florida State University. Exposed filters were shipped back to FSU for analyses.

One streaker motor was replaced at station 120 when it started showing signs of intermittent operation. The streaker samplers operated almost trouble free; however, the constant flow pumps exhibited early signs of trouble. The flow meter in the pump at station 120 had to be replaced. Many of the electronic parts had to be replaced because of severe damage caused by corrosion at station 120. The pump failed at station 124 and because of the inability to get replacement parts was shipped back to FSU. A heavy-duty Gast pump was used as a replacement and gave trouble free operation throughout the rest of the sampling program.

On 14 February 1977 RAMS station 124 was deactivated and the streaker and all associated equipment was removed and transported to RAMS station 125, where it was installed at the 10 meter level on the tower. The streaker was operable on 15 February 1977.

The streaker filtering system ran through 8 April 1977 at which time the system was shutdown and the equipment dismantled and packed for shipment. After the equipment was packed it was turned over to the EPA Task Coordinator.

The silicon cell pyranometer was installed on the roof of RAMS station 124. The sampling system consisted of the sensor and a strip chart recorder. The sensor operated trouble free throughout the life of the sampling period and required very little maintenance. The maintenance required by the sensor consisted of cleaning the diffuser and insuring that the strip above the sensor was rotating. The inking system on the strip chart recorder gave considerable trouble. The inking pen exhibited a tendency to easily become clogged. However, a new type of ink and chart paper apparently solved the problem. It was also noted that the sensitivity of the strip chart recorder was probably too high, and the resulting jittery action of the inking pen loosened fibers out of the chart paper and forced them up into the tip of the inking pen. The completed radiometer charts were shipped to the Argonne National Laboratory.

The pyranometer and strip chart recorder were removed from station 124 on 14 February 1977 and installed at station 125 on 15 February 1977, at which date it became operable. The system operated without incident until 8 April 1977 and on this date the system was shutdown, the equipment removed and packed for shipment. The pyranometer, strip chart recorder and all unused supplies were turned over to the EPA Task Coordinator.

APPENDIX A

SAMPLING EQUIPMENT

CONTENTS

FIGURES

1.0 SAMPLING EQUIPMENT (1)

The LBL Automatic Dichotomous Air Sampler (ADAS) is designed to sample ambient aerosols at a rate of 50 l/min and divide the incoming particles into two aerodynamic size fractions; greater than 2.0 microns and less than 2.0 microns for unit density spheres. The particles are deposited separately on two 37 mm diameter cellulose membrane type filters for subsequent total mass measurements via beta-gauge and elemental analysis via X-ray fluorescence analysis. The effective area of the deposits on the filters is approximately 7 cm^2. The inlet adapter is designed to sample isokinetically from a vertically downward flow of 217 cm/sec. Automatic control functions in the sampler unit allow unattended operation for up to 36 sample exposures for preset time intervals from 1 to 100 hours, Figures 1 and 2.

1.1 VIRTUAL IMPACTOR

The size fractionation is accomplished by a two-stage virtual impactor preceding the membrane filter collectors. The schematic of the complete virtual impactor design is shown in Figure 3. The size separation is accomplished aerodynamically in a manner similar to that used in more conventional impactors, with the exception that the streamlines of the flow are maintained in part without the use of a mechanical impaction surface. Instead, an open tube opposes the inlet orifice permitting the large particles to be "impacted" into a low flow region within the tube from which they are subsequently collected on the membrane filter. The small particles follow

(1) Much of the information contained in this section was excerpted and paraphrased from the operation and maintenance manual supplied with the ADAS and publication LBL-3854, "Dichotomous Virtual Impactors for Large Scale Monitoring of Airborne Particulate Matter", B. W. Loo, J. M. Jaklevic, and F. S. Goulding, 1975.

the bulk of the flow around the tube and are collected by a separate filter. Since optimum operation requires that approximately 20 to 25% of the small particles are drawn out of the flow with the larger particles, the completed unit consists of two separation stages. Thus, the idealized output of the unit would be 100% of the large particles (greater than 2.0 microns) collected on filter A, together with 5% of the small particles, and 95% of these small particles (less than 2.0 microns) collected on filter B. A cross section of the virtual impactor is shown in Figures 4, and 5. Air is drawn through the inlet jets (part 1) in parallel. Their protrusion into the first stage cavity is necessary to eliminate the "backwall" losses on part 2 due to the spatial oscillation of streamlines as found in the Environmental Research Corporation design, as well as in some conventional impactors. Part 3 forms the first stage cavity. The three small holes in this part are symmetrically located about the three central axis but are offset 60° azimuthally with respect to the coarse particle receiving tubes (parts 4) to minimize flow interference. These holes, in combination with the one in part 7, also govern the internal flow distribution. The Q_1/Q_0 for the first stage was adjusted to be 25% to minimize wall losses in the cavity in Figure 4. The tapered lips on the tubes have no significant effect on the cut point although they do tend to defocus the streamlines and reduce cavity losses.

The three coarse particle jets are then converged by a 15° cone (part 6) onto the second stage of separation after passing through the drift tube (part 5) Figure 5. Parts 8 are three positioning rods which form an open cavity for the second stage jets. The ratio Q_1/Q_0 (Figure 4) here is chosen to be 20% Thus, 2.5 l/min of air will pass through filter A carrying all the coarse particles, along with 5% of the fine particles. The fine particle stream of the second stage will merge with that from the first stage and be deposited on filter B. Thus, 70% of the fine particles are drawn from the stream in the first stage of separation and 25% in the second stage. The large particle filter will contain all of the large particles along with 5% of the small particles. In analyses, a correction for the 5% contamination of filter A can be made based on the amount of the uncontaminated 95% of the fine particles on filter B. The overall construction utilizes all stainless steel parts (excepting part 6) for mechanical integrity and corrosion resistance, compression O-ring seals and tie rods (part 13) with thumb nuts (part 12) for easy disassembly. Stragetic corners are shaped to minimize losses. Figure 6 shows the virtual impactor disassembled.

