



R E S E A R C H T R I A N G L E I N S T I T U T E

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Final Report
Analysis of Commercial Cylinder Gases
of Nitric Oxide, Sulfur Dioxide, and Carbon Monoxide
at Source Concentrations
Results of Audit 3

Prepared for

Quality Assurance Division
Environmental Monitoring Systems Laboratory
Environmental Research Center
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

EPA Contract No. 68-02-3222

September 1979

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by

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TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
1.0	SUMMARY.....	1
2.0	INTRODUCTION.....	4
3.0	CYLINDER GAS ANALYSIS AND TRACEABILITY PROCEDURE....	8
	3.1 Analysis of NO Cylinders.....	8
	3.2 Analysis of SO ₂ Cylinders.....	9
	3.3 Analysis of CO Cylinders.....	10
	3.4 EPA Quality Assurance Program.....	11
4.0	RESULTS OF CYLINDER GAS ANALYSES.....	13
5.0	SUMMARY OF RESULTS OF AUDITS 1, 2, and 3.....	19

SECTION 1

SUMMARY

Manufacturers of commercial cylinder gas, if requested, will supply gas standards with a certified analysis and a statement of accuracy. Generally, the level of accuracy is specified as ± 1 to 3 percent of the component value. In order to ascertain the accuracy of commercially available cylinder gas, EPA has initiated a national performance audit program of commercial gas manufacturers. Audit 1 was performed from May to July 1978 and Audit 2 was performed in January 1979. Audits 1 and 2 included cylinders of sulfur dioxide and nitric oxide at source concentrations. Results of these audits were reported in the publication entitled "Analysis of Commercial Cylinder Gases of Nitric Oxide and Sulfur Dioxide at Source Concentrations - Results of Audits 1 and 2."* A summary of these results is also included in Tables 10 and 11 of this report.

The purpose of Audit 3 was two-fold. The first objective was to analyze the concentration of cylinder gases purchased from a representative sample of manufacturers and determine the accuracy of the manufacturers' certified concentrations. The second objective was to reanalyze the cylinder gases analyzed in Audit 2 to determine stability of these gases since the initial analysis in January 1979.

Audit 3 of commercial cylinder gas included cylinders of sulfur dioxide (SO_2) at 90 and 500 ppm, nitric oxide (NO) at 50 and 300 ppm, and carbon monoxide at 50 and 500 ppm obtained from twelve different manufacturers. Audit 3 was performed in August and September 1979. The procedure used to analyze Audit 3 cylinder gases was EPA's "Trace-

*Report available from the Quality Assurance Division, Environmental Monitoring Systems Laboratory, Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

ability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors (Protocol No. 1, June 15, 1978). A summary of Audit 3 results is presented in Table 1.

TABLE 1. SUMMARY OF RESULTS FOR AUDIT 3 OF COMMERCIAL CYLINDERS FOR
SULFUR DIOXIDE, NITRIC OXIDE, AND CARBON MONOXIDE

Manufacturer	Sulfur Dioxide		Nitric Oxide		Carbon Monoxide	
	Nominal Conc. (ppm)	Percent Accuracy	Nominal Conc. (ppm)	Percent Accuracy	Nominal Conc. (ppm)	Percent Accuracy
Airco Industrial Gases	500	- 0.8	300	3.5	500	3.3
Air Products & Chemical, Inc.	500	1.0	300	5.6	500	1.9
Big Three Indus- tries	500	- 5.5	300	- 6.3	500	- 3.5
Ideal Gas Products	500	- 8.8	300	3.1	500	9.2
	90	- 7.0	50	4.7	50	- 1.2
Liquid Carbonic Corp.	500	- 1.0	300	- 3.4	500	- 1.1
Matheson Gas Products	500	0.4	300	-12.4	500	- 1.1
MG Scientific Gas Products	500	- 0.8	300	5.7	500	- 7.5
	90	- 3.3	50	22.2	50	7.9
North East Cryogenics	500	- 3.8	300	4.0	500	- 1.5
	90	-21.6	50	>100*	50	- 3.9
Scientific Gas Products, Inc.	500	-12.2	300	0	500	2.6
	90	- 3.0	50	0	50	0.2
Scott Environ- mental Tech., Inc.	500	1.7	300	- 1.0	500	1.2
	90	3.2	50	- 2.8	50	- 3.3
Scott-Marrin, Inc.	500	0.2	300	- 0.6	500	2.8
Linde Div. of Union Carbide	500	8.9	300	8.3	500	1.6
	90	3.8	500**	- 1.6	50	17.8

