

QC
807.5
.U6
A7
no.150

*Series
Analyzed*

NOAA Technical Memorandum ERL ARL-150



NOAA/GMCC CALIBRATIONS OF CO₂-IN-AIR REFERENCE GASES: 1979-1985

K. W. Thoning
P. Tans
T. J. Conway
L. S. Waterman

Air Resources Laboratory
Silver Spring, Maryland
January 1987

LIBRARY

MAR 24 1987

N.O.A.A.
U S Dept. of Commerce

noaa

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

/ Environmental Research
Laboratories

QC
807.5
• 4647
No. 150

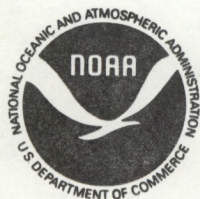
NOAA Technical Memorandum ERL ARL-150

NOAA/GMCC CALIBRATIONS OF CO₂-IN-AIR REFERENCE GASES: 1979-1985

K. W. Thoning
P. Tans
T. J. Conway
L. S. Waterman

Geophysical Monitoring for Climatic Change
Boulder, Colorado

Air Resources Laboratory
Silver Spring, Maryland
January 1987



UNITED STATES
DEPARTMENT OF COMMERCE

Malcolm Baldrige,
Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

Anthony J. Calio,
Administrator

Environmental Research
Laboratories

Vernon E. Derr,
Director

NOTICE

Mention of a commercial company or product does not constitute an endorsement by NOAA Environmental Research Laboratories. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

CONTENTS

	PAGE
ABSTRACT.....	1
1. INTRODUCTION.....	1
2. NOAA SECONDARY CO ₂ STANDARDS.....	2
3. NOAA TERTIARY CO ₂ STANDARDS.....	3
4. CALIBRATION METHOD.....	4
5. RESULTS.....	6
6. COMPARISON WITH SIO.....	8
7. COMPARISON WITH NBS.....	10
8. REFERENCES.....	10
Appendix 1: Calibration History of NOAA/GMCC Secondary CO ₂ -in-Air Standards at SIO.....	23
Appendix 2: Calibrations of NOAA/GMCC Tertiary CO ₂ -in-Air Standards Relative to the NOAA/GMCC Secondary Standards.....	27
Appendix 3: SIO Calibration Data of NOAA/GMCC Secondary CO ₂ Standards.....	31
Appendix 4: Summary of all GMCC CO ₂ -in-Air Reference Gas Calibrations for the Years 1979 through 1985.....	35

NOAA/GMCC Calibrations of CO₂-in-Air Reference Gases: 1979-1985

K. W. Thoning*, P. Tans*, T.J. Conway, and L. S. Waterman

ABSTRACT. The results of 423 CO₂-in-air reference gas calibrations from 1979 to 1985 are presented. Time dependent concentrations for the NOAA secondary and tertiary standards are plotted and tabulated. A preliminary analysis of the uncertainty of the assigned CO₂ concentrations for the reference gases used in the field for atmospheric measurements gives a value of 0.07 ppm relative to the WMO scale maintained by SIO. A comparison of 23 tanks with both SIO and NOAA calibrations shows no significant difference between them, the mean difference being 0.03 ± 0.03 ppm. Calibrations by NOAA of 3 NBS SRM CO₂-in-air tanks show an average offset of 0.25 ppm from the NBS certified values.

1. INTRODUCTION

Measurements of atmospheric CO₂ using non-dispersive infrared analyzers (NDIR) and gas chromatographs (GC) require reference gases of known CO₂ concentrations in order to make a relative measurement of the unknown atmospheric CO₂ concentration. CO₂-in-nitrogen gases were first used as reference standards. Later, due to the dependence of the CO₂ response of NDIR analyzers on the composition of the carrier gas (e.g. Griffith, 1982 and Griffith et al., 1982), CO₂-in-air standards were developed. Since 1979, NOAA/GMCC has calibrated CO₂-in-air gases at its laboratory in Boulder, Colorado. This report presents the results of all CO₂-in-air calibrations from 1979 to 1985. Details of the methodology involved can be found in Komhyr et al. (1985).

*Cooperative Institute for Research in Environmental Sciences, University of Colorado/NOAA/Boulder, CO 80309.

2. NOAA SECONDARY CO₂ STANDARDS

Figure 1 shows the different levels of CO₂ standards used at NOAA/GMCC. The Scripps Institution of Oceanography (SIO) has been designated as the World Meteorological Organization (WMO) Central Calibration Laboratory (CCL), and as such is ultimately responsible for the scale in which CO₂ concentrations are expressed. The primary CO₂ reference gases are maintained by SIO, and all GMCC standards have calibrations traceable to these primary gases. The GMCC secondary standards have been calibrated by SIO either manometrically or by infrared analysis approximately every three years since 1978. These secondary standards are a set of eight CO₂-in-natural air gases with concentrations ranging from 301 to 396 ppm and are listed in Table 1.

In May of 1986, SIO provided GMCC with revised values for all SIO calibrations of GMCC CO₂ reference gases, including the GMCC secondary standards, which are reported in the 1985 WMO provisional scale (Keeling et al., 1985). The values for the secondary standards are plotted in Appendix 1 and listed in Appendix 3. It can be seen from the figures that all but one of the secondary standards drift in concentration with time. A linear least squares regression line was fitted to the data for each tank and the coefficients of the lines are listed in Table 1. For all tank calibrations using the secondary standards as the reference tanks, the values of the linear regression lines for the appropriate tank and dates were used. The standard deviations of the residuals about the regression line are also shown in Table 1. The values range from 0.05 ppm to 0.09 ppm, which represents the scatter of individual SIO determinations.

3. NOAA TERTIARY CO₂ STANDARDS

The GMCC tertiary standards are a set of CO₂-in-synthetic air gases (See Komhyr et al., 1985 for details) ranging in concentration from 310 to 380 ppm. These standards are calibrated relative to the drift-corrected secondary standards approximately twice each year. Results for each of the calibrations of the tertiary standards are listed in Appendix 4 and plotted in Appendix 2. A linear least squares regression line was fitted to the data for each tank, using calibrations relative to the secondary standards through April 1986. The CO₂ concentration as a function of time for each tank is shown in Table 2. A total of 12 tanks have been used as tertiary standards and six of them seem to drift with time. The residual standard deviations for drifting tanks and the sample standard deviations for the tanks that don't drift are also listed, and on average are slightly higher than those for the secondary standards (0.08 ppm compared to 0.06 ppm). The scatter of the individual calibrations of the tertiaries is a characteristic of the GMCC infrared comparisons. All but one of the tertiary standards are contained in steel tanks. Tank 2315 is an aluminum tank (AIRCO size 300A). There is some evidence suggesting that CO₂-in-air standards are more stable in aluminum tanks than in steel tanks (D. J. Moss, private communication).

The tertiary standards are in turn used to calibrate all other CO₂-in-air gases used by GMCC. These include gases used in Boulder, as well as gases sent to the four GMCC observatories for monitoring of atmospheric CO₂ concentration.

4. CALIBRATION METHOD

A detailed description of the calibration method is given by Komhyr et al. (1985). Briefly, four known reference gases (L, M, H, Q) are used to determine the CO₂ concentrations for two unknowns (W1 and W2). The four reference gases can be from any of the calibration levels, depending on the use for W1 and W2. Each gas flows at a rate of 300 cc/min for 5 minutes twice each hour resulting in a cycle time of one hour (Figure 2). Because of the non-linearity of the analyzer, the unknown gases are computed from a least squares quadratic fit to the reference gases:

$$C = a + b*V + c*V^2$$

where C represents the CO₂ concentration and V is the voltage output of the analyzer. The concentrations of W1 and W2 are computed for each cycle for five cycles. The mean and standard deviations are then computed from the five values as a final result.

