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MEASUREMENT OF THE CONCENTRATION OF SULFUR DIOXIDE, NITROGEN OXIDES, AND OZONE IN THE NATIONAL ARCHIVES BUILDING

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November 1983

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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Introduction

The ubiquitous nature of certain gaseous substances in the atmosphere assures us that if these substances exist in appreciable quantities outside of a building they will surely exist to an equal or lesser degree within the building unless some sort of barrier is interposed between the interior and exterior of the building. A brief study performed in 1977 at the National Archives indicated that both ozone and nitrogen oxides passed freely into the building through the ventilating system, but that sulfur dioxide was reduced in concentration compared to that expected from the outside air. The study described in this report was performed in a similar manner, but with several major differences in scope and with a somewhat different outcome. [The original report is appended.]

In the 1977 National Archives study, ozone, sulfur dioxide and nitrogen oxide were measured in only one area. In the present study, measurements were made at eleven locations, each supplied by a different supply fan.[1] The conclusion reached in 1977 regarding the reduction in sulfur dioxide could not be confirmed by the present study, although the finding regarding nitrogen oxide was essentially the same.

In addition, measurements were made at single sites in the Madison Building of the Library of Congress and in the library area of the East Wing of the National Gallery of Art. These measurements were intended to offer a comparison between an older ventilating system (circa 1932) and newer systems designed specifically for buildings intended for archival storage.

Experimental Approach

The measurements had a two-fold purpose: first, to determine whether or not the ventilating system modified the quality of atmospheric air during passage into the building, and second, to measure the concentration of each of the three species of interest in air passing into the stack (archival storage) areas of the building. The second purpose can be fulfilled by interior measurements using calibrated instruments. The first could be satisfied by simultaneous measurments of the air entering the ventilating system and air exiting the system into the stacks. However, such simultaneous measurements would require duplicate instrumentation, considerably more time at each location, and substantially increased costs. In any case, it was concluded in the 1977 National Archives study that this approach was not feasible because of the geometry of the building and the inaccessibility of the intakes of many of the systems. It was concluded, nonetheless, that observations of the pattern of concentration changes in the ambient atmosphere of Washington, D.C. and the pattern of changes within the building would yield sufficient information regarding the current capability of the system for removing portions of the pollutant gases of interest. Fortunately, the District of Columbia continuously monitors these gases, and the data from such measurements were made readily available for this study.

The supply air entering each sampling site was measured for a minimum of 24 hours, but in most cases for at least 48 hours. Nitrogen oxides as NOx (NO_2 + NO) and sulfur dioxide were measured continuously, while ozone was measured for several short periods of time during each day of sampling. Calibrations were performed at the beginning and end of each sampling period, and once every 24 hours during that period. Permeation tubes were used to calibrate the sulfur dioxide analyzer, while permeation tubes and an analyzed mixture of nitric oxide in nitrogen were used to calibrate the nitrogen oxide analyzer.

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[1] Nine consecutively numbered heating and air conditioning systems serve the National Archives Building. Each, with the exception of systems 2 and 4, is composed of two supply fans and one return fan. Systems 2 and 4 each have one supply fan and one return fan.

The ozone instrument was operated as an "absolute" instrument whose measurement characteristics were predetermined at NBS. It was only necessary to measure instrument temperature and barometric pressure to calculate the ozone content of the sampled air.

During each analytical period several measurements of barometric pressure, temperature, and relative humidity were made. These measurements were made near the analytical site, away from the direct flow of supply air, but close enough to be reasonably sure that the sampled air originated in the particular ventilating system. Temperature and humidity measurements are summarized in Table 9.

Sample Sites

The sample sites are listed in Table 2 in the order in which the measurements were made. The information regarding stack areas and the identification of the supply fans and ventilating system supplying each area was furnished by the National Archives. The sample probe was located directly in the path of the air entering the area from the ventilating system. In most cases, the probe was moved at least once during each sampling period to an area away from the inlet vent.

The sample site in the Madison Building was in the Manuscript Preparation Section adjacent to a doorway marked LM123. The sample inlet probe was located about 2.5 meters above floor level.

Table 1. Sampling Location and Dates at The National Archives.

Sequence	Sampling Site	Supply Fan	Sampling Period
1	3E3	9A	Dec. 1-3, 1982
2	1E2A	5B	Dec. 3-7, 1982
3	9E1	7A	Dec. 7-9, 1982
4	7E4	9B	Dec. 9-10, 1982
5	10E2	7B	Dec. 12-17, 1982
6	9W4	8B	Dec. 28-30, 1982
7	9W3	8A	Jan. 3-5, 1983
8	9W2	6A	Jan. 5-7, 1983
9	19W2	6B	Jan. 11-13, 1983
10	17W1A	1B	Jan. 13-14, 1983
11	3W2B	5A	Jan. 19-27, 1983

Sampling in the East Wing of the National Gallery of Art was done in stack level "B" in the library area. The probe was located at ceiling level adjacent to an air inlet duct.

Data Collection — Sulfur Dioxide and Nitrogen Oxides

The signals generated by the sulfur dioxide and the nitrogen oxides were continuously recorded on a strip chart recorder. The "zero" for each instrument was established during daily calibration periods by analyzing "zero air" produced by a clean air generator. The signal produced by the sampled air was adjusted for zero and converted to a concentration using one of the calibration factors determined

during the daily calibration. Several points on each chart were read during each hourly period and the final concentrations are expressed as hourly averages. All of the hourly averages for sulfur dioxide and nitrogen oxide for each sample site are included in Tables 4 and 6. Tables 5, 7 and 8 include the hourly averages of nitrogen oxides, sulfur dioxide and ozone measured by the Air Monitoring Division of the Bureau of Air and Water Quality of the District of Columbia.

Data Collection — Ozone

Ozone measurements at the first few sites were made at approximately 30 second intervals for periods of up to 16 hours. As the study progressed, it became obvious that little or no ozone was present in the building and the sample periods were shortened in length. Initially, the data were averaged over the sampling period or for one-hour intervals (whichever was larger), and the averages were compared to the averages from "zero air".

Calibration

The accuracy required for a study such as the one described in this report is not great. An uncertainty in the measurements of 10% will still allow reasonable conclusions to be drawn. It was possible, therefore, to devise a calibration scheme that was adequate relative to the accuracy needed, and which also lay within the bounds set by the requirements for portability, availability, and economy. As previously mentioned, permeation tubes were used as calibrants for sulfur dioxide and nitrogen dioxide, while a gas mixture of nitric oxide in nitrogen was used to calibrate for nitric oxide. The uncertainty of the gas mixture was ±2 percent relative, and was established by analysis against primary gravimetric standards.