* Actual percent accuracy not calculated but was greater than 100%.

** Nominal 50 ppm ordered but 500 ppm shipped.

Percent Accuracy = 100(Manufacturer - RTI)/RTI

SECTION 2

INTRODUCTION

There are basically three types of gas standards available from commercial manufacturers. These are primary standards, analyzed or certified standards, and unanalyzed standards. The primary standards are prepared gravimetrically on a high load, high sensitivity analytical balance with a tolerance of ± 1 percent of the component. The analyzed or certified standards are prepared by a variety of gravimetric and pressure-volume-temperature techniques. The mixture is then analyzed by instrumental and/or wet chemical methods with a component tolerance of ± 3 percent. The unanalyzed standards are prepared in the same manner as the analyzed standards, but a chemical analysis is not performed. The unanalyzed standards may have a tolerance of ± 15 percent or greater from the nominal concentration ordered.

Commercial cylinder gas manufacturers will supply gas standards and provide a certified analysis of gas concentration when requested. The purpose of this project was to analyze cylinders obtained from a representative sample of gas manufacturers and compare the measured concentrations with the manufacturers' quoted analyses. The gases of interest were NO, CO, and SO₂, each in a balance of nitrogen.

A survey was conducted of manufacturers who routinely provide cylinder gases that are used for calibration and auditing. A list of these companies is given in Table 2. Each company was contacted as to the types of gases produced and/or supplied. From the thirty-one companies shown in Table 2, twelve were selected to supply gas cylinders for analysis. These twelve manufacturers are listed in Table 3. The companies not included were eliminated because: (1) they do not supply gases used in environmental studies (i.e., they supply hospital, welding, or nuclear tagged gases), or (2) they do not blend and analyze their own gases but merely label another manufacturer's product.

TABLE 2. SURVEY OF GAS CYLINDER MANUFACTURERS

Air Products and Chemicals, Incorporated
Airco Industrial Gases
Automotive Environmental Systems, Incorporated
Big Three Industries
Chemetron Industrial Gases
Edmond Scientific Company
Essex Chemical Corporation
Ideal Gas Products
J. T. Baker Chemical Company
J. W. Goodliffe Air Products Company
Liquid Carbonic Corporation
Matheson Gas Products
MG Scientific Gases
National Welders Supply Company, Incorporated
New England Nuclear
Northeast Cryogenics
Nuclear Sources and Services, Incorporated
Ohio Chemical and Manufacturing Company
Pipe Welding Supply Company, Incorporated
PPG Industries, Incorporated
Puritan Compressed Gas Corporation
Scientific Gas Products, Incorporated
Scientific Products, Division of American Hospital Supplies
Scott Environmental Technology, Incorporated
Scott-Marrin, Incorporated
Stauffer Chemical Company
Sulfrian Cryogenics, Incorporated
Supelco, Incorporated
Texas Gulf, Incorporated
Union Carbide Corporation, Linde Division
Virginia Chemical, Incorporated