1.2 FLOW CONTROLLER

Flow regulation is essential for precise measurement of the air volume sampled and the maintenance of a fixed particle-size cut point. This is accomplished as shown in Figure 5 by sensing (through part 15) the pressure differential P_0, Figure 3, between the inlet and the second stage of the impactor with a diaphragm operated null switch (Dwyer Model 1640-5) which in turn causes the opening in a motor driven valve to be increased or decreased to maintain the preset null condition. The valve is simply a 5.1 mm diameter orifice pierced by a traveling micrometer shaft with a 2° taper. A fixed orifice limits the flow through filter A to 2.5 l/min. The variable orifice and the null switch thus form a feedback loop to compensate any impedance change in filter B. The carbon vane vacuum pump used (Gast Model 0522-103-G18D) has adequate pumping power to overcome an increase of about 70% in impedance from a typical initial value of 26.2 torr-cm^2/l/min (1.2 micron cellulose membrane filter manufactured by Nuclepore Corporation). Figure 7 shows the flow controller instrument panel.

1.3 FILTERS

The filters used are 37 mm discs of cellulose membrane filters supplied and mounted in 5.1 cm x 5.1 cm plastic frames by the Nuclepore Corporation. Up to 36 of these slides are carried in a linear array standard 35 mm slide projector cartridges (Argus Camera). Figure 8 shows such a pair of cartridges containing the digitally labeled filter holders.

1.4 SAMPLE CHANGER

The function of the slide changer is to extract a matched pair of filters from side by side slide trays corresponding to the A and B filter stacks, Figure 3. A horizontal shuttle manipulates the slides into their sampling positions where they are clamped in the output tubes of the virtual impactor. Upon the completion of the sampling interval, they are unclamped and withdrawn back into the slide trays. The over-travel of the shuttle actuates a "Geneva wheel" which advances the stack by one vertical increment to be ready for the next insertion. A single motor drives the shuttle which performs the function of transporting, clamping and unclamping slides, together with advancing the trays with a single forward and return stroke.

1.5 FLOW MONITOR

Several types of out-of-range conditions in the flow circuit are detected and indicated by the system. Excessive travel of the micrometer valve due to the presence of leaks or broken filters causes out-of-range switches to be activated. An auxiliary pressure sensing snap switch P1 (Figure 3) is used to detect improper clamping or a broken filter. Since the vacuum needed for the fixed limiting orifice results from the proper flow condition in the fine particle stream, P1 actually monitors the conditions at filter B even before the micrometer valve reaches its limits.

1.6 ELECTRONIC CONTROLLER

The selection of sampling intervals, execution of the sequential steps, regulation of flow, detection of errors, monitoring and display of the system status and communication to an optional remote computer are performed via the control module shown in Figure 7.

In order to maintain the synchronism of the samplers with the clock, ten seconds are allowed for a sample insertion or withdrawal cycle, which normally requires about seven seconds, to complete. Figure 9 illustrates the time sequence of a typical sampling period. While the vacuum is turned on continuously, actual sampling starts at the twenty second mark when the solenoid valve is opened. Another ten seconds are allowed for steady flow conditions to be established before the flow controller is activated. The right hand column of the figure indicates the sequence in which error conditions are checked. The maximum times allowed to complete a sample transport and flow adjustment are ten seconds and twelve minutes respectively.

To ensure synchronization in the event of short a.c. power failures (less than 10 min.) the elapsed time clock and logic control circuits are automatically switched to a rechargeable battery.