The uncertainty of composition of a calibration mixture generated by permeation tubes depends on the uncertainty of the permeation rate of the tube and the uncertainty in the flow of diluent air passing over the tube. The flow of air was measured with a calibrated rotameter. The permeation rate at the time of each calibration was estimated from the measured temperature dependence of the rate, and the temperature of storage just before calibration. It is difficult however to assign uncertainties to the various parameters affecting the concentration; therefore, the uncertainties of the concentrations of the calibration mixture generated with permeation tubes are estimated from measured instrument responses. This assumes that the instrument is stable and that the day-to-day variations are due to differences between the calculated and actual concentrations. The observed variation of the sensitivity (signal/concentration) for both sulfur dioxide and nitrogen oxides analyzers calibrated with permeation tubes was about ±10 percent relative over the more than two months course of the measurements. It should be noted that the ±10 percent variation affects the absolute measurement and not the relative measurements. That is, variations during an analysis can be defined with much greater certainty than can the absolute concentration at any time.

The calibration mixture uncertainty affects the measurement of sulfur dioxide much more than the oxides of nitrogen. This is because the primary calibration of the oxides of nitrogen depended on a stable gas mixture, with the permeation tubes used as an additional confirmation of instrument sensitivity (and to assure that the measured NOx reflected the true sum of NO + NO_2). Consequently, the maximum uncertainty of the measurement of oxide of nitrogen does not exceed ±5 percent relative.

The ozone instrument is essentially an absolute photometer. The absorption path length and the absorption coefficient for ozone are both known with a small uncertainty. It is only necessary to measure the temperature and pressure of the sample in the absorption cell to allow a calculation of the ozone concentration. However, because little or no ozone was measured at any of the sampling sites, it was

really necessary only to be sure that the instrument was on and functioning during each sampling period.

Results — Oxides of Nitrogen

The principal source of oxides of nitrogen in Washington, D.C. is the internal combustion engine of motorized vehicles. Since these oxides are distributed over the entire urban area, it is expected that patterns of concentration would be similar in different parts of the city. This we found to be true when comparing the concentrations measured by the District of Columbia at 24th and L Streets, N.W., with concentrations measured at the National Archives, the Madison Building of the Library of Congress, and the East Wing of the National Gallery of Art (Tables 4 and 5). In general, the diurnal pattern of nitrogen oxide at any location shows two peaks corresponding to the morning and evening rush-hours. The minimum concentration occurs between 2:00 and 5:00 a.m. During daylight hours between the morning and evening rush there is another period of decreased concentration. However, this concentration is usually higher than the early morning minimum. Figure 1 represents measurements made over a 48-hour period at site 9W2 in the National Archives and measurements made during the same period at 24th and L, N.W. While the magnitude of the peaks are different, the peaks occur at the same times and, more importantly, the periods of reduced traffic (and presumably more diffuse sources) show surprisingly good coincidence. The differences in peak heights are most likely due to different physical locations of the sample probes and local variation in traffic density. The 24th and L probe is suspended at a height of about 8 meters above L Street. The sample probe at the Archives was located inside the building and was sampling air obtained from rooftop level.

Figure 2 represents similar measurements made at site 9W4, and Figure 3 represents measurements made at site 9E1. Site 9W4 gave results a little more typical than 9W2, only in that the coincidence of the two separate curves was somewhat less ideal. The measurements at 9E1 illustrate a situation which is not readily explained. Beginning around 1700 of Day 1 very unexpectedly high concentrations were recorded, and the signal exceeded the range of the recorder at the Archives' site early in the evening. The interesting point is that the concentration within the Archives is precisely tracking the external atmospheric concentration.

In several cases, the concentration of nitrogen oxides within the Archives exceeded that measured by the District of Columbia throughout the entire sampling interval or during a substantial part of the interval. The differences between the District of Columbia measurements and the measurements in the Archives can be correlated with the location of the intake for a particular system. If the results are examined carefully, the two systems with four attic or roof intakes have lower nitrogen oxide contents than the measurements made simultaneously by the District of Columbia. Those systems with intakes at ground level show higher values than the simultaneous District of Columbia measurements, with few exceptions. Even the exceptions, 9E1 and 10E2, show the correlation during part of the sampling period. This is summarized in Table 2.

The oxides of nitrogen measured at the Madison Building of the Library of Congress and at the East Wing of the National Gallery of Art track the concentration measured by the District of Columbia in a similar manner to the National Archives (Figs. 4 and 5). Perhaps because the ventilating system intakes for these two buildings are located at rooftop level, the measurements inside are generally less than the measurements at 24th and L, N.W.

Table 2. Relationship Between Air Inlet and Relative Concentration of Nitrogen Oxides.

Supply Fan	Stack	Intake Location	Archives Relative to D.C.
8A	9W3	Attic	Less
8B	9W4	"	"
9A	3E3	"	"
9B	7E4	"	"
1B	17W1A	Ground	Greater
5A	3W2B	"	"
5B	1E2A	"	"
6A	9W2	"	"
6B	19W2	"	"
7A	9E1	"	Inconclusive
7B	10E2	"	"

Results — Sulfur Dioxide

The bulk of the sulfur dioxide in the atmosphere arises from a small number of fixed sources unlike the oxides of nitrogen which arise from a large number of widely distributed sources. Consequently, sulfur dioxide measured at a particular location will vary according to source strength and wind direction. Because of this, it is difficult to relate the concentration observed by the District of Columbia to measurements made at the National Archives.

Sulfur dioxide was detected in the incoming air at all of the sample sites at the National Archives. The hourly average concentrations are shown in Table 6. The hourly average concentrations measured at 24th and L Streets, N.W. are shown in Table 7. The reason for the wide variation in concentrations at different locations and at different times in the Archives is not known at the present time and, as yet, no attempt has been made to correlate results at a particular location to wind direction, ambient temperature, or other meteorological parameters.