Beginning in June of 1982, a modification of this scheme was used. An initial cycle, Cycle 0, was added at the beginning of the calibration to allow proper flushing and conditioning of the gas tubing. This cycle was not used in the computation of the final result. In addition, after cycle 5 was completed, if the standard deviation of the individual cycles about the mean of either W1 or W2 was greater than 0.10 ppm, then the cycle whose value was farthest from the mean was flagged and another cycle was run. After cycle 6, the same check was made and cycle 7 run if needed. The calibration always stopped after cycle 7.

A total of 6 NDIR CO₂ analyzers have been used to perform CO₂ tank calibrations. These are listed in Table 3 with the dates of their use. Each calibration gives a mean and standard deviation about the mean for the two unknown tanks W1 and W2. The standard error of the mean is the standard deviation divided by the square root of 5, where 5 is the number of cycles for each calibration. Averaging the standard errors for all of the calibrations for each analyzer gives the precision value listed in Table 3. These precision values are determined by the stability of the analyzer during one day. The results of calibrations performed many days apart usually differ by more than the precision values due to long term variability of the calibration system. Prior to June of 1982, all calibrations were performed on the semi-automatic flask analysis apparatus (Komhyr et al., 1983). The voltage output of the analyzer for this apparatus is digitized at a rate of 32 readings per 10 seconds. Since June 1982, a similar apparatus built solely for tank calibrations has performed almost all of the calibrations. The digitizing rate for this apparatus is 2 readings per second.

All relevant information about the calibration is stored by computer. Therefore, final results for each calibration can be recomputed if new values for the reference gas concentrations are given. Since all tank calibrations of CO₂-in-air gases used either the secondary or tertiary standards as the reference gases, the revised CO₂ values for each tank calibration can then be automatically computed. Usually, only calibrations that are affected by SIO scale changes, or calibrations for tanks that are currently being used for CO₂ measurements are recomputed. However, for this report all calibrations performed at GMCC were recomputed, and the results are listed in Appendix 4, expressed in the WMO 1985 scale. A total of 423 calibrations were performed, 138 relative to the secondary standards, and 285 relative to the tertiary standards.

When GMCC first converted to CO₂-in-air reference gases, 12 tanks were filled in February of 1981 with mixtures which by mistake did not contain Argon. These tanks are listed in Table 4, along with the dates they were refilled with CO₂-in-air. Only four of these tanks were calibrated in Boulder. The results from these four tanks have not been used in the following discussion.

5. RESULTS

It can be seen from the table in Appendix 4 that the standard deviation about the mean for repeated measurements of a single tank over a period of time can vary widely from tank to tank. Most of the variation is due to drifts of the CO₂ concentration in the tanks. These drifts also vary widely from tank to tank, ranging from almost stable concentrations to drifts greater than 1 ppm/year. The reasons for CO₂ drift in tanks are not certain. The concentration of CO₂ in a tank usually becomes very unstable at pressures below approximately 400 psi. Long time drifts at high tank pressures can be due to back diffusion of high CO₂ air from an improperly flushed pressure regulator. Surface effects between CO₂ and the walls of the cylinder is another likely source of drift.

A linear least squares regression line was fitted to each tank that had at least three calibrations over at least a three month period. The significance of the slope for each line was tested using the F test at the 5% level. 29 tanks were found to have significant drift, and 57 tanks remained for which drift could not be established. A histogram of the standard errors of the means for all 86 tanks is plotted in Figure 3. The standard error of

the mean is here defined as the residual standard deviation about the regression line divided by the square root of the number of calibrations for tanks that drifted, and as the sample standard deviation (SDEV in Appendix 4) divided by the square root of the number of calibrations for tanks without drift. The figure shows that the error associated in assigning a CO₂ concentration value to a tank is generally less than 0.10 ppm. The average of all the standard errors in Figure 3 is 0.038 ppm. This calibration system uncertainty, σ_{sys} , is due mainly to day to day changes in the calibration analysis system. The sources of these changes may be contamination from pressure regulators, long term changes in the analyzer, and variable drift rates in the tank (due to pressure, temperature, etc.).

The uncertainty of the assigned values of CO₂ for the working tanks that are used for atmospheric measurements of CO₂ at the GMCC observatories are dependent on the errors involved in the calibration levels above them. If we assume that the uncertainty of the assigned reference gas concentrations is uncorrelated at each calibration level, then each level should have an uncertainty added due to the calibration levels above it. For each of the tertiary standards:

$$\sigma_t^2 = \sigma_s^2 + \sigma_m^2$$

where σ_s = standard error due to the secondary standards,

σ_m = standard error of the mean for an individual tank.

If we generalize that $\sigma_m = \sigma_{\text{sys}} = 0.04$ ppm for each tertiary standard, and $\sigma_s = 0.02$ ppm from Appendix 3, then $\sigma_t = 0.04$ ppm. Similarly for each of the station standards:

$$\sigma_{\text{ss}}^2 = \sigma_t^2 + \sigma_m^2$$

and $\sigma_{ss} = 0.06$ ppm again assuming $\sigma_m = 0.04$ ppm. Finally for the station working tanks which are calibrated relative to the station standards:

$$\sigma_w^2 = \sigma_{ss}^2 + \sigma_m^2$$

and $\sigma_w = 0.07$ ppm with σ_m set equal to 0.04 ppm. This estimate is based on the assumptions that there is not a constant offset added at each calibration level, and that the system uncertainty σ_{sys} is equal at each of the calibration levels. These assumptions will be looked at more closely in future reports, incorporating calibrations performed at each of the GMCC observatories.

6. COMPARISON WITH SIO

A comparison was made of CO₂-in-air tanks that were calibrated both by SIO and GMCC at least 5 times from 1978 to 1985. The tanks selected for this comparison had to meet the following criteria:

1. There were at least three GMCC calibrations performed on the tank.
102 tanks met this requirement.
2. At least two SIO calibrations were performed. 44 tanks remained after this step.
3. The remaining tanks were tested for drift by fitting a linear least squares regression to the GMCC data and using the F test at the 5% level to check for 0 slope. Those tanks that were found to have significant slope were rejected. 25 tanks remained after this step.

4. A subjective selection of tanks was performed. Two tanks were added that failed step 3, and four tanks were rejected that passed the first three steps. In these cases it was felt that the F test failed due to limited number of calibrations and/or limited time span between calibrations.

For the 23 tanks that remained, the differences between the means determined by SIO and by GMCC were examined. The results of these are listed in Table 5 and plotted in Fig. 4. The weighted mean difference (GMCC minus SIO) is 0.01 ± 0.01 ppm (one sigma). Only in five cases out of 23 do the one sigma error bars cross the zero axis. This suggests that there is another source of discrepancy which causes a significant difference in concentration between GMCC and SIO measurements for an individual tank. In other words, the error as determined by repeated measurements on the same tank within each laboratory (σ_1 in Table 5) is insignificant compared to the unknown source which causes the difference between GMCC and SIO for most of the tanks (X_1 in Table 5).

Therefore it would be better to apply equal weighting to each of the data points, since the unknown error dominates over each of the individual errors. Doing this gives a mean difference (GMCC minus SIO) of 0.03 ppm and a standard error of the mean of 0.03 ppm. This shows that there is no significant bias between SIO and GMCC. The standard deviation about the mean is 0.14 ppm and represents the magnitude of the unknown source which causes the individual tank differences.