TABLE 3. CYLINDER GAS MANUFACTURERS INCLUDED IN
AUDIT PROGRAM

Manufacturer's Name	Manufacturer's Address
Airco Industrial Gases	Research Triangle Park, North Carolina
Air Products and Chemicals, Inc.	Tamaqua, Pennsylvania
Big Three Industries	Houston, Texas
Ideal Gas Products	Newark, New Jersey
Liquid Carbonic Corporation	Baltimore, Maryland
Matheson Gas Products	Morrow, Georgia
MG Scientific Gases	Somerville, New Jersey
North East Cryogenics	Newtonville, Massachusetts
Scientific Gas Products, Inc.	South Plainfield, New Jersey
Scott Environmental Technology, Inc.	Plumsteadville, Pennsylvania
Scott-Marrin, Inc.	Riverside, California
Union Carbide Corporation, Linde Division	Raleigh, North Carolina

The following gas mixtures were obtained through a third party to maintain anonymity, since the results of the first two audits had been published. The nominal concentrations ordered were as follows:

- (1) 300 ppm NO; balance Nitrogen.
- (2) 500 ppm SO₂; balance Nitrogen.
- (3) 500 ppm CO; balance Nitrogen.

In addition, from selected manufacturers, a second cylinder of each gas at a lower concentration was obtained. The nominal concentrations of these cylinders were as listed below:

- (1) 50 ppm NO; balance Nitrogen.
- (2) 90 ppm SO₂; balance Nitrogen.
- (3) 50 ppm CO; balance Nitrogen.

Specifications as to the type of analysis or the type of cylinder (steel or aluminum) were not included on the purchase request. The third party purchased the cylinders under the pretense of requiring the cylinders for field applications, thereby insuring representative samples. The only specifications given to the manufacturers were cylinder size, component, nominal concentration levels, and a request for a certified analysis.

SECTION 3

CYLINDER GAS ANALYSIS AND TRACEABILITY PROCEDURE

Each cylinder was received and then cataloged by manufacturer, pollutant species, and concentration. The NO, CO, and SO₂ analyses were performed separately using source emission analyzers. Each commercial cylinder was analyzed three times. Between each analysis an NBS-SRM (National Bureau of Standards-Standard Reference Material) or a GMPS (Gas Manufacturers Precision Standard) which had met the EPA criteria of less than an average of 1 percent per month degradation was introduced as a control check on the analyzer. All procedures met or exceeded the guidelines set forth in EPA's "Protocol for Establishing the Traceability of Calibration Gases Used with Continuous Source Emission Monitors" (Protocol No. 1, June 15, 1978). Immediately prior to analysis of the commercial cylinders, RTI was required to participate in an EPA audit for NO, CO, and SO₂.

3.1 ANALYSIS OF NITRIC OXIDE CYLINDERS

A Thermo-Electron Corporation (TECO) chemiluminescent NO-NO₂-NO_x analyzer-Series 10 (S/N 10AR-6795-88) was used to analyze the NO cylinder concentrations. The multipoint calibration procedure specified in EPA's "Protocol for Establishing the Traceability of Calibration Gases Used with Continuous Source Emission Monitors" was used to calibrate the TECO analyzer. Two NBS-SRM NO in N₂ cylinders and zero gas were used to generate calibration concentrations in the range of 0 to 500 ppm. A multipoint calibration (zero level and five upscale concentrations) was performed prior to each set of cylinder gas analyses. The multipoint calibration was accomplished by dilution of the highest NBS-SRM (approximately 500 ppm) with zero gas using a calibration flow system. At the conclusion of the multipoint calibration, a check of the calibration curve was performed using the lower NBS-SRM without dilution. The response of the instrument based on the original cali-

bration curve (dilution of higher NBS-SRM) was compared to the response to the true concentration of the lower NBS-SRM. If the difference between the apparent concentration (based on dilution of higher NBS-SRM) was less than 3 percent of the concentration of the lower NBS-SRM, then the analysis of the commercial cylinders was performed. If not, the multipoint calibration was repeated. Audit cylinders provided by EPA were then analyzed. Agreement to within ± 5 percent between EPA audit and measured concentration was required prior to analysis of the commercial cylinders. Zero and span checks were performed during the analysis period, according to EPA Protocol No. 1, to insure stable instrument performance.