The significance of the sulfur dioxide measurements at the National Archives became obvious when compared to the results obtained at the Madison Building and the East Wing of the National Gallery. The sulfur dioxide concentration at these latter two sites did not exceed the lower detectable limit. At the time of the analyses, this limit was 0.0005 ppm at the Madison Building and 0.001 ppm at the East Wing of the National Gallery. (It should be noted that during a period of about one hour on February 8, 1983 the instrument noise level was such that a detectable limit of 0.005 ppm was observed at the East Wing.) During the sampling periods at the Madison Building and the National Gallery, the concentrations measured by the District Government were consistently above the lower detectable limits (Table 7).

The concentrations measured in the Archives are consistently larger than those measured at 24th and L Streets, N.W. If the averages of the two sets of measurements are compared, it is found that the ratio of the average of the Archives measurements to the average of the 24th and L Streets measurements is always less than 1.0.

However, the value ranges from 0.86 down to 0.16 with no obvious relationship between location of intake and the ratio.

Results — Ozone

No significant concentration of ozone was found at any of the locations sampled either in the National Archives, the Madison Building, or the East Wing of the National Gallery. The data supplied by the District of Columbia (Table 8) indicated a maximum of 21 ppb during any sampling period. Measurements made at the same time at all locations were indistinguishable from zero. The explanation is that, given a low ambient concentration to begin with and anticipating substantial losses in the air handling system, it is reasonable to expect that little ozone will reach the stack area. The situation may be quite different at times when the ambient ozone concentration is higher (such as during the summer or fall), but during the months of December, January, and February, the absence of ozone inside the buildings is not unexpected.

Other Measurements

The measurements at the National Archives summarized earlier in this report were all made with the sample probes positioned directly in the air stream issuing from an inlet vent. This was done in order to assess the quality of the incoming air without allowing the possibility of alteration of the composition by local materials or conditions. At several sample sites, the probes were removed from the inlet duct and were placed in the stack area in a position out of direct line with the inlet vent. While no change in the concentration of the oxides of nitrogen was observed, in several cases a reduction of up to 50 percent of the sulfur dioxide was seen. More often, the reduction was less, but it occurred often enough to be of some potential interest. Table 3 contains a qualitative summary of the effect observed at the various sites at the National Archives.

Table 3. Difference of Sulfur Dioxide in the Stack Areas Compared to Incoming Air.

Location	Observation
3E3	15% Reduction
1E2A	No difference
9E1	25% Reduction
7E4	Inconclusive
10E2	50% Reduction
9W4	Not measured in stack area
9W3	20% Reduction
9W2	50% Reduction
19W2	25% Reduction
17W1A	25% Reduction
3W2B	Not measured in stack area

Caution should be exercised in drawing conclusions from these results without further observations.

A series of ozone measurements were made in areas of the Archives at and near several high-use copying machines to determine whether ozone was being generated by the machines, and if so, whether it was being carried into document storage areas. No significant difference was observed between the instrument readings in the immediate vicinity of the copying machines (area 7E1), the stack area directly over the duplicating area (8E1), and measurements made at other locations throughout the Archives. The measurements indicate that the copying machines are not contributing a measurable amount of ozone to the atmosphere inside the National Archives.

Conclusions

The ventilating systems of the National Archives, the Madison Building of the Library of Congress and the East Wing of the National Gallery of Art do not appreciably reduce the concentration of nitrogen oxides in the air which passes through them. However, the ambient concentration of the oxides of nitrogen may decrease with increasing altitude, and a system drawing air from rooftop level may exhibit a lower concentration than a system with an inlet at ground level.

The measurements indicate that all sulfur dioxide is removed from the air entering the systems at the Madison Building and the East Wing, while the concentration entering the system at the National Archives appears to pass through the system with little or no change.

The effect of ventilating systems on the concentration of ozone could not be determined primarily because of the relative absence of ozone in the atmosphere.

Acknowledgment

This work was sponsored by the National Archive and Record Service and by the Public Building Service of the General Services Administration. We wish to thank Mr. Amantha Padmanabha and the staff of the Air Monitoring Division of the Department of Environmental Services of the District of Columbia for their advice and data.

Table 4. Hourly Average Concentrations[a] of Nitrogen Oxides Measured at National Archives, Madison Building and East Wing.

		Sampling Location and Starting Date													
	Time	3E3 12/2/82	1E2A 12/6	9E1 12/7	7E4 12/9	1062 12/15	9W4 12/28	9W3 1/3/83	9W2 1/5	19W2 1/12	17W1A 1/13	3W2B 1/19	MAD. Bldg. 1/31	MAD. Bldg. 2/2	East Wing 2/7
	10	116	81											(Contd.)	
D	11	121	73			75	44	42		78		76			
	12	116	64	70		69	40	39		72	64	68	35	45	
A	13	126	59	66		69	31	36		71	64	65	32	33	36
	14	119	60	58	28	69	28	39	140	64	55	68	32	24	30
Y	15	134	67	60	35	70	34	41	150	65	55	62	28	20	31
	16	106	80	91	36	69	41	44	159	75	62	89	38	21	40
1	17	93	100	111	43	79	48	58	172	92	87	93	52	18	50
	18	80	99	104	44	80	40	80	160	77	90	85	57	14	47
	19	65	80	160	43	89	34	75	134	60	75	65	68	11	34
	20	55	65	--	51	101	32	63	113	46	78	42	92	9	24
	21	53	57	--	61	109	41	54	98	36	101	39	96	7	17
	22	51	41	--	58	109	36	41	100	32	111	37	78	4	14
	23	52	31	--	51	112	35	38	87	25	80	33	78	4	14
	24	49	27	--	46	116	40	34	75	30	79	35	78	5	12
	1	52	25	--	45	109	32	34	63	25	146	24	81	7	12
D	2	37	21	--	41	57	21	32	57	23	178	23	76	14	10
	3	22	18	--	39	29	15	29	46	21	136	19	64	23	8
A	4	19	16	--	38	15	12	24	38	20	97	15	67	31	7
	5	18	16	--	36	10	14	26	40	23	73	18	69	21	8
Y	6	32	24	--	39	13	22	36	66	32	70	23	88	15	14
	7	53	45	--	52	56	32	64	164	67	101	59	114	20	24
2	8	55	75	--	79	118	48	89	252	102	132	123	146	36	39
	9	57	88	298	90	139	49	84	223	107	120	98	154	43	37
	10	57		234	93	152	45	--	168		93	79	118	42	32
	11	52		155	84	136	44	--	133				89		26
	12	50		112	78	90	62	45	106				52		22

Table 4. Continued.