It is most likely that the source of the differences is actual concentration drift in the tanks that was not detected as significant by the F test, combined with the fact that 17 of these tanks were calibrated by SIO

first and then by GMCC, with a significant time interval (ranging from one month to two years) between measurements.

7. COMPARISON WITH NBS

In June of 1983, GMCC received three CO₂-in-air Standard Reference Material (SRM) tanks from the National Bureau of Standards (NBS). These three tanks have been calibrated by GMCC relative to the secondary standards at least 4 times since then, including calibrations performed in April 1986. The results of these calibrations are listed in Table 6. The table shows a consistent offset (GMCC minus NBS) of about 0.25 ppm between the NBS certified values and the GMCC measurements. The difference is slightly greater than the two sigma uncertainty of 0.2 ppm that is assigned to the NBS values. This offset would present a problem in the continuity of CO₂ measurements if the NBS SRM's were to be used as the scale for CO₂ concentration rather than the SIO scale currently being used.

Acknowledgments: We thank N. Trivett of the Atmospheric Environment Service of Canada for the loan of the Siemens Ultramat 3 #R02-212 infrared analyzer during 1984.

8. REFERENCES

Griffith, D.W.T, 1982: Calculations of carrier gas effects in nondispersive infrared analyzers I. Theory. Tellus, 34:376-384.

Griffith, D.W.T., C.D. Keeling, R.B. Bacastow, P.R. Guenther and D.J. Moss,
1982: Calculations of carrier gas effects in nondispersive infrared
analyzers II. Comparison with experiment. Tellus, 34:385-397.

Keeling, C.D., P.R. Guenther and D.J. Moss, 1985: Scripps reference gas
calibration system for Carbon Dioxide-in-air standards: Revision of
1985. A report prepared for the Environmental Monitoring Program of the
World Meteorological Organization.

Komhyr, W.D., L.S. Waterman and W.R. Taylor, 1983: Semiautomatic nondispersive
infrared analyzer apparatus for CO₂ air sample analyses. J. Geophys.
Res., 88:1315-1322.

Komhyr, W.D., T.B. Harris and L.S. Waterman, 1985: Calibrations of
nondispersive infrared CO₂ analyzers with CO₂-in-air reference gases. J.
Atmos. and Oceanic Tech., 2:82-88.



Table 1.--NOAA/GMCC Secondary CO₂-in-air standard gas tanks

Serial number	CO ₂ concentration* (ppm)	Value on 1 Jan 86	Std. dev.+ (ppm)
3080	301.23	301.23	0.09++
3082	313.22 + .03753*Date	316.45	0.05
3074	324.93 + .05009*Date	329.23	0.05
3091	336.08 + .06701*Date	341.84	0.09
3071	347.55 + .05911*Date	352.63	0.05
3092	363.98 + .03359*Date	366.86	0.06
3087	380.36 + .01685*Date	381.81	0.07
3089	392.48 + .03978*Date	395.90	0.05

* - Coefficients of linear least squares regression line. Slope is in ppm/year and Date is in years, with Date = 0 at Jan 1, 1900.

+ - Standard deviation of residual points about the linear regression line, except for values marked with ++, which are the standard deviations about the mean for tanks that did not seem to exhibit a linear drift with time.

Table 2.--NOAA/GMCC Tertiary CO₂-in-air standard gas tanks

Serial number	CO ₂ concentration* (ppm)	Dates used	Value on 1 Jan 86	Std. dev.+ (ppm)
2315	341.14	Sep 85 - present	341.14	0.02++
44580	340.13	Mar 82 - May 84	-----	0.06++
44591	319.57	Mar 82 - present	319.57	0.07++
44631	359.52	Mar 82 - present	359.52	0.06++
44660	315.22 - .05256*Date	Mar 82 - present	310.70	0.05
44709	345.63 + .05361*Date	Mar 82 - Jul 84	-----	0.12
44730	330.66	Mar 82 - Jul 84	-----	0.08++
44759	384.52 - .05689*Date	Mar 82 - present	379.63	0.08
44785	373.54 - .04816*Date	Mar 82 - present	369.40	0.14
47295	344.31 + .06613*Date	Jul 84 - present	350.00	0.09
61119	339.71	May 84 - Sep 85	-----	0.13++
95981	321.90 + .09787*Date	Jul 84 - present	330.32	0.06

* - Coefficients of linear least squares regression line. Slope is in ppm/year and Date is in years, with Date = 0 at Jan 1, 1900.

+ - Standard deviation of the residual points about the linear regression line, except for values marked with ++, which are the standard deviations about the mean for tanks that did not seem to exhibit a linear drift with time.

Table 3.--CO₂ NDIR analyzers used in NOAA/GMCC tank calibration program

Analyzer	Dates used	Number of calibrations	Precision* (ppm)
UNOR 2 #631710	Sep 79 - Mar 85	81	0.025
UNOR 2 #631521	Aug 80 - Apr 83	113	0.018
UNOR 2 #631268	Apr 83 - Feb 8	61	0.019
URAS 2T #029	Feb 84 - Mar 86	160	0.017
UNOR 4N #719	22 Mar 85	1	0.036
ULTRAMAT 3 #R02-212	Dec 84	7	0.005

* - Average standard error of the mean for all calibrations performed for each analyzer.

Table 4. CO₂-in-Argon free air tanks used by GMCC

Serial #	Code*	Date refilled with CO ₂ -in-air
95954	-	Feb 84
95973	-	Jan 82
95981	-	Feb 84
95987	A	Feb 84
96002	-	Jun 82
96079	-	Feb 84
96081	A	Jul 84
96101	-	Aug 83
96105	-	Jan 82
96111	A	Jul 84
96117	A	Sep 84
96128	-	Jun 82

* - Code designates filling code used in Appendix 4.

Table 5.--Comparison of SIO and GMCC CO₂-in-air tank calibrations

Serial No.	N _S	SIO calcs.		N _G	GMCC CALS.		GMCC-SIO	
		mean	σ _S		mean	σ _G	X _i	σ _i
3076 A	2	317.36	0.10	5	317.43	0.08	0.07	0.08
3085 A	6	318.43	0.12	5	318.52	0.04	0.09	0.05
39376 A	3	331.72	0.06	7	331.96	0.04	0.24	0.04
36684 A	6	325.45	0.10	5	325.29	0.17	-0.16	0.09
39444 A	3	343.85	0.04	7	344.08	0.05	0.23	0.03
44580 A	2	340.27	0.04	9	340.13	0.06	-0.14	0.03
44591 A	2	319.63	0.05	9	319.57	0.07	-0.06	0.04
44631 A	2	359.49	0.04	10	359.51	0.07	0.02	0.04
44709 A	2	349.86	0.11	11	350.05	0.14	0.19	0.09
44730 A	2	330.58	0.13	10	330.66	0.08	0.08	0.10
44759 A	2	379.70	0.05	7	379.76	0.10	0.06	0.05
44785 A	2	369.36	0.25	7	369.57	0.16	0.21	0.19
45625 A	2	327.34	0.02	6	327.22	0.06	-0.12	0.03
47266 A	4	324.45	0.02	3	324.27	0.11	-0.18	0.06
47286 B	4	334.71	0.05	3	334.55	0.04	-0.16	0.03
47293 A	4	330.51	0.07	4	330.60	0.05	0.09	0.04
53896 A	3	335.52	0.17	4	335.32	0.03	-0.20	0.10
58682 A	4	339.29	0.08	5	339.35	0.07	0.06	0.05
58739 A	4	336.14	0.16	7	336.07	0.06	-0.07	0.08
61080 A	4	349.83	0.03	8	349.87	0.09	0.04	0.04
61119 A	2	342.93	0.05	3	343.04	0.06	0.11	0.05
61146 A	4	361.88	0.10	10	362.09	0.17	0.21	0.07
74311 A	2	329.95	0.02	4	329.94	0.14	-0.01	0.07