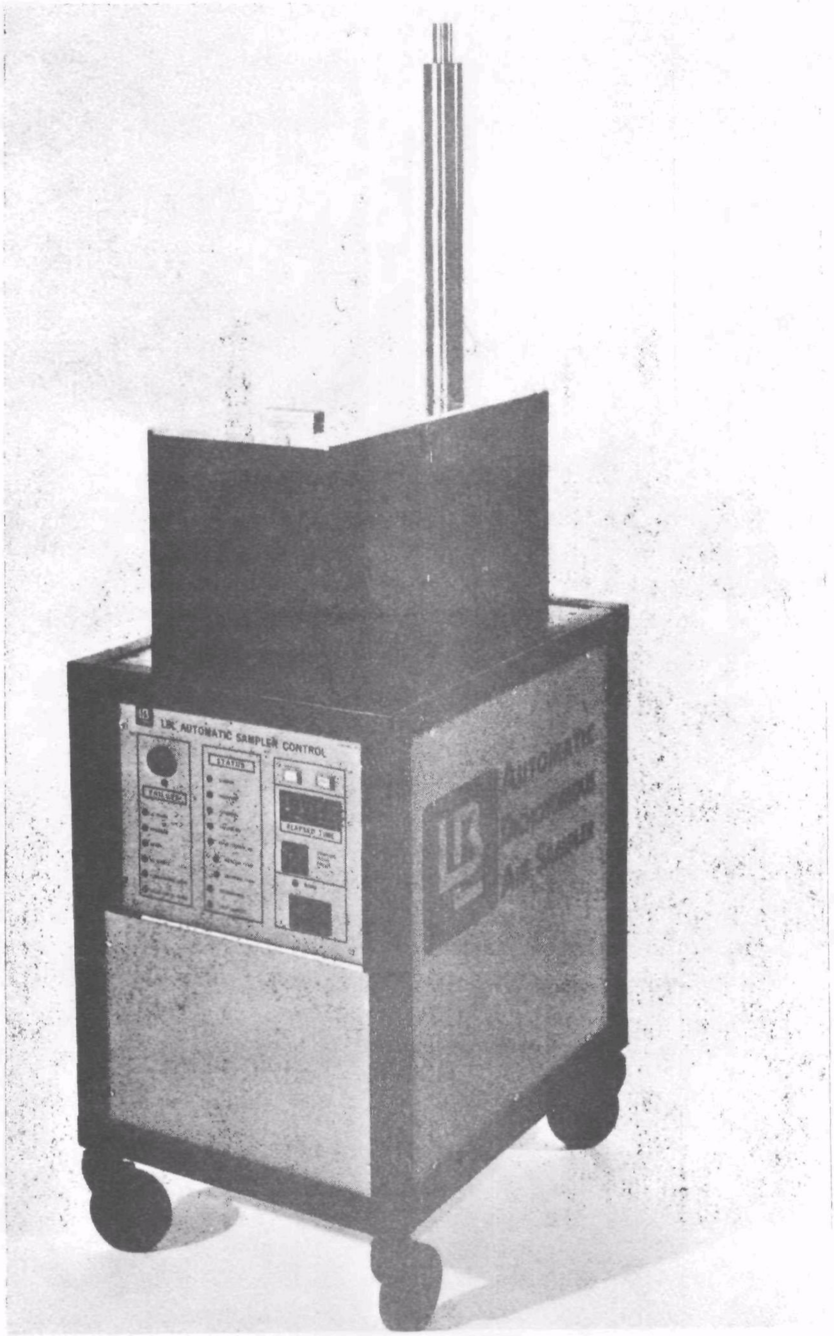


FIGURE 1. LBL AUTOMATIC DICHOTOMOUS AIR SAMPLER WITH DUSTCOVER IN PLACE

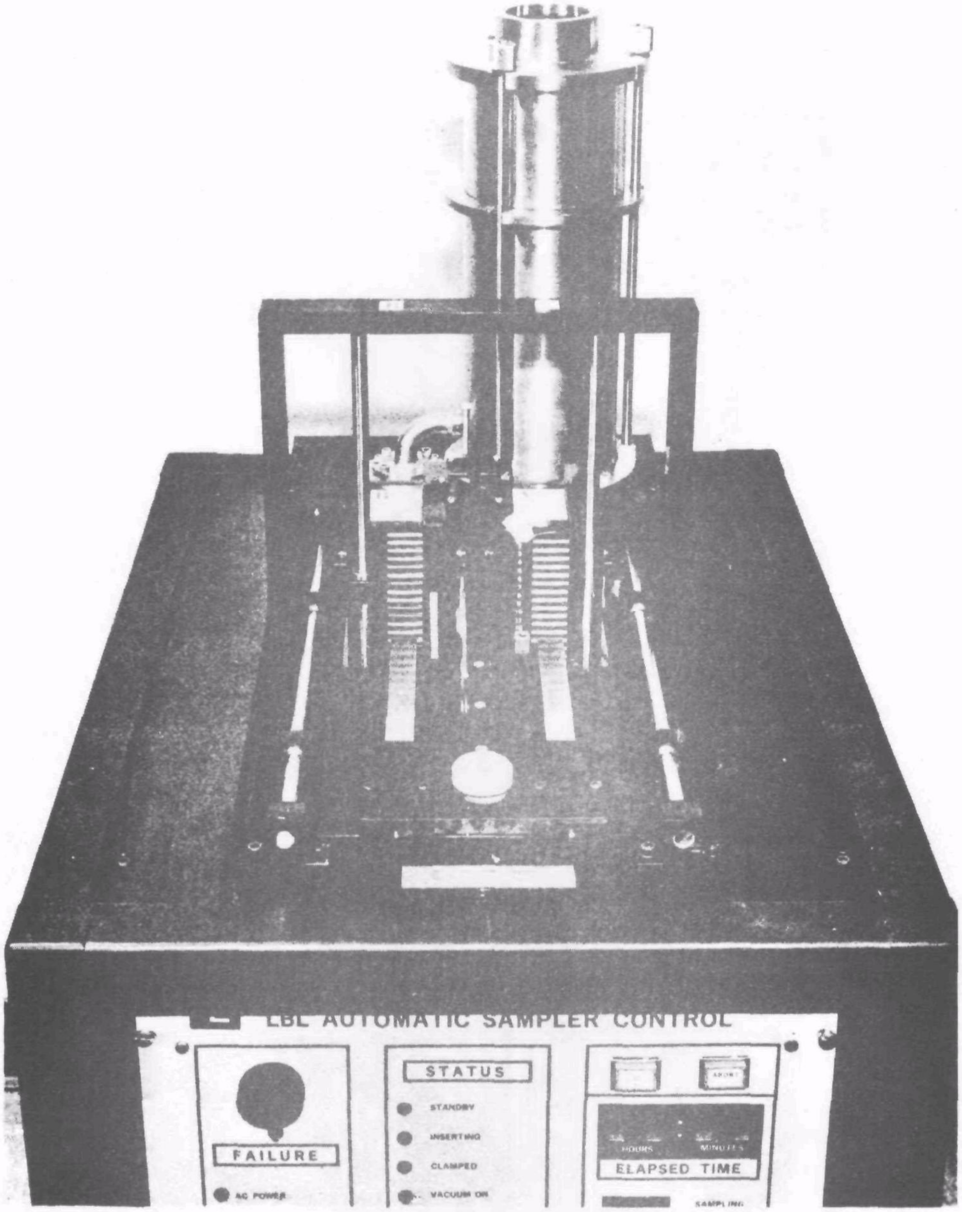


FIGURE 2. ADAS WITH DUSTCOVER REMOVED

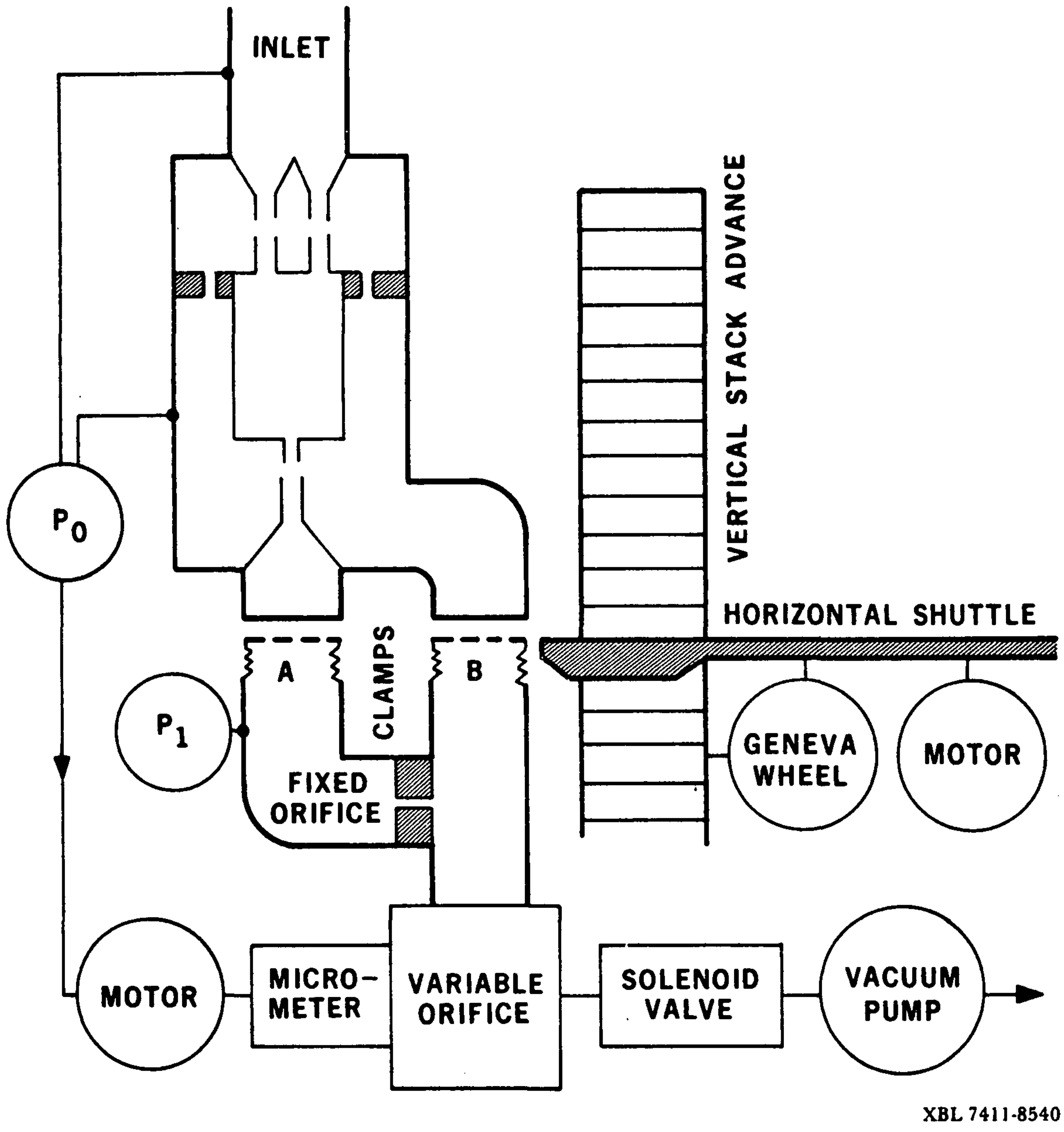


FIGURE 3. SCHEMATIC OF THE AUTOMATIC DICHOTOMOUS AIR SAMPLER

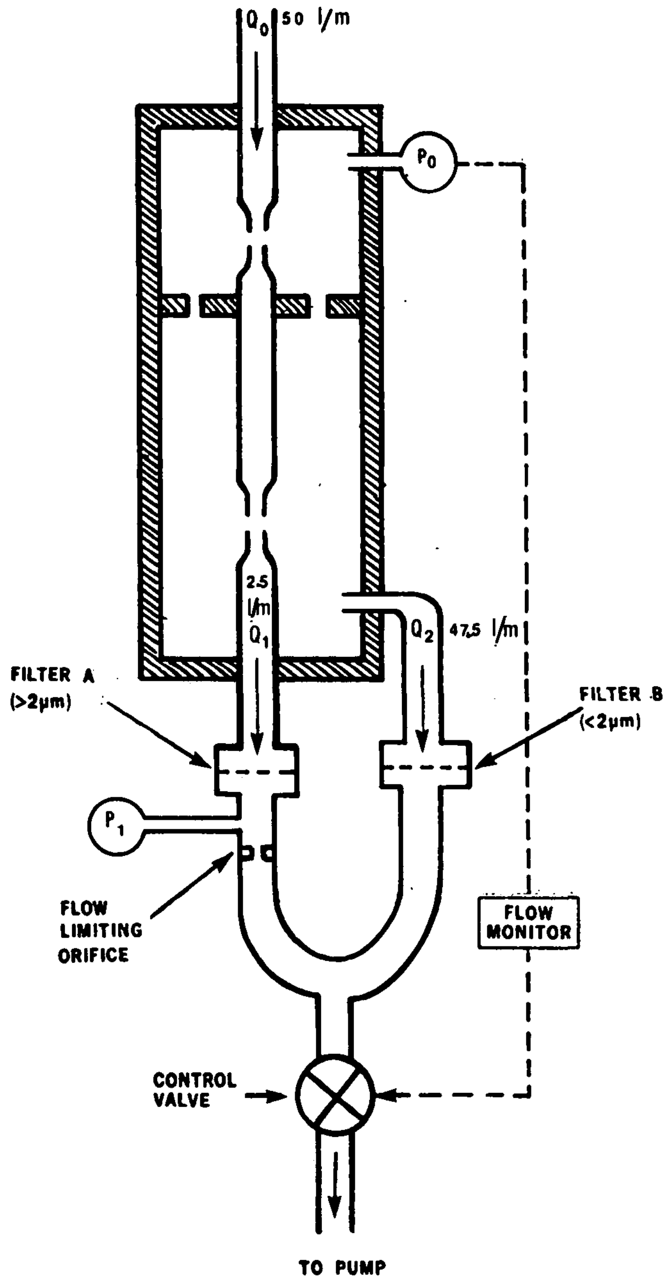


FIGURE 4. SCHEMATIC OF A TWO-STAGE DICHOTOMOUS VIRTUAL IMPACTOR

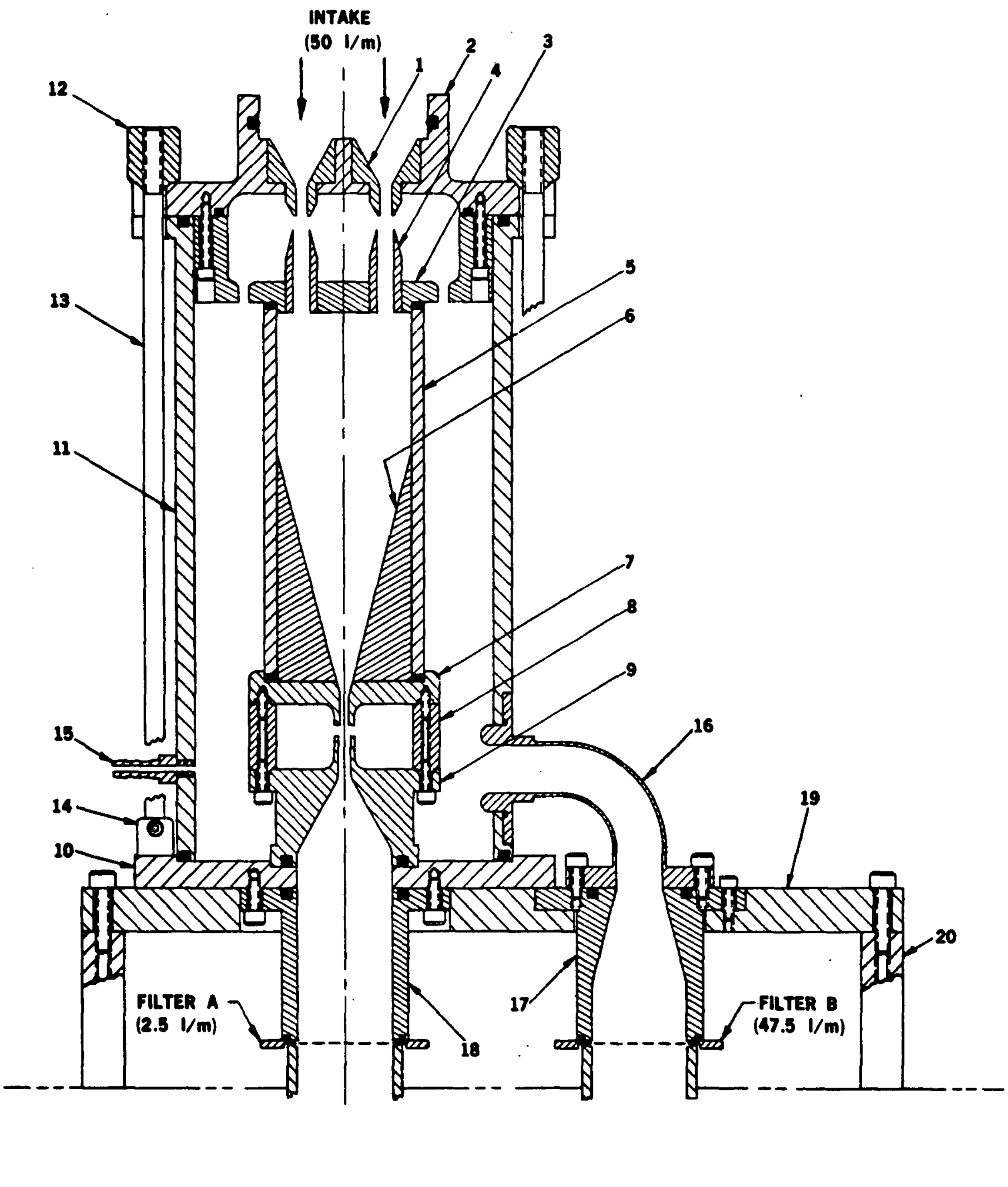


FIGURE 5. DETAILS OF THE VIRTUAL IMPACTOR

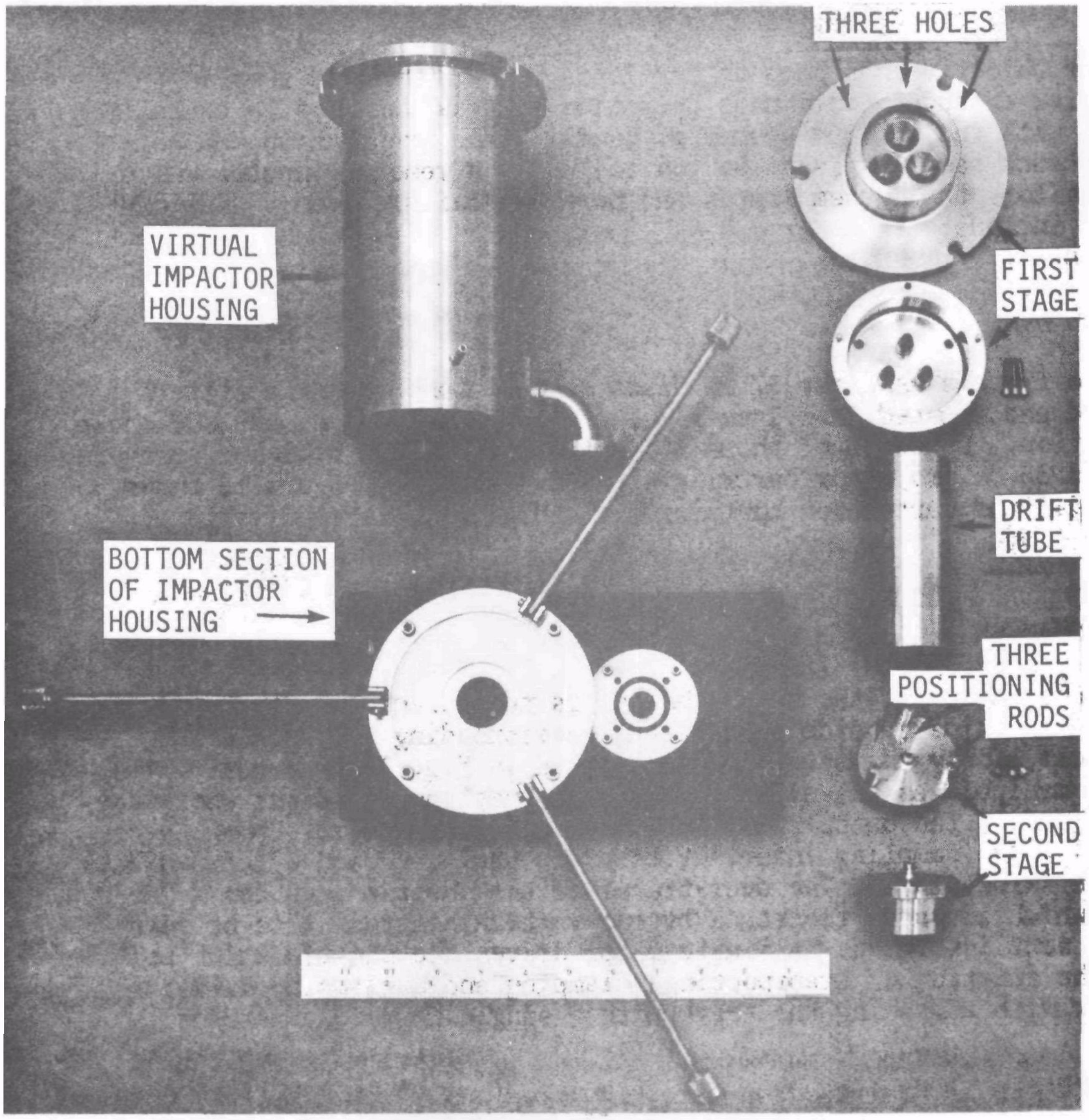


FIGURE 6. DISASSEMBLED COMPONENTS OF THE VIRTUAL IMPACTOR

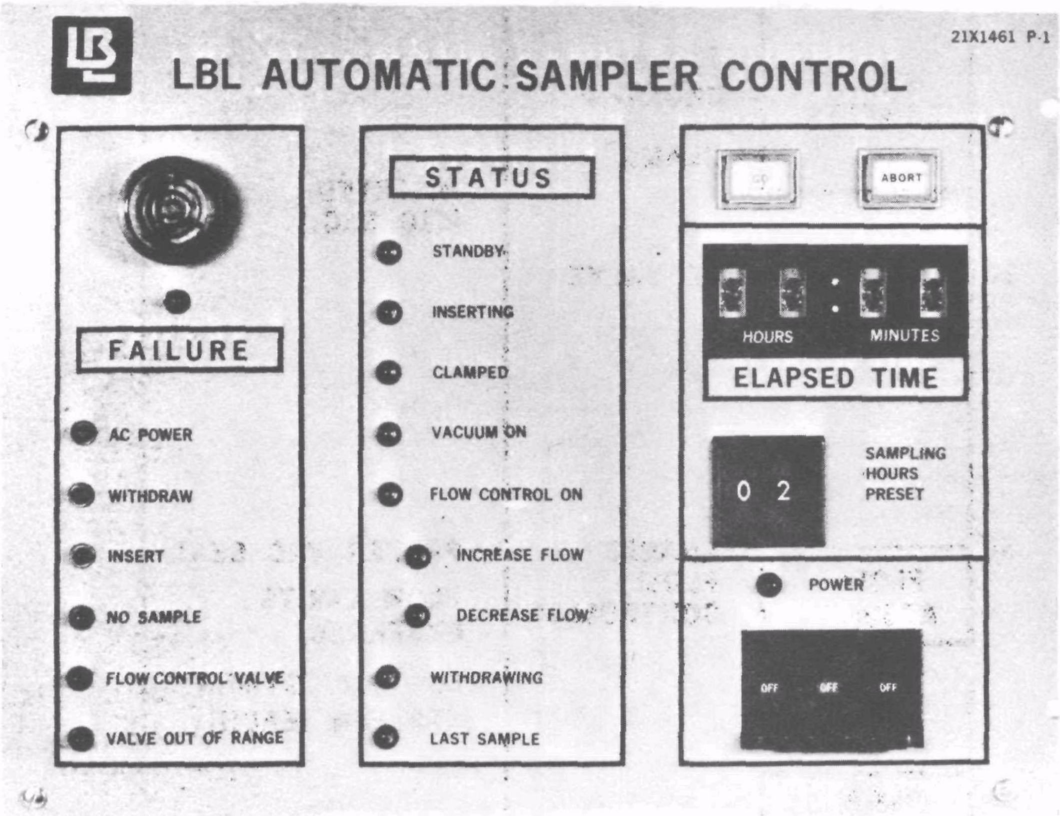


FIGURE 7. FLOW CONTROLLER INSTRUMENT PANEL

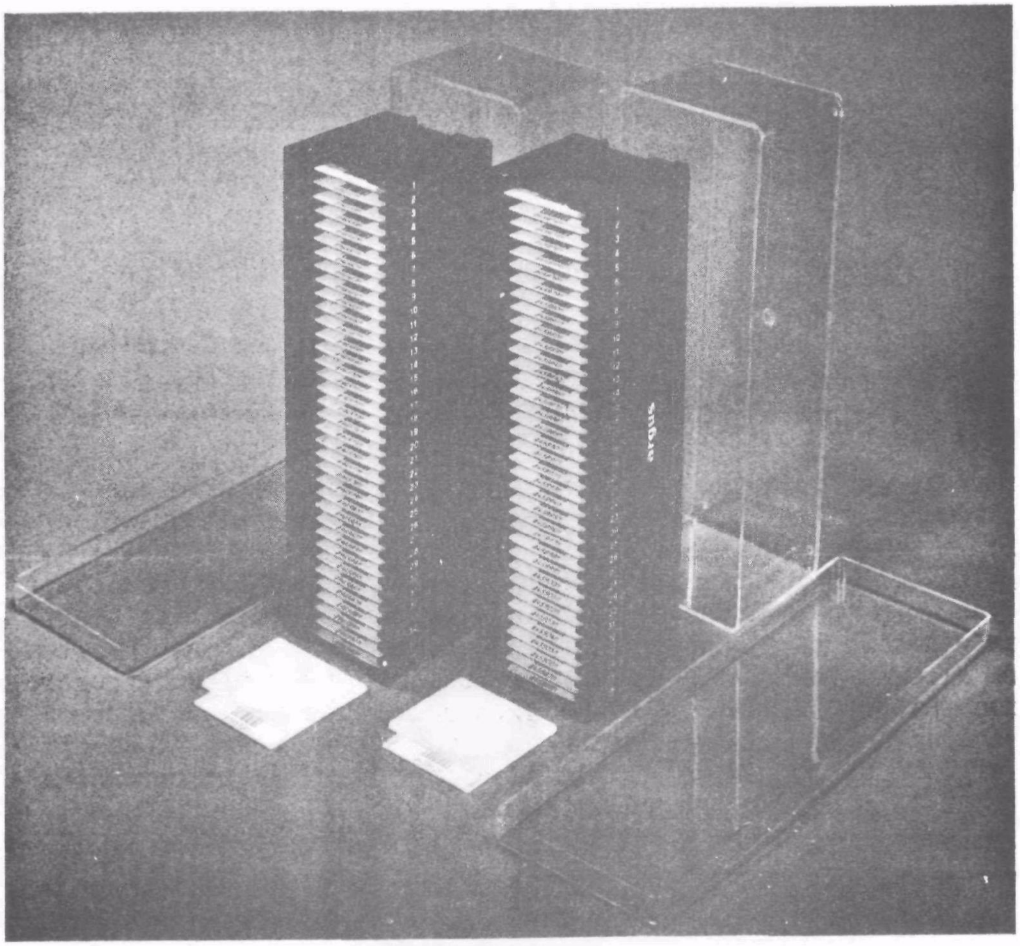