		Sampling Location and Starting Date												
	Time	3E3 12/2/82	1E2A 12/6	9E1 12/7	7E4 12/9	1062 12/15	9W4 12/28	9W3 1/3/83	9W2 1/5	19W2 1/12	17W1A 1/13	3W2B 1/19	MAD. Bldg. 1/31	MAD. Bldg. 2/2	East Wing 2/7
	13			59		72	62	42	89				45		21
D	14			65		64	58	36	78				43		22
	15			57		66	62	38	84				36		24
A	16			73		81	63	39	106				37		33
	17			90		99	70	53	130				37		44
Y	18			98		110	60	71	123				40		39
	19			82		96	44	72	138				41		29
3	20			68		83	36	78	174				48		23
	21			62		69	32	80	231				56		19
	22			75		47	36	90	198				63		18
	23			73		62	31	91	135				50		19
	24			66		59	29	107	90				31		18
	1			49		51	24	103	63				19		16
D	2			44		40	23	87	49				14		14
	3			45		32	22	76	35				10		12
A	4			43		24	19	65	38				8		11
	5			54		23	23	56	35				8		17
Y	6			86		33	29	59	39				14		23
	7			118		64	48	78	59				27		38
4	8			132		98	79	104	76				40		48
	9			128		102	75	122	80				55		46
	10			98		82		137	82				60		36
	11					69		131	71				57		
	12					66							45		

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[a] Concentrations in parts per billion by mole (ppb).

Table 5. Hourly Average Concentrations[a] of Nitrogen Oxides Measured by D.C. Government at 24th and L Streets, N.W.

Starting Date

	Time	12/2/82	12/6	12/7	12/9	12/15	12/28	1/3/83	1/5	1/12	1/13	1/19	1/31	2/2	2/7
	10	195	61											(Cont.)	
D	11	168	33			158	66	65		44		--			
	12	179	31	31		161	--	34		37	43	31	61	129	
A	13	180	56	37		140	--	49		31	40	45	46	91	68
	14	196	39	55	64	157	84	57	114	31	32	40	53	88	65
Y	15	226	41	38	43	143	50	54	105	32	40	31	81	67	67
	16	120	49	51	49	145	64	36	124	38	66	36	73	72	76
1	17	155	86	104	58	174	67	67	147	34	86	38	109	76	77
	18	119	58	242	59	197	46	93	137	42	98	39	208	74	80
	19	92	44	419	62	153	36	86	94	40	115	35	173	77	73
	20	90	42	538	52	177	36	81	82	27	172	26	219	77	66
	21	80	25	466	59	148	30	50	99	22	178	29	161	72	53
	22	75	18	445	49	188	38	39	56	20	169	31	116	58	52
	23	73	18	418	40	179	51	33	50	22	219	26	115	66	53
	24	65	18	341	39	177	45	27	50	21	127	20	89	76	49
	1	61	15	316	46	94	34	30	44	22	114	17	90	58	49
D	2	57	14	316	47	63	13	35	42	24	106	18	86	53	45
	3	34	14	265	42	42	12	29	39	22	101	19	156	41	43
A	4	25	11	233	38	39	10	24	39	22	96	24	148	41	40
	5	28	12	238	33	44	12	27	43	22	98	27	154	46	40
Y	6	48	22	346	52	43	24	43	71	33	115	37	252	45	48
	7	93	61	516	80	47	60	108	156	62	110	69	318	83	71
2	8	137	84	507	109	97	78	210	192	79	92	83	247	72	78
	9	109	62	248	144	152	56	132	147	65	71	90	156	66	59
	10	83		125	87	89	88	--	88		71	82	94	55	
	11	77		114	81	31	98	--	61				76		51
	12	85		--	68	32	78	--	49				72		53

Table 5. Continued.

		Starting Date													
	Time	12/2/82	12/6	12/7	12/9	12/15	12/28	1/3/83	1/5	1/12	1/13	1/19	1/31	2/2	2/7
	13			--		26	73	--	51				74		54
D	14			--		21	60	46	64				88		54
	15			--		24	65	58	75				109		66
A	16			106		31	40	69	61				107		62
	17			160		39	41	87	125				107		69
Y	18			199		48	34	92	170				110		66
	19			190		41	28	87	307				110		62
3	20			165		36	28	86	527				116		56
	21			131		34	32	82	499				124		54
	22			110		39	33	137	339				113		54
	23			90		37	31	175	179				84		57
	24			63		34	31	126	79				68		55
	1			55		34	31	117	62				64		51
D	2			63		24	27	71	58				57		51
	3			48		15	23	62	65				54		50
A	4			43		17	26	70	43				51		49
	5			50		14	40	123	47				51		54
Y	6			--		21	73	114	72				69		65
	7			--		54	163	159	147				103		92
4	8			--		119	191	169	166				139		87
	9			--		134	124	192	141				134		71
	10			--		83		118	130				135		61
	11					70		149	78				145		
	12					36							129		

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[a] Concentrations in parts per billion by mole (ppb).

Table 6. Hourly Average Concentrations[a] of Sulfur Dioxide Measured at the National Archives.

		Sampling Location and Starting Date										
	Time	3E3 12/2/82	1E2A 12/6	9E1 12/8	7E4 12/9	10E2 12/15	9W4 12/29	9W3 1/4/83	9W2 1/5	19W2 1/12	17W1A 1/13	3W2B 1/26
	10		1	5				5				
D	11		2	8		11	3	6			9	20
	12	8	3	9		--	4	5		9	9	16
A	13	12	2	9	2	--	2	5		9	9	16
	14	9		8	4	6	2	5	6	8	9	18
Y	15	28		9	8	--	2	5	7	8	9	20
	16	24		9	9	--	2	5	6	9	10	22
	17	19		9	10	6	2	4	6	9	12	25
1	18	18		9	9	6	2	6	6	9	12	28
	19	20		9	7	5	2	5	6	9	11	23
	20	26		8	7	4	3	4	6	10	12	32
	21	--		8	7	4	5	4	6	10	12	34
	22	--		9	6	3	7	4	6	10	16	30
	23	--		8	6	2	6	4	6	9	17	30
	24	--		8	5	2	4	4	6	10	15	33
	1	--		9	5	3	4	5	7	10	16	32
D	2	--		12	5	4	4	2	7	8	14	29
	3	--		12	4	4	4	3	7	7	13	26
A	4	--		12	4	4	4	4	8	7	11	25
	5	--		12	4	4	3	5	7	6	10	25
Y	6	--		13	3	4	3	6	8	6	11	25
	7	--		16	3	4	4	5	8	8	10	25
	8	--		17	2	4	6	4	9	10	9	28
2	9	--		10	2	3	3	4	12	5	8	21
	10	12		11	1	2	3	2	9			
	11	11				5		1	13			
	12	12				5			11			
	13					5			9			
	14					5			8			
	15					5			8			
	16					5			9			
	17					4			10			
	18					5			8			
	19					5			8			
	20					5			8			
	21					5			10			
	22					7			11			
	23					8			10			
	24					7			7			
	1					5			7			
D	2					5			6			
	3					4			4			
A	4					4			6			
	5					3			6			
Y	6					4			8			
	7					4			5			
	8					4			4			
3	9					4			3			
	10					3						
	11					2						
	12					2						
Average		18	2	10	5	4	4	4	7	8	11	25