N = 23

Weighted ave. μ = 0.01 ppm

σ_μ = 0.01 ppmUnweighted ave. \bar{x} = 0.03 ppmσ _{\bar{x}} = 0.03 ppm X_i = GMCC mean - SIO mean. $\sigma_i = (\sigma_g^2/N_g + \sigma_s^2/N_s)^{1/2}$ $\mu = \Sigma(X_i/\sigma_i^2) / \Sigma(1/\sigma_i^2)$ $\sigma_\mu = (1/\Sigma (1/\sigma_i^2))^{1/2}$ $\bar{x} = X_i/N$ $\sigma_{\bar{x}} = (\Sigma(X_i - \bar{x})^2/(N*(N-1)))^{1/2}$

Table 6.--GMCC calibrations of NBS SRM CO₂-in-air reference tanks

Serial No.	NBS Value (ppm)	GMCC Calibrations		Mean	Difference (GMCC - NBS)
		Date	Conc.		
18017	350.6 ± 0.2	03 NOV 83	350.91		
		26 JUN 84	350.99		
		27 JUN 84	350.80		
		16 SEP 85	350.78		
		09 APR 86	350.77		
				350.85 ± 0.10	0.25
18035	335.7 ± 0.2	06 JUL 83	335.96		
		25 APR 84	336.13		
		06 SEP 85	335.88		
		08 APR 86	335.90		
				335.97 ± 0.11	0.27
18508	342.5 ± 0.2	03 NOV 83	342.71		
		06 JUN 84	342.83		
		06 SEP 85	342.73		
		09 APR 86	342.70		
				342.74 ± 0.06	0.24

Uncertainty values for GMCC calibrations are one standard deviation about the mean.

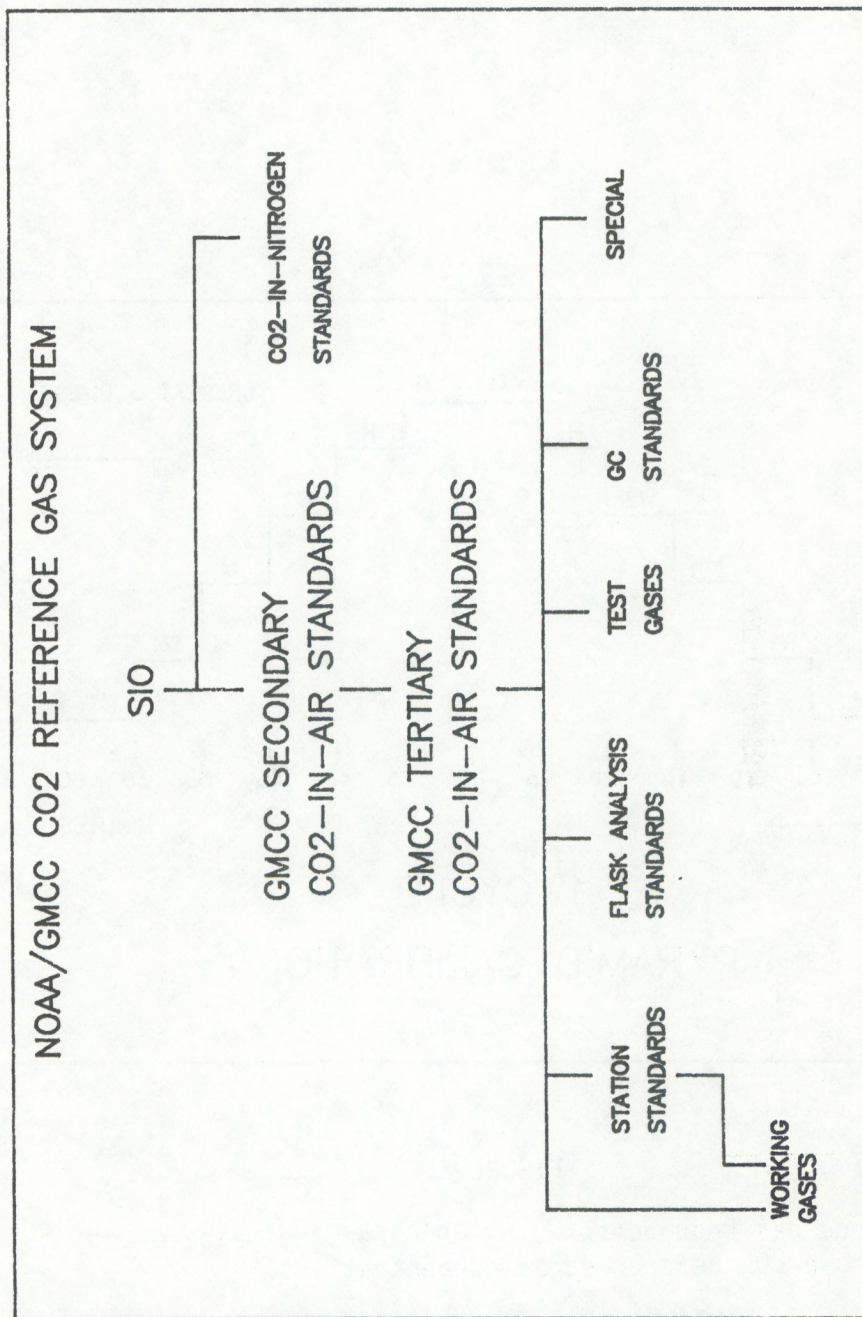


FIGURE 1.

Schematic diagram of the different calibration levels used by the NOAA/GMCC CO₂ reference gas calibration system.