The analyses of Audit 3 cylinder gases were performed during the period September 14-20, 1979. Cylinders of NO in N₂ from Audit 2 were also reanalyzed during this period to determine the stability of these gases since Audit 2, which was performed in January of 1979.

Because of the large number of cylinders (35) to be analyzed and the relatively high flow rate (2 cfh) required by the analyzer, it was decided that a GMPS (Gas Manufacturers Precision Standard) would be used for span checks rather than an NBS-SRM. A cylinder of NO in N₂ prepared by Scott-Marrin for Audit 2 was compared with the SRM and found to have had degradation of less than the average 1 percent per month specified in EPA Protocol No. 1. This cylinder was used as the GMPS for Audit 3.

3.2 ANALYSIS OF SULFUR DIOXIDE CYLINDERS

A TECO pulsed fluorescent SO₂ analyzer-Series 40 (S/N SDM-6997-90) was used to analyze the SO₂ cylinder concentrations. The analyzer was calibrated as described above in Section 3.1, except that only one NBS-SRM (500 ppm) was used to provide calibration concentrations by dilution. SRMs for SO₂ below 500 ppm are not yet available from NBS. A lower concentration cylinder of SO₂ in nitrogen referenced to the NBS-SRM was used without dilution to check the calibration curve. After the multipoint calibration, audit cylinders provided by EPA were analyzed. Agreement to within ± 5 percent between the EPA audit and

the measured concentrations was required prior to analysis of the commercial cylinders. Zero and span checks were performed during the analysis, according to EPA Protocol No. 1, to insure stable instrument performance.

The analyses of Audit 3 cylinder gases were performed during the period August 28-September 13, 1979. Cylinders of SO₂ in N₂ from Audit 2 were reanalyzed during this period to determine the stability of these gases since Audit 2, which was performed in January 1979.

Because of the large number of cylinders (35) to be analyzed and the relatively high flow rate (3 cfh) required by the analyzer, it was decided that a GMPS would be used for span checks rather than an NBS-SRM. A cylinder of SO₂ in N₂ prepared by Scott Environmental Technology for Audit 2 was compared with the SRM and found to have had degradation of less than the average 1 percent per month specified in EPA Protocol No. 1. This cylinder was used as the GMPS for Audit 3.

3.3 ANALYSIS OF CARBON MONOXIDE CYLINDERS

A Bendix nondispersive infrared analyzer Model 8501-5C(S/N 54351) was used to analyze CO cylinder concentrations. The analyzer was calibrated as described above in Section 3.1, except that only one NBS-SRM (470 ppm) was used to provide calibration concentrations by dilution. A lower concentration cylinder of CO in nitrogen referenced to the NBS-SRM was used without dilution to check the calibration curve. After the multipoint calibration, an audit cylinder provided by EPA was analyzed. Agreement to within ± 5 percent between the EPA audit and the measured concentrations was required prior to analysis of the commercial cylinders. Zero and span checks were performed during the analysis, according to EPA Protocol No. 1, to insure stable instrument performance.

The analyses of Audit 3 cylinder gases were performed during the period August 16-21, 1979.

3.4 EPA QUALITY ASSURANCE PROGRAM

In order to assess the quality of data obtained during the analysis of commercial cylinders, EPA conducted an external quality assurance program on RTI consisting of a performance audit of the source analyzers used to determine cylinder concentrations. EPA provided audit cylinders of NO, CO, and SO₂ in nitrogen to RTI for analysis immediately prior to analyses of Audit 3 cylinder gases. RTI analyzed the EPA audit cylinders, determined the concentration based on the calibration curve of the source analyzers, and reported the data to EPA. If the agreement between the audit cylinder and measured concentration was within ± 5 percent, RTI proceeded to analyze each commercial gas cylinder. If the measured level exceeded the ± 5 percent limit, then a recalibration of the source analyzer and reanalysis of additional audit cylinders were required. The data obtained from the EPA performance audit of RTI are shown in Table 4. The agreement between the RTI measured concentrations and the EPA audit concentrations was well within ± 5 percent for all cylinders.