---

[a] Concentrations in parts per billion by mole (ppb).

Table 7. Hourly Average Concentrations[a] of Sulfur Dioxide Measured by D.C. Government at 24th and L Streets, N.W.

		Starting Date										
	Time	12/2/82	12/6	12/8	12/9	12/15	12/29	1/4/83	1/5	1/12	1/13	1/26
	10		14	24				26				
D	11		4	18		28	10	24			27	29
	12	30	4	16		--	13	21		13	28	26
A	13	41	7	15	--	--	11	15	16	11	25	32
	14	56		14	10	--	15	15	10	10	23	28
Y	15	99		17	8	--	14	21	11	10	28	27
	16	36		23	11	--	8	20	9	18	36	24
	17	49		22	10	47	13	19	10	20	32	26
1	18	15		42	9	61	16	23	12	21	33	26
	19	16		73	12	38	18	23	8	22	35	30
	20	37		35	21	38	28	18	9	20	34	34
	21	34		12	27	33	37	21	8	19	33	34
	22	23		10	22	36	37	20	6	17	32	36
	23	16		10	14	39	26	19	4	17	36	28
	24	17		10	13	36	20	27	4	19	36	28
	1	29		15	20	36	19	24	3	20	40	23
D	2	27		20	27	59	18	25	4	22	42	30
	3	9		16	29	41	19	24	7	22	40	28
A	4	5		16	25	38	22	19	11	23	46	25
	5	5		14	17	40	33	32	12	19	45	23
Y	6	10		16	25	24	28	34	15	20	35	26
	7	26		24	29	10	30	36	23	27	33	29
	8	34		27	47	15	30	25	50	28	32	46
2	9	33		13	48	25	26	24	25	25	32	40
	10	27		7	20	20	30	18	25			
	11	17			29	13		15	25			
	12	28			18	14			34			
	13					13			25			
	14					14			27			
	15					13			29			
	16					13			35			
	17					15			38			
	18					16			44			
	19					15			43			
	20					16			37			
	21					29			35			
	22					25			43			
	23					20			41			
	24					16			26			
	1					17			21			
D	2					12			22			
	3					7			27			
A	4					7			14			
	5					8			18			
Y	6					10			17			
	7					14			20			
	8					19			21			
3	9					19			18			
	10					14						
	11					11						
	12					17						
Average		29	7	20	21	23	22	23	21	19	34	29

---

[a] Concentrations in parts per billion by mole (ppb).

Table 8. Ozone Measured at 24th and L Streets, N.W. by the District of Columbia.

Date	Concentration[a] of Ozone Mean	Concentration[a] of Ozone Maximum
12/6/82	10	18
12/7/82	10	21
12/8/82	3	11
12/9/82	6	16
12/10/82	4	11
12/15/82	3	5
12/16/82	5	12
12/17/82	8	15
12/28/82	3	10
12/29/82	5	20
12/30/82	2	8
1/3/83	5	12
1/4/83	5	11
1/5/83	1	1
1/6/83	2	8
1/7/83	4	11
1/12/83	10	17
1/13/83	8	14
1/14/83	5	13
1/15/83	9	14

---

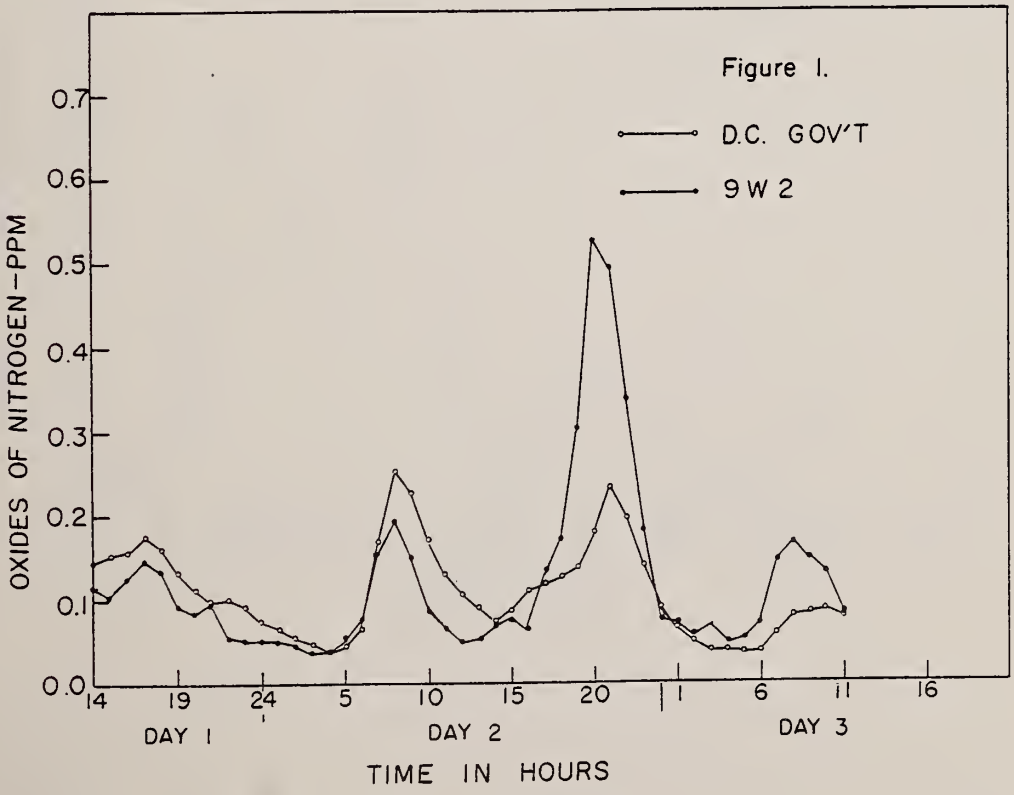
[a] Concentrations in parts per billion by mole ($1/10^{-9}$).