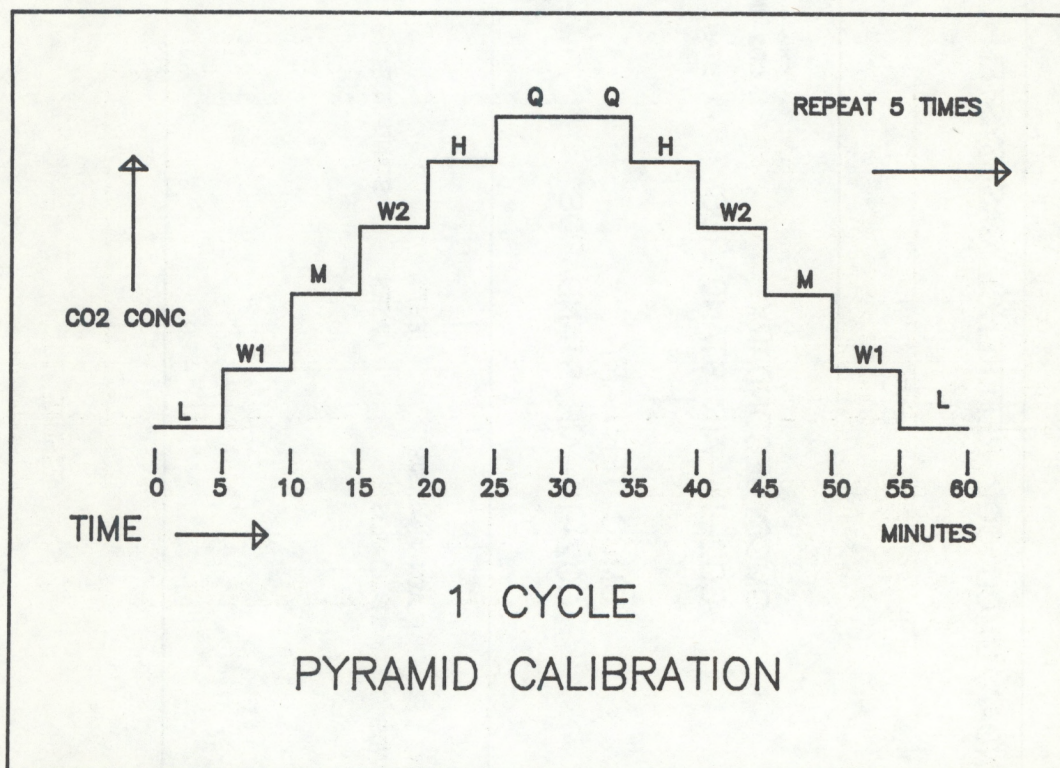


FIGURE 2.

Reference gas sequence used by GMCC for the measurement of unknown CO₂ reference gas concentrations.

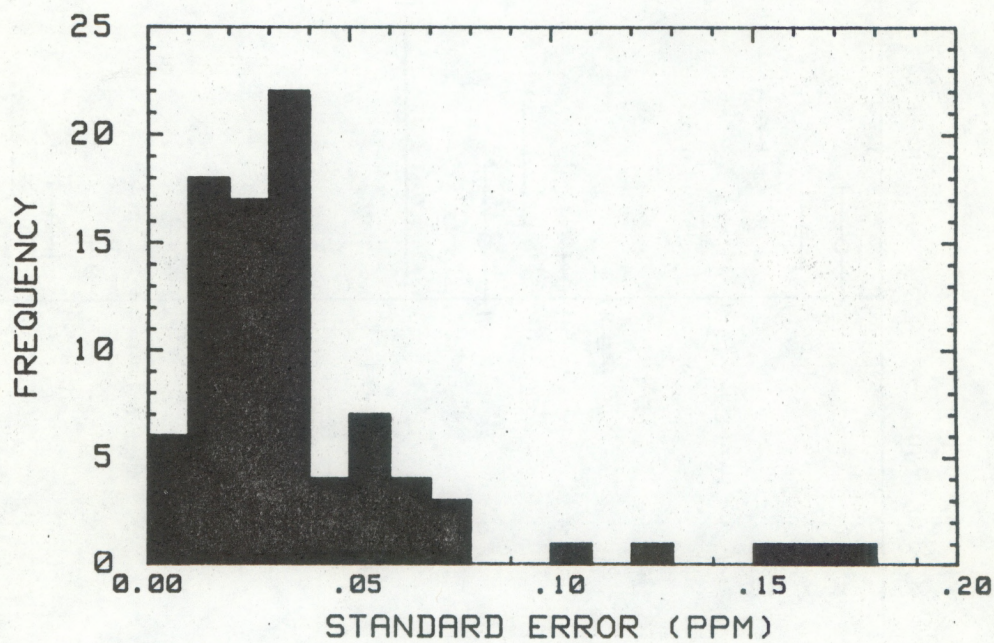


Figure 3.

Distribution of the standard errors of the means for 86 tanks with at least three calibrations by GMCC.