TABLE 4. EPA PERFORMANCE AUDIT OF RTI SOURCE ANALYZERS

Cylinder no.	Pollutant	RTI analysis date	RTI measured conc. (ppm)	EPA audit conc. (ppm)	Difference RTI-EPA (ppm)	Percent accuracy
SD10020	CO Bal. N ₂	August 16, 1979	518	520	- 2	-0.4
FF6739	SO ₂ Bal. N ₂	August 30, 1979	481	481	0	0
FF1167	SO ₂ Bal. N ₂	August 30, 1979	158	158	0	0
FF6395	NO Bal. N ₂	September 14, 1979	236	243	- 7	-2.9
FF1577	NO Bal. N ₂	September 18, 1979	48.5	48.5	0	0

Percent Accuracy = $100(\text{RTI} - \text{EPA})/\text{EPA}$

SECTION 4

RESULTS OF CYLINDER GAS ANALYSES

The certified accuracy of analysis quoted by most manufacturers typically ranges from ± 2 to 3 percent of the component concentration. Based upon this specification, the manufacturer's analysis should be within ± 5 percent of the mean concentration measured by RTI. The results for Audit 3 are given in Tables 5 through 7. Each table includes manufacturer, cylinder type, manufacturer's analysis, mean of RTI analysis, standard deviation, ppm difference, and percent accuracy. Table 5 gives the results for sulfur dioxide. Table 6 gives the results for carbon monoxide, and Table 7 gives the results for nitric oxide. Table 8 gives the reanalysis results for sulfur dioxide cylinder gases from Audit 2. Table 9 gives the reanalysis results for nitric oxide cylinder gases from Audit 2. The results in Tables 8 and 9 show the stability of the Audit 2 cylinder gases from January 1979 to September 1979.

TABLE 5. RESULTS OF SULFUR DIOXIDE CYLINDER ANALYSES (AUDIT 3)

Manufacturer	Cylinder Construction	Manufacturer's Analysis* ppm	Mean of RTI Analysis** ppm	STD Dev. of RTI Analyses ppm	Difference MFG - RTI ppm	Percent Accuracy
Airco Industrial Gases	Aluminum	490	494	1.5	- 4	- 0.8
Air Products & Chemical, Inc.	Steel	490	485	1.5	5	1.0
Big Three Industries	Aluminum	484	512	3.1	-28	- 5.5
Ideal Gas Products	Steel	480	526	1.0	-46	- 8.8
	Steel	80	86	1.0	- 6	- 7.0
Liquid Carbonics Corp.	Aluminum	488	493	1.0	- 5	- 1.0
Matheson Gas Products	Aluminum	506	504	1.0	2	0.4
MG Scientific Gas Products	Aluminum	493	497	2.6	- 4	- 0.8
	Aluminum	88	91	0	- 3	- 3.3
North East Cryogenics	Steel	450	468	1.7	-18	- 3.8
	Steel	80	102	1.0	-22	-21.6
Scientific Gas Products, Inc.	Steel	542	617	0.6	-75	-12.2
	Steel	98	101	1.0	- 3	- 3.0
Scott Environmental Tech., Inc.	Aluminum	536	527	0.6	9	1.7
	Aluminum	93.9	91	1.2	2.9	3.2
Scott-Marrin Inc.	Aluminum	483	482	2.6	1	0.2
Linde Div. of Union Carbide	Steel	500	459	1.0	41	8.9
	Steel	100	104	0.6	- 4	- 3.8