Table 9. Summary of Temperature and Relative Humidity Measurements.

Location	Temperature Average	Temperature Range	Relative Humidity Average	Relative Humidity Range
3E3	21.1	20.5-21.4	57	55-58
1E2A	22.0	21.5-22.3	54	49-56
9E1	22.6	21.4-23.5	36	54-57
7E4	21.3	20.4-22.6	48	48-48
10E2	22.7	22.1-22.5	49	45-53
9W4	22.7	20.7-23.5	55	50-60
9W3	22.0	21.2-23.2	52	48-57
9W2	21.3	21.0-22.0	43	36-47
19W2	24.1	22.4-25.2	41	39-42
17W1A	22.2	21.6-22.8	50	49-52
3W2B	22.9	22.4-23.7	35	31-42
Madison Building	21.4	20.8-23.0	55	51-58
East Wing	21.8	21.3-22.2	54	52-56

Figures 1 - 5

A plot of the concentration of oxides of nitrogen measured at the indicated location compared to a plot of the data of the District of Columbia measurements made at 24th and L Streets, N.W., Washington, D.C.



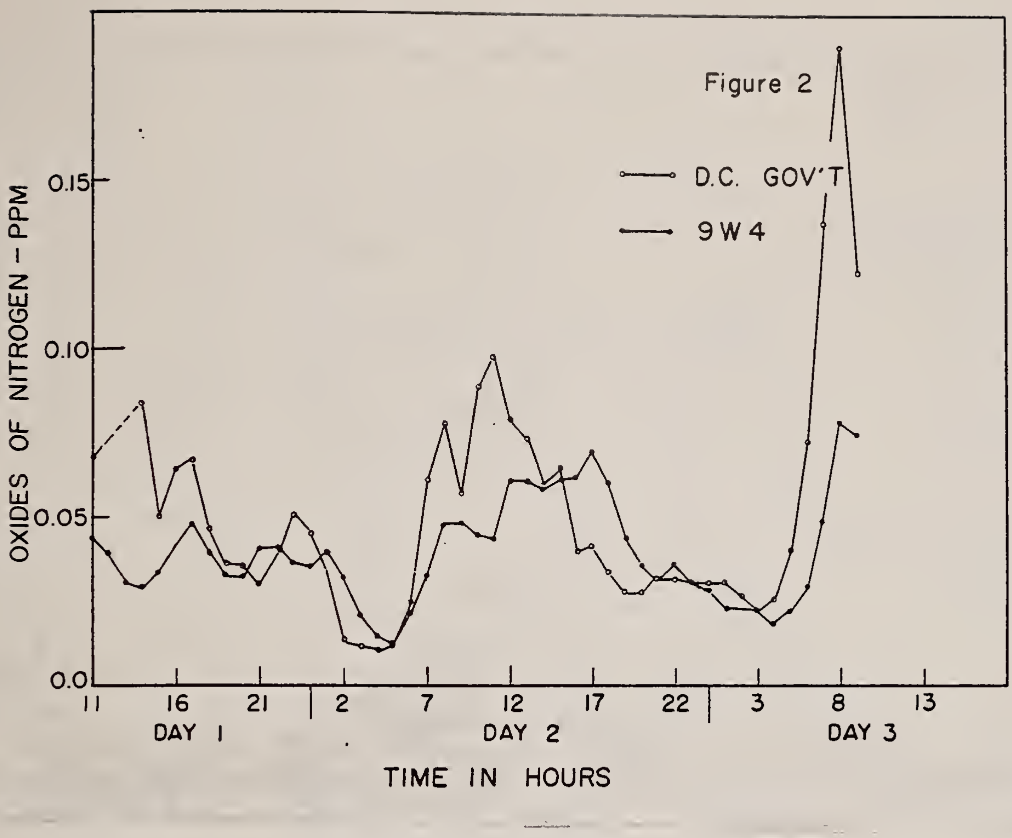


Figure 2

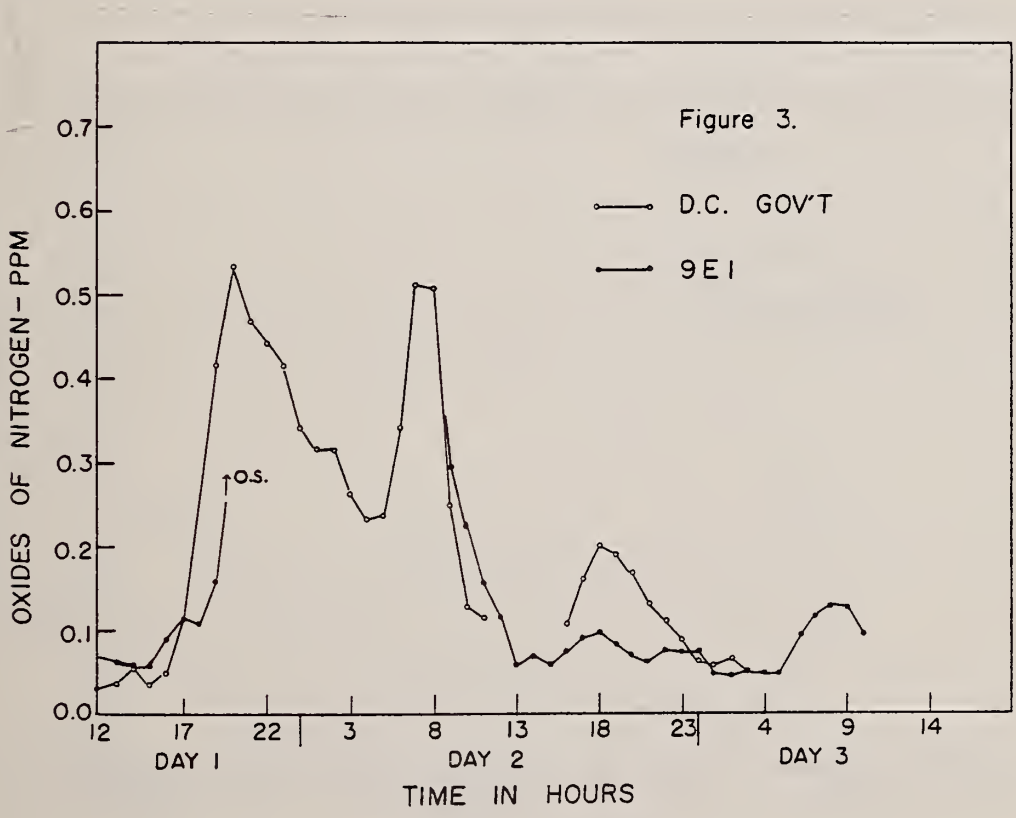


Figure 3.