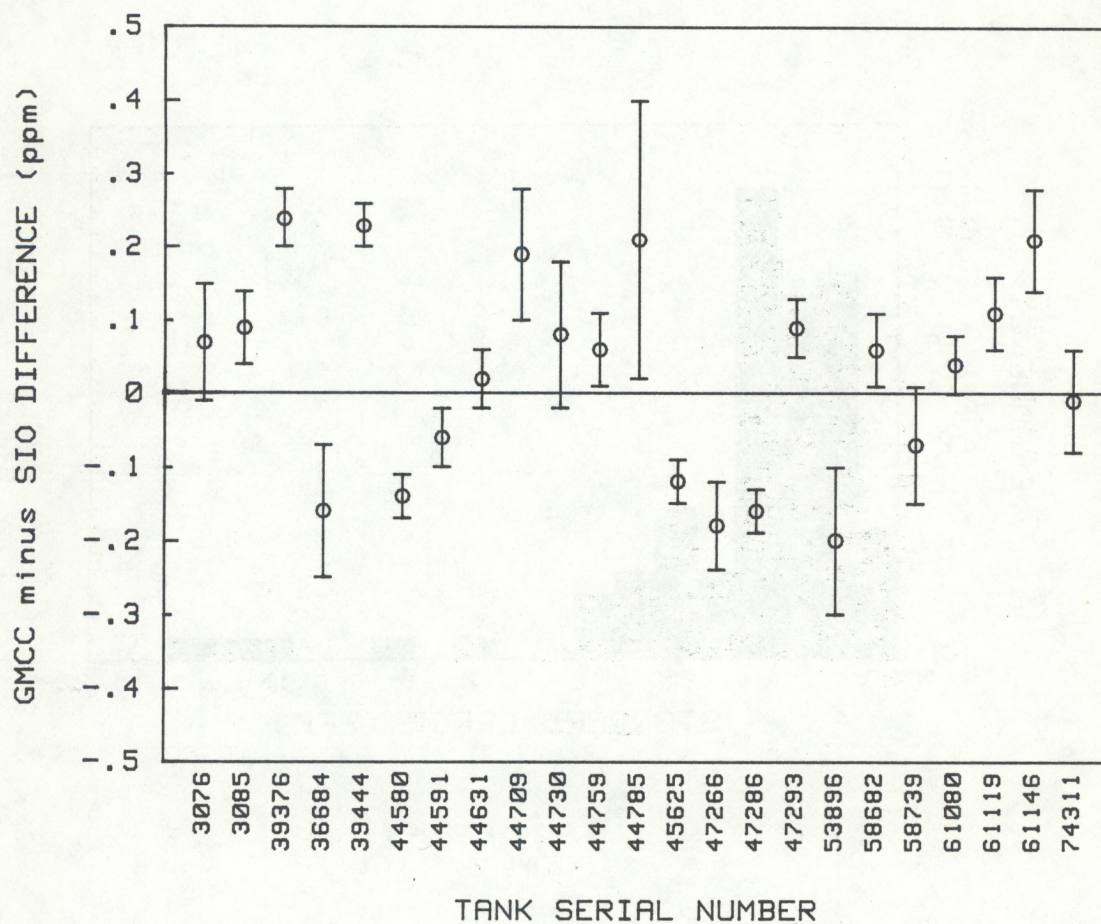


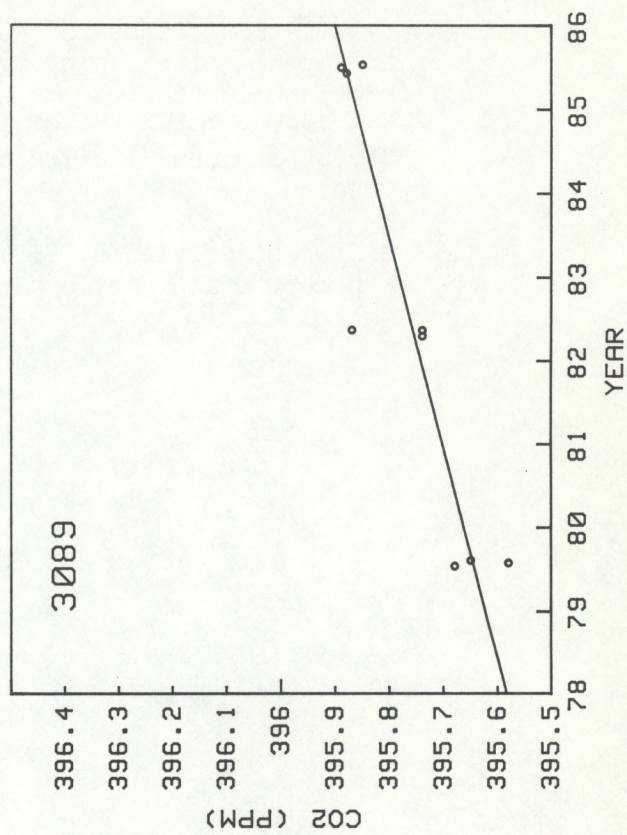
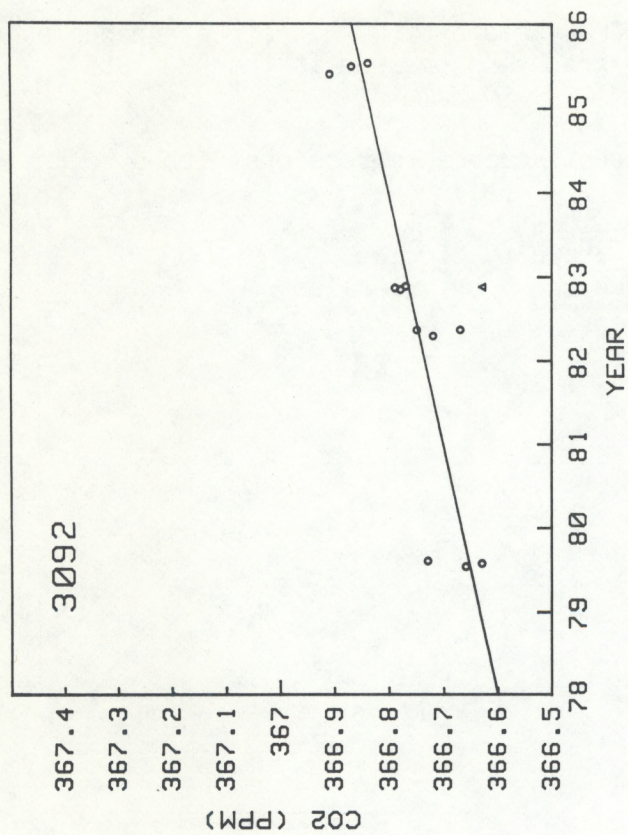
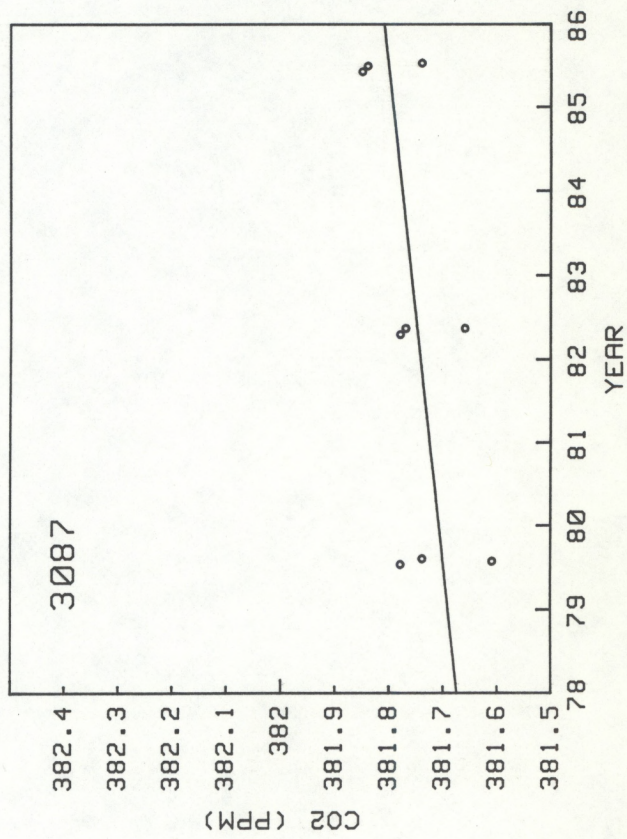
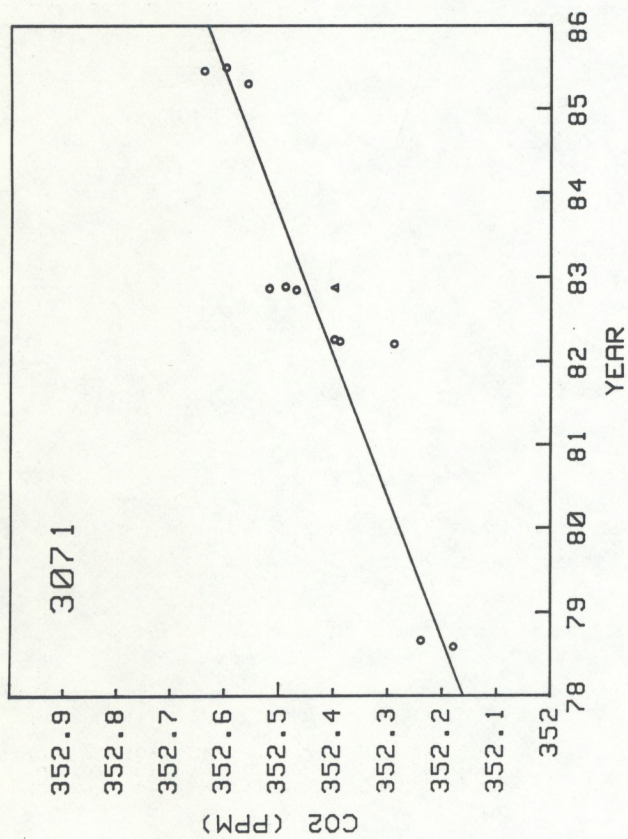
Figure 4.