FIGURE 8. SLIDES AND SLIDE TRAYS USED IN ADAS

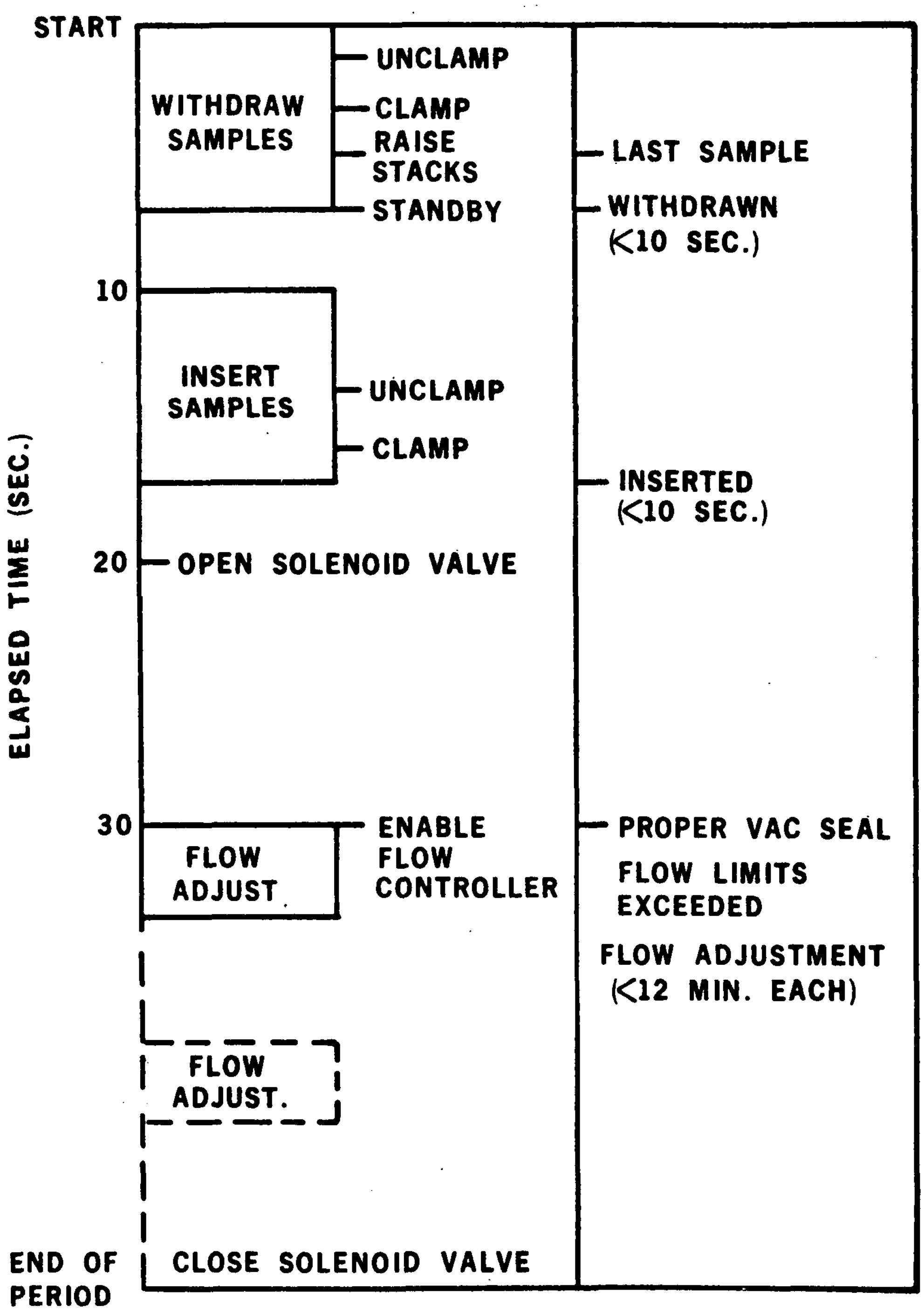


FIGURE 9. THE FUNCTIONAL TIME SEQUENCE OF A SAMPLING PERIOD

APPENDIX B

QUALITY ASSURANCE

CONTENTS

FIGURES

1.0 INTRODUCTION

The quality assurance plan described the quality assurance activities planned by AMC personnel in support of the operation and maintenance of the Lawrence Berkeley Laboratories (LBL) Dichotomous Sampling Units. Under a previous task order the AMC installed the samplers in the RAMS shelters and operated them for approximately six months. Under this task order the AMC continued the operation and routine maintenance activity.