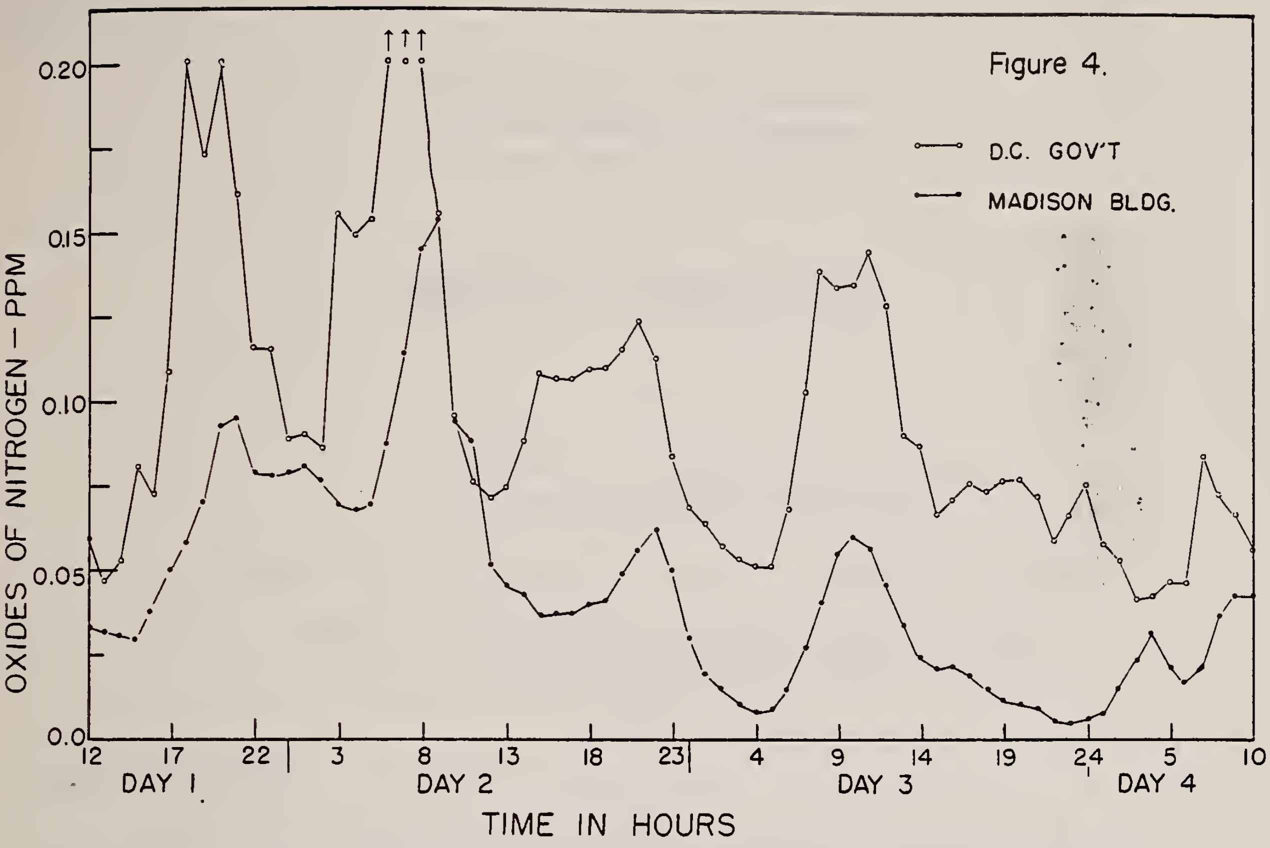


Figure 4.

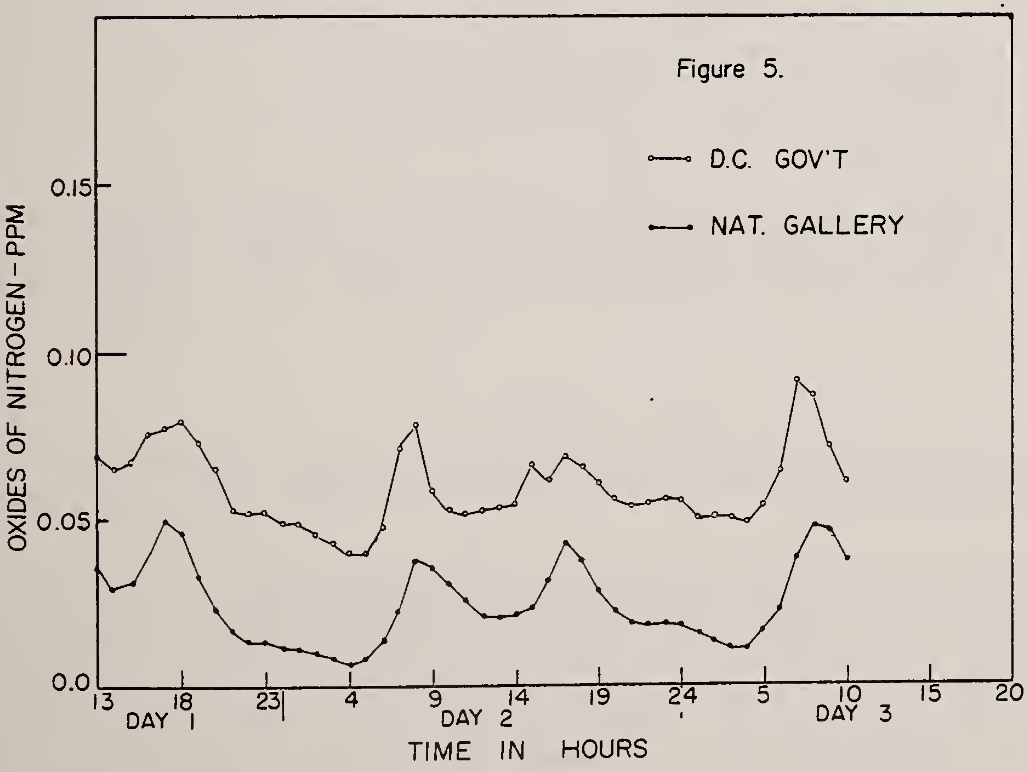


Figure 5.