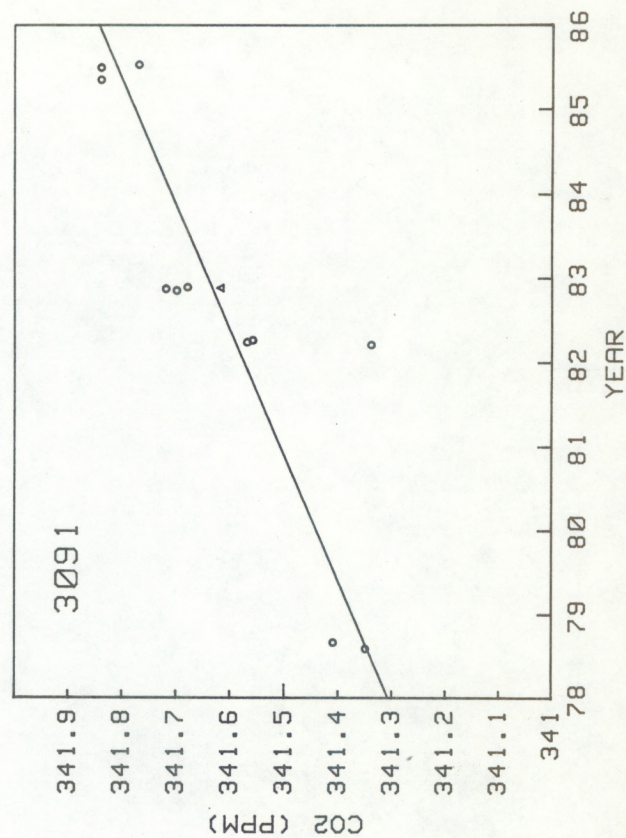
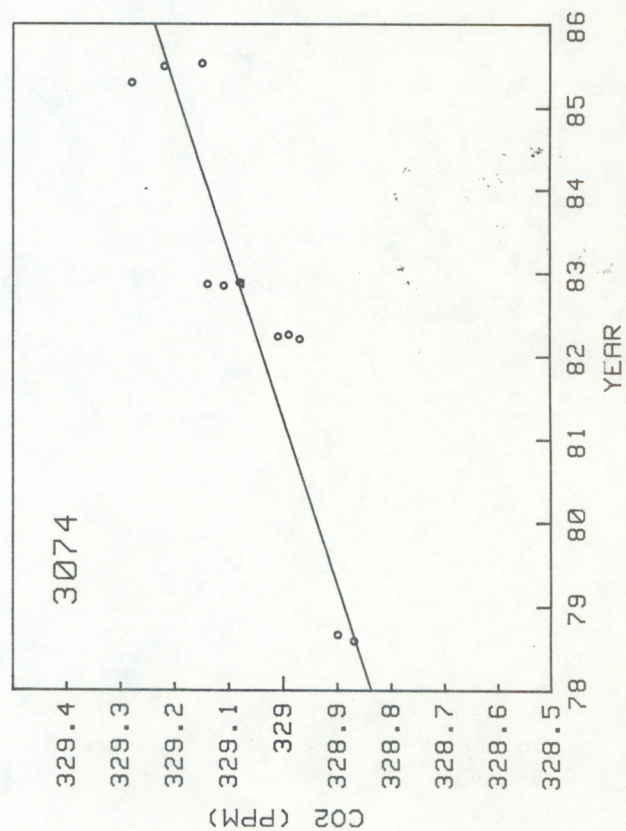
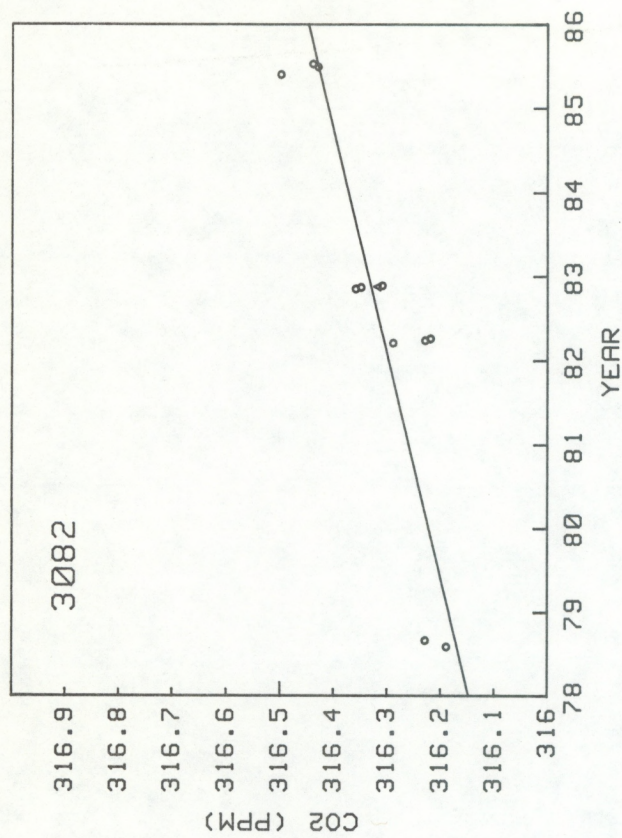
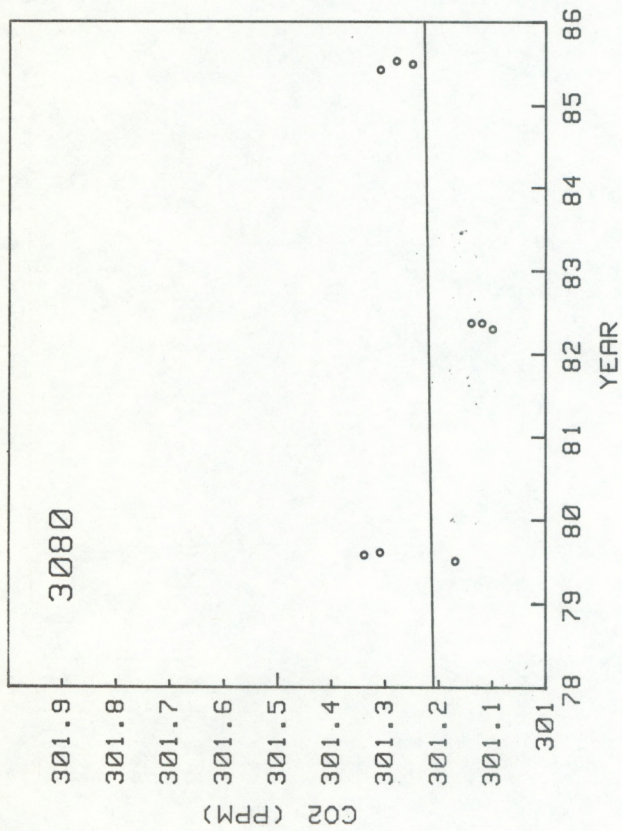
Plot of the differences between SIO and GMCC measurements for 23 tanks calibrated by both laboratories. Data points are plotted in the same order as in Table 5.

Appendix 1: Calibration history of NOAA/GMCC secondary CO₂-in-air standards at Scripps Institution of Oceanography, expressed in the WMO 1985 provisional scale.

The solid lines are linear least squares regressions fitted to the data.

Infrared analyses by SIO are shown by circles.
Manometric analyses by SIO are shown by triangles.