Since LBL, unlike other vendors, assumed an active role in this work, a brief description of the relative roles of the AMC and LBL is appropriate. LBL supplied AMC with slide cartridges filled with beta gauged and serialized filters. The AMC processed these filters according to the procedures described in this plan. The slides and relevant data concerning their exposure were then returned to LBL for analysis. AMC personnel provided preventative maintenance and normal corrective maintenance. Catastrophic or extraordinary failures were corrected by using parts from a spare sampling unit and returning the malfunctioning parts to LBL.

2.0 ON SITE QUALITY ASSURANCE

The following sections describe the procedures employed by AMC personnel in the treatment of filters and the operation and maintenance of the sampling units to assure the quality of the dichotomous data.

2.1 STATUS CHECKS

The RAMS data acquisition and control system was used for surveillance of the sampling network to detect sampler malfunction. A computer operator prepared a check list three times daily indicating the operating condition of each sampler. This list indicated whether a sampler had failed or was operating normally. A master check sheet was kept at the main office indicating the operating condition of each sampler, the number of the slide tray and the estimated slide position, valid and invalid slides, and cause of invalidation. The information contained in the master check sheet was obtained from check sheets filled out when each site was visited, and a visual inspection was made by the visiting personnel. When these check sheets were returned, they were checked and the data recorded on the master check sheet. The master check sheet, over a given period of time, shows the operating history of all samplers in the sampling network, Filter Record 1 and Check Sheet 1 (Figure 1 and Figure 2).

2.2 PREVENTATIVE MAINTENANCE

Normal maintenance of the system consists mainly of removing the accumulation of dust from the virtual impactor. A maintenance log was kept at each sampler location and appropriate entries were made indicating sampler malfunction and corrective measures.