* Manufacturer's Certified Analysis

** Mean of three analyses

Percent Accuracy = 100(Manufacturer - RTI)/RTI

TABLE 6. RESULTS OF CARBON MONOXIDE CYLINDER ANALYSES (AUDIT 3)

Manufacturer	Cylinder Construction	Manufacturer's Analysis* ppm	Mean of RTI Analysis** ppm	STD Dev. of RTI Analyses ppm	Difference MFG - RTI ppm	Percent Accuracy
Airco Industrial Gases	Aluminum	510	494	0	16	3.3
Air Products & Chemical, Inc.	Steel	490	481	0	9	1.9
Big Three Industries	Aluminum	483	500	1.0	-17	- 3.5
Ideal Gas Products	Steel	520	476	0.6	44	9.2
	Steel	56.5	57.2	0.0	- 0.7	- 1.2
Liquid Carbon-Ics Corp.	Aluminum	455	460	0.6	- 5	- 1.1
Matheson Gas Products	Aluminum	516	522	1.2	- 6	- 1.1
MG Scientific Gas Products	Steel	455	492	0.6	-37	- 7.5
	Steel	52.2	48.4	0	3.8	7.9
North East Cryogenics	Steel	523	531	0.6	- 8	- 1.5
	Steel	56.5	58.8	0	- 2.3	- 3.9
Scientific Gas Products, Inc.	Steel	520	507	0	13	2.6
	Steel	51	50.9	0	0.1	0.2
Scott Environmental Tech., Inc.	Aluminum	500	494	0	6	1.2
		50.2	51.9	0	- 1.7	- 3.3
Scott-Marrin, Inc.	Aluminum	515	501	0.6	14	2.8
Linde Div. of Union Carbide	Steel	504	496	1.2	8	1.6
	Steel	50.4	42.8	0	7.6	17.8

* Manufacturer's Certified Analysis

** Mean of Three Analyses

Percent Accuracy = 100(Manufacturer - RTI)/RTI

TABLE 7. RESULTS OF NITRIC OXIDE CYLINDER ANALYSES (AUDIT 3)

Manufacturer	Cylinder Construction	Manufacturer's Analysis* ppm	Mean of RTI Analysis** ppm	STD Dev. of RTI Analyses ppm	Difference MFG - RTI ppm	Percent Accuracy
Airco Industrial Gases	Aluminum	322	311	0	11	3.5
Air Products & Chemical, Inc.	Steel	318	301	0	17	5.6
Big Three Industries	Aluminum	285	304	1.2	-19	- 6.3
Ideal Gas Products	Steel	298	289	0	9	3.1
	Steel	45	43	0	2	4.7
Liquid Carbonics Corp.	Aluminum	280	290	0.6	-10	- 3.4
Matheson Gas Products	Aluminum	276	315	0.6	39	-12.4
MG Scientific Gas Products	Steel	299	283	0.6	16	5.7
	Steel	45.4	37	0	8.4	22.2
North East Cryogenics	Steel	288	277	0	11	4.0
	Steel	45	11	0	34	>100***
Scientific Gas Products, Inc.	Steel	314	314	0.6	0	0
	Steel	50	50	0	0	0
Scott Environmental Tech., Inc.	Aluminum	307	310	1.0	- 3	- 1.0
	Aluminum	52.5	54	0.6	- 1.5	- 2.8
Scott-Marrin, Inc.	Aluminum	306	308	0	- 2	- 0.6
Linde Div. of Union Carbide	Steel	503	511	0.6	- 8	- 1.6
	Steel	287	265	2.9	22	8.3