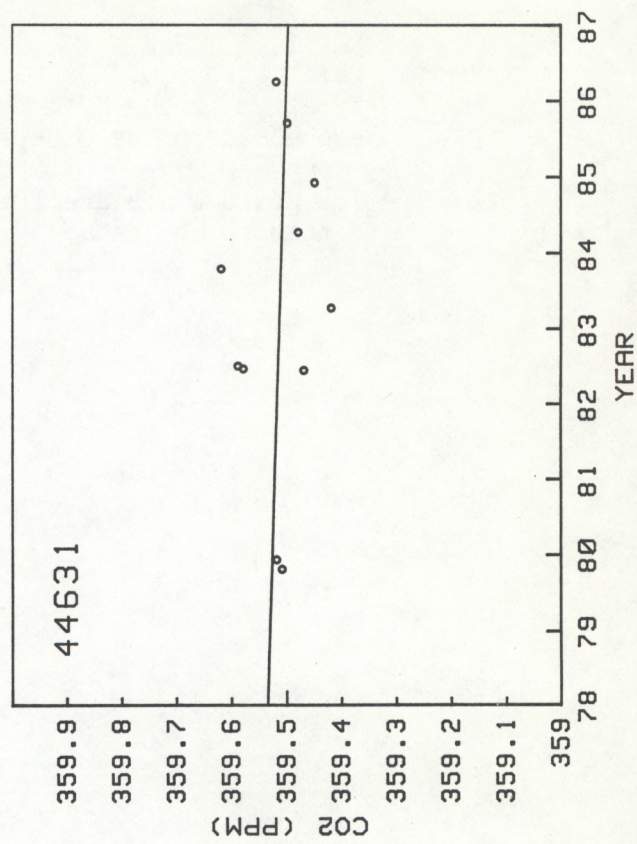
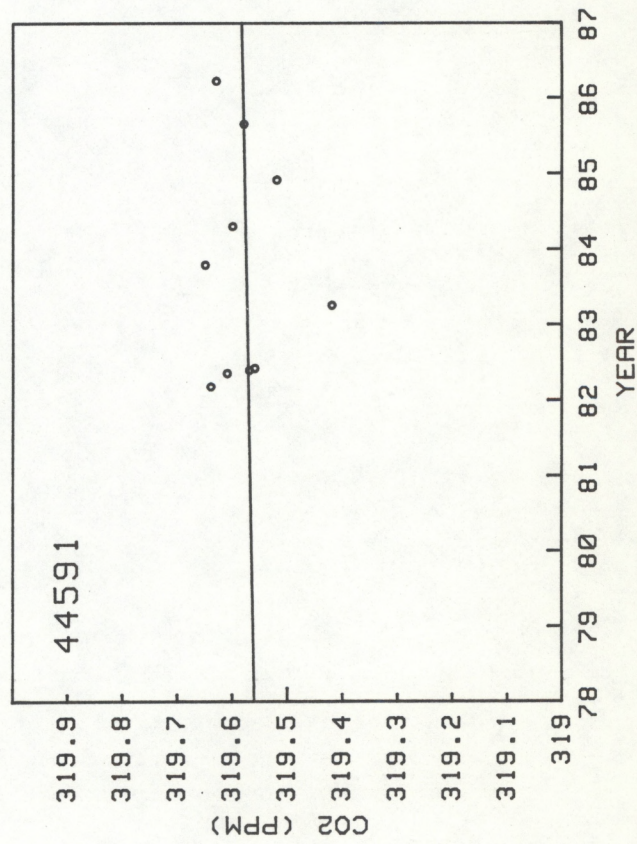
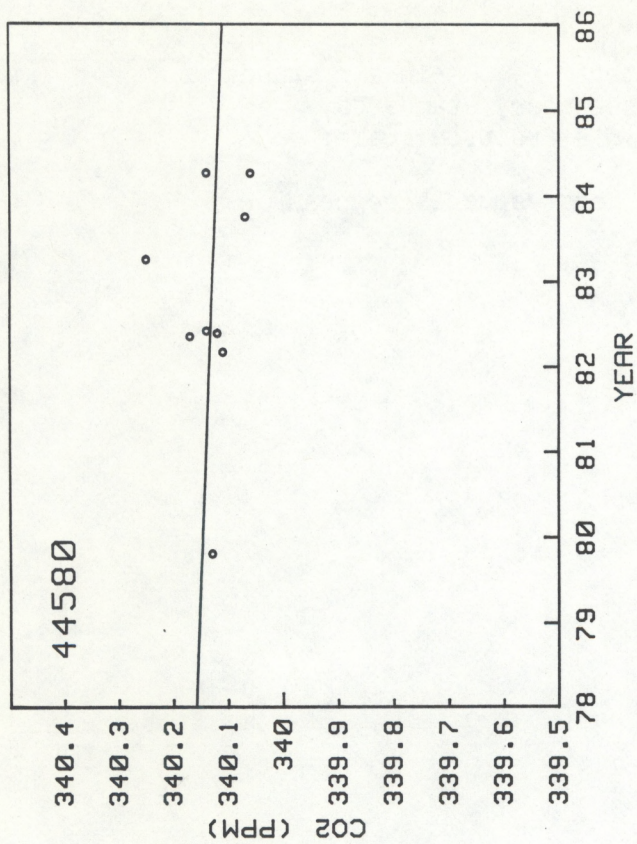
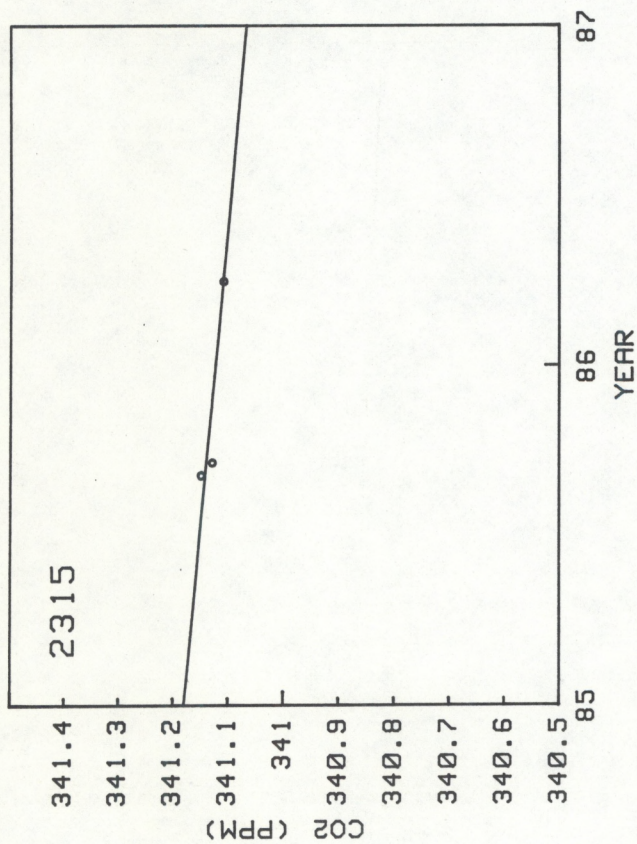


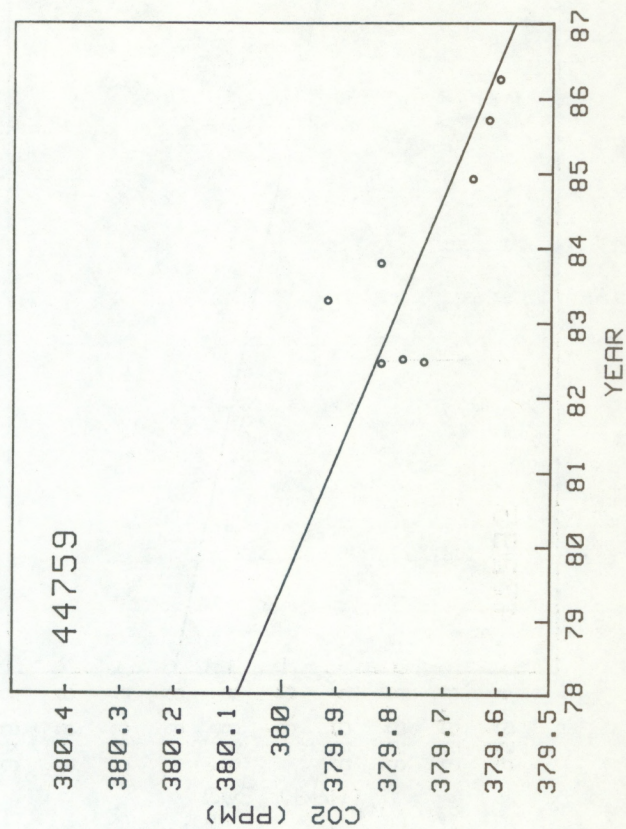