2.2.1 Monthly

At approximately 30 day intervals the virtual impactor was disassembled and cleaned with a washing of ethyl alchol and de-ionized water and wiped

FILTER RECORD 1 YEAR 75 SAMPLING SITE 115

TRAY	A 07011	B 07011	Start	Stop	Time	Period	Date (Julian Day)	Notes
Slide Position	Serial Number	Serial Number	(x)	(x)	(Hour)	(Hour)		
VALID 1	05634	55634	X		1200	06	218	1
2	06452	56452	X		1800	06	218	1
3							219	
4								
5								
6								
7							220	
8								
9								
10								
11							221	
12								
13								
14								
15							222	
16								
17								
18								
19							223	
20								
21								
22								
23							224	
24								
25								
26								
27							275	
INVALID 28	06478	56478		X	1041	06	225	2
29	06479	56479	X		1200	06	226	3
30								
31								
32								
33								
34								
35								
36	06486	56486		X				
VALID								4

NOTES:
1) First sample from previous tray, anticipated start #2 position.
2) Flow control valve failure light, slide intact, tighten brass sleeve on micrometer valve-flow OK.
3) Unit cleaned and sampling resumed.
4) Last sample in summer intensive.

FIGURE 1. FILTER RECORD 1

CHECK SHEET 1

0 = START
X = STOP

✓ = CONTINUE
* = FAILED

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YEAR 75

J. Day 268	Hrs. 0715	103	105	106	108	112	115	118	120	122	124
RUN STATUS		✓	✓	✓	X	✓	✓	✓	✓	*	✓
SAMPLING PERIOD		06	06	12	12	12	12	12	12	12	12
TRAY POSITION	EXPECT.	25	17	18	1	5	9	13	34	?	2
	OBSERV.										
TRAY NUMBER		02029	03028	04014	05019	06020	07015	08011	09013	10012	11013

NOTES: Status Check
SITE 108-Instrument Off-Bullet Wound!
SITE 122-Cause Unknown

J. Day 268	Hrs. 1150	103	105	106	108	112	115	118	120	122	124
RUN STATUS										*	
SAMPLING PERIOD										12	
TRAY POSITION	EXPECT.									?	
	OBSERV.									30	
TRAY NUMBER										10012	

NOTES: Withdrawn, no failure indication
probably station power failure at 00:23 hours Julian 268

J. Day 268	Hrs. 1200	103	105	106	108	112	115	118	120	122	124
RUN STATUS										✓	
SAMPLING PERIOD										12	
TRAY POSITION	EXPECT.									1	
	OBSERV.									1	
TRAY NUMBER										10013	

NOTES: Change tray in sync.

J. Day 268	Hrs. 1200	103	105	106	108	112	115	118	120	122	124
RUN STATUS					✓						
SAMPLING PERIOD					12						
TRAY POSITION	EXPECT.				2						
	OBSERV.				2						
TRAY NUMBER					05019						

NOTES: Unit repaired. Shafts on two inside rollers of the knife edge assembly bent causing improper seal.

FIGURE 2. CHECK SHEET 1

dry with Kimwipes. The jets were cleaned with a washing of ethyl alcohol and de-ionized water with Q-Tips.

O-rings on the sliding seals on the inlet pipe were greased with Dow Corning 33 silicone grease as well as were the two O-rings which make the top seal between the sample and the impactor.

Knife edge clamps and screens were cleaned with alcohol and wiped dry with Kimwipes. Dry accumulations of dust were also removed from other parts of the sampler changer with alcohol, water and Kimwipes.

While the impactor was disassembled a visual inspection was made and preventative maintenance was performed if necessary.

2.2.2 Tri-Monthly

All cooling fan hub bearings that are capable of being lubricated were lubricated with light oil as well as sleeve bearings on shuttle and stack loader assemblies. The limiting flow orifice was washed with alcohol and water.

The sampler was vacuumed and the slipping clutches adjusted as required. The output filter on the vacuum pump was cleaned and replaced when necessary.

Flow calibrations were checked with the flow meters that had been calibrated at Lawrence Berkeley Labs, namely the total flow at the inlet and the flow through the limiting orifice. The vacuum pressure of the pump was checked and the vacuum pump vanes replaced when pressure fell below 25" Hg. The calibrations were extremely stable.

2.2.3 Yearly

Flexible hose was replaced as well as all worn O-rings. The sensor pressure was checked at 5 cm water column.

2.3 FILTER VALIDATION

All filters were visually inspected to determine if they were in the proper sequence and were not cracked or broken before being placed in the sampler. Located at each sampler site was a notebook for logging sampler malfunctions and corrective action, as well as a filter tray record sheet indicating the sampling site number, tray number filter position, filter start and stop time, sampling time, Julian day and a section for notes detailing periods when a filter had failed to sample correctly. When a paired tray set had finished its sample run the filters were validated by checking the log sheets filled out on each visit to the site, verifying the Julian day start and ending dates and the master check sheet. All valid and invalid filters were indicated and when a suitable number of paired trays were collected the filter tray record sheet, site visitation log sheet and filters were shipped to LBL for mass determination and analysis, Filter Record 1. A copy of all log sheets and filter records were kept at the Rockwell International Air Monitoring Center in St. Louis. Dr. B. W. Loo was contacted by telephone for help in solving difficult problems.

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(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Ten of twenty-five stations making up the Regional Air Monitoring System (RAMS) in St. Louis were equipped with dichotomous samplers and high volume filter samplers for aerosol measurements. The dichotomous samplers, built by Lawrence Berkeley Laboratories (LBL), were designed for automatic operation and were capable of collecting up to 36 samples in each of two size fractions before filter stacks must be changed. Most of the time, the samplers operated to collect 12-hour samples (0000-1200 and 1200-2400), except that at two stations with high aerosol loadings, the sampling intervals were split into two 6-hour intervals. Sample filters were pre-weighed by beta gauging before exposure in St. Louis and subsequently returned to LBL for determination of aerosol mass in each size fraction, as well as determination by x-ray flourescence of the concentrations of the following elements: Al, Si, P, Cl, K, Cr, Mn, Ga, Rb, Sr, Sn, Sb, Ba, Hg, S, Ca, Ti, V, Fe, Ni, Co, Zn, As, Se, Br, Cd, and Pb. Approximately 33,000 samples were collected between March 1975 and March 1977. Analytic data are stored in the RAPS Data Bank at Research Triangle Park, N.C.

The operation of the samplers in the RAMS network is described along with problems encountered and procedures used for preventive maintenance and quality control. Also described are two streaker samplers specially installed for continuous aerosol measurements and a silicon cell pyranometer.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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