* Manufacturer's Certified Analysis

** Mean of three analyses

*** Actual percent accuracy not calculated but was greater than 100%

Percent Accuracy = 100(Manufacturer - RTI)/RTI

TABLE 8. STABILITY OF SULFUR DIOXIDE CYLINDER GASES FROM AUDIT 2

Manufacturer	Cylinder Construction	Manufacturer's Analysis ppm	RTI Analysis January 1979 ppm**	RTI Analysis Sept. 1979 ppm**	Difference ppm (1)	Percent Difference (2)
Airco Industrial Gases	Aluminum	496	499	496	- 3	- 0.6
Air Products & Chemicals, Inc.	Steel	478	466	460	- 6	- 1.3
Big Three Industries	Steel	498	491	483	- 8	- 1.6
Ideal Gas Products	Steel	460	447	430	-17	- 3.8
	Steel	81	126	118	- 8	- 6.3
Liquid Carbonics Corp.	Aluminum	513	517	511	- 6	- 1.2
Matheson Gas Products	Steel	526	530	524	- 6	- 1.1
MG Scientific Gas Products	Aluminum	577	569	561	- 8	- 1.4
North East Cryogenics	Steel	450	514	510	- 4	- 0.8
Scientific Gas Products, Inc.	Aluminum	532	544	542	- 2	- 0.4
Scott Environmental Tech., Inc.	Aluminum	520	524	520	- 4	- 0.8
Scott-Marrin, Inc.	Aluminum	499	502	500	- 2	- 0.4
Linde Div. of Union Carbide	Steel	500	524	520	- 4	- 0.8
	Steel	90	92.3	84	- 8.3	- 8.9

* Manufacturer's Certified Analysis

** Mean of three analyses

(1) Difference = September 1979 analysis - January 1979 analysis

(2) % Diff. = 100(Sept. 79 analysis - Jan. 79 analysis)/Jan 79 analysis

TABLE 9. STABILITY OF NITRIC OXIDE CYLINDER GASES FROM AUDIT 2

Manufacturer	Cylinder Construction	Manufacturer's Analysis ppm	RTI Analysis January 1979 ppm**	RTI Analysis Sept. 1979 ppm**	Difference ppm (1)	Percent Difference (2)
Alrco Industrial Gases	Aluminum	310	304	294	-10	- 3.3
Air Products & Chemicals, Inc.	Steel	295	294	285	- 9	- 3.1
Big Three Industries	Steel	288	294	289	- 5	- 1.7
Ideal Gas Products	Steel	285	255	232	-23	- 9.0
	Steel	50	57.4	59	- 1.6	2.8
Liquid Carbonics Corp.	Aluminum	295	301	297	- 4	- 1.3
Matheson Gas Products	Steel	330	323	314	- 9	- 2.8
MG Scientific Gas Products	Aluminum	326	344	337	- 7	- 2.0
North East Cryogenics	Steel	325	302	302	0	0
	Steel	50	32.5	13	-19.5	-60
Scientific Gas Products, Inc.	Aluminum	290	298	294	- 4	- 1.3
Scott Environmental Tech., Inc.	Aluminum	312	311	307	- 4	- 1.2
	Aluminum	51.4	50.0	51	1	2.0
Scott-Marrin, Inc.	Aluminum	302	299	300	1	0.3
Linde Div. of Union Carbide	Steel	302	292	287	- 5	- 1.7
	Steel	45	44.8	46	1.2	2.7

* Manufacturer's Certified Analysis

** Mean of three analyses

(1) Difference = September 1979 analysis - January 1979 analysis

(2) % Diff. = 100(Sept. 79 analysis - Jan. 79 analysis)/Jan 79 analysis

SECTION 5

SUMMARY OF RESULTS OF AUDITS 1, 2, AND 3

The results for Audits 1, 2, and 3 of commercial cylinder gases are summarized in Tables 9 and 10. Table 9 gives the results for sulfur dioxide and Table 10 gives the results for nitric oxide. Audit 3 was the first audit performed for carbon monoxide; therefore, a summary table is not presented.