Attachment: Report of the 1977 study at the National Archives building.

FORM NBS-348
(12-65)

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

REPORT OF ANALYSIS

of

The Atmosphere at Several Locations
in the National Archives

Requested by General Services Administration

Act No. 10477380, Document No. B0000051
Project No. 3100645

Introduction

Air from the ventilating system was analyzed for ozone, oxides of nitrogen, and sulfur dioxide. The analyses were performed separately and at different times for each of the substances. Samples were obtained both in the stack areas and at the receiving room loading platform. The stacks are supplied with air from the ventilating system, while the receiving room loading platform receives air from both the interior of the building and directly from the outside.

Ozone was measured with a Dasibi Model 1003 AH ultraviolet adsorption instrument. Oxides of nitrogen were measured with a Monitor Labs Model 8440 Nitrogen Oxide analyzer. Sulfur dioxide was measured with a Monitor Labs Model 8450 Sulfur Monitor.

Ozone

Ozone was measured in the location identified as 18-E-3, 5-E-3, and 7-W-2, and at the receiving room loading platform on September 1, 1977.

The air in the room and the air coming directly out of a register of the ventilating system were sampled in the three stack areas. The ozone concentration in all three areas was essentially the same as the air delivered to the area by the ventilating system. In area 5-E-3 and 7-W-2, the concentration in the room air was the same as in the incoming air, but in area 18-E-3 the ozone concentration in the room air was somewhat higher than the ozone content of the incoming air. No explanation for this anomaly has been found.

The concentration of ozone at the loading platform was considerably higher than that found in any of the stack area inlet air ducts. The high concentration probably reflects the mixing of a large amount of outside air with some inside air. The value of the concentration of ozone at this point is similar to the ozone concentration measured by the District of Columbia Air Monitoring Station at 427 New Jersey Avenue.

The results of the ozone measurements are summarized below:

Area	Source	Concentration Range in Parts per Million by Volume
5-E-3	Incoming Air	0.005 - 0.012
5-E-3	Room Air	0.009 - 0.013
7-W-2	Incoming Air	0.000 - 0.006
7-W-2	Room Air	0.000 - 0.004
18-E-3	Incoming Air	0.009 - 0.020
18-E-3	Room Air	0.031 - 0.042
Rec Rm.	Loading Platform	0.070 - 0.110
Outside Air		0.097*

---

*Value obtained from D.C. Government for period corresponding to sampling at Rec. Rm. Loading Platform.

Oxides of Nitrogen

Oxides of nitrogen were measured in area 5-E-3 and at the loading platform of the receiving room on September 14 and 15, 1977. The value measured in the duct of 5-E-3 remained at a concentration between 0.020 and .030 ppm between 3:00 p.m. on September 14, and 7:00 a.m. on September 15. The concentration in the outside air measured by the D.C. Government ranged between 0.016 and 0.070 ppm during this period. The average value was 0.041 ppm. The values measured in area 5-E-3 did not reflect changes in the concentration of the oxide of nitrogen in the outside air. At 7:00 a.m. on September 14, the value of the concentration in area 5-E-3 began to rise, and reached a maximum of 0.060 ppm at 9:30 a.m. This rise was matched by a similar rise in the concentration in the outside air which began at 4:00 a.m. and which reached a value of 0.080 ppm at 8:30. The measurements by the D.C. Government were interrupted at this time, but the trend in the concentration at the time was definitely rising.

The values of the oxides of nitrogen measured in the receiving room loading dock area ranged from a low of 0.055 ppm to a high of 0.13 ppm during a one-hour sampling period starting at 11:30 a.m. on September 14. The average value for the same period measured by the D.C. Government was about 0.06 ppm. The reason for the higher values inside the building is no doubt due to auto exhaust gases generated by vehicles moving in and out of the receiving room area.

Sulfur Dioxide

Sulfur dioxide was measured in area 5-E-3 and in the loading dock area of the receiving room on November 29 and 30, 1977. The concentration in the air entering the 5-E-3 area through the ventilating system and the room air itself never exceeded a concentration of 0.003 ppm sulfur dioxide.

Measurements made in the receiving room loading dock area varied from a low value of 0.009 ppm to a high of 0.044 ppm. The concentration measured in the area appeared to follow the concentration of sulfur dioxide in the outside air as measured by the D.C. Government. The concentration in the outside air during the period of time when measurements were being made in area 5-E-3 were between 0.032 and 0.040 parts per million.

Conclusion

The maximum concentration of sulfur dioxide in the stack areas does not exceed 0.003 ppm, although the outside air contains more than ten times this concentration. The ozone concentration in the stack area does not exceed 0.042 ppm when the outside air contains as much as 0.097 ppm. It appears, therefore, that substantial amounts of sulfur dioxide and ozone are removed by passage of outside air through the ventilating system.

Nitrogen dioxide concentration in the building appears to respond to changes in the concentration of nitrogen dioxide in the outside air and are probably not removed in substantial quantities by passage through the ventilating system.

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January 30, 1978

NBS-114A (REV. 2-80)

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5. AUTHOR(S)

E.E. Hughes and R. Myers

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

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Washington, DC 20407

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Continuous measurements of nitrogen oxides, sulfur dioxide and ozone were made consecutively at locations in the stack areas of the National Archives building in Washington, DC. Similar measurements were made at single locations in the Madison Building of the Library of Congress and the East Wing of the National Gallery of Art. The results indicate that the ventilating system of the National Archives has no effect on the concentration of nitrogen oxides or sulfur dioxide drawn into the building. The results for ozone were inconclusive. The newer ventilating systems of the Madison Building and the East Wing are effective in removing sulfur dioxide but not the oxides of nitrogen.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

air pollution; air pollution removal; archival storage; nitrogen oxides; sulfur dioxide

13. AVAILABILITY

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