TABLE 10. SUMMARY OF RESULTS FOR AUDITS 1, 2, and 3 OF COMMERCIAL CYLINDERS FOR
SULFUR DIOXIDE

Manufacturer	Cylinder Construction	Nominal Conc. (ppm)	Percent Accuracy		
			Audit 1	Audit 2	Audit 3
Airco Industrial Gases	Aluminum	500	(*)	- 0.6	- 0.8
Air Products & Chemical, Inc.	Steel	500	9.0	2.6	1.0
Big Three Industries	Steel	500	7.5	1.4	- 5.5
	Aluminum	500			
Ideal Gas Products	Steel	500	4.0	2.9	- 8.8
	Steel	90	-8.0	-35.7	- 7.0
Liquid Carbonics Corp.	Steel	500	2.1	- 0.8	- 1.0
	Aluminum	500			
Matheson Gas Products	Steel	500	(*)	- 0.8	0.4
	Aluminum	500			
MG Scientific Gas Products	Aluminum	500	-7.2	1.4	- 0.8
	Aluminum	90	-9.4		- 3.3
North East Cryo- genics	Steel	500	14.7	-12.5	- 3.8
	Steel	90	-10.1	-15.6	
	Steel	500	- 4.8(1)		
	Steel	500	- 1.0(1)		
	Steel	90	-19.7(1)	-21.6	
Scientific Gas Products, Inc.	Steel	500	- 2.4	- 2.2	-12.2
	Aluminum	500			- 3.0
	Steel	90			
Scott Environ- mental Tech., Inc.	Aluminum	500	- 1.6	- 0.8	1.7
	Aluminum	90	-11.3	- 3.1	3.2
Scott-Marrin, Inc.	Aluminum	500	0.2	- 0.6	0.2
Linde Div. of Union Carbide	Steel	500	5.8	- 4.6	8.9
	Steel	90	2.2	- 2.5	- 3.8

(*) Company not included in audit survey.

(1) These cylinders were not part of the first audit but were procured and analyzed after reviewing the results of the first audit.

Percent Accuracy = $100(\text{Manufacturer} - \text{RTI})/\text{RTI}$

TABLE 11. SUMMARY OF RESULTS FOR AUDITS 1, 2, AND 3 OF COMMERCIAL CYLINDERS FOR NITRIC OXIDE

Manufacturer	Cylinder Construction	Nominal Conc. (ppm)	Percent Accuracy		
			Audit 1	Audit 2	Audit 3
Airco Industrial Gases	Aluminum	300	(*)	2.0	3.5
Air Products & Chemical, Inc.	Steel	300	2.2	0.2	5.6
Big Three Industries	Steel	300	11.1	- 2.0	- 6.3
	Aluminum	300			
Ideal Gas Products	Steel	300	>100(**)	11.8	3.1
	Steel	50	>100(**)	-12.9	4.7
Liquid Carbonics Corp.	Steel	300	- 7.0	- 2.0	- 3.4
	Aluminum	300			
Matheson Gas Products	Steel	300	(*)	2.2	-12.4
	Aluminum	300			
MG Scientific Gas Products	Steel	300	- 4.8	- 5.2	5.7
	Steel	50			
North East Cryogenics	Steel	300	>100(**)	7.6	4.0
	Steel	50	>100(**)	53.8	>100**
	Steel	300	- 0.7(1)		
	Steel	50	4.0(1)		
Scientific Gas Products, Inc.	Steel	300	- 2.0	- 2.8	0
	Steel	50			
Scott Environmental Tech., Inc.	Aluminum	300	0.0	0.3	- 1.0
	Aluminum	50	0.2	2.8	- 2.8
Scott-Marrin, Inc.	Aluminum	300	2.3	1.0	- 0.6
Linde Div. of Union Carbide	Steel	300	2.3	3.4	8.3
	Steel	50	0.8	0.4	
		500			- 1.6

* Company not included in audit survey.

** Actual percent accuracy not calculated but was greater than 100%.

(1) These cylinders were not part of the first audit but were procured and analyzed after reviewing the results of the first audit.

Percent Accuracy = $100(\text{Manufacturer} - \text{RTI})/\text{RTI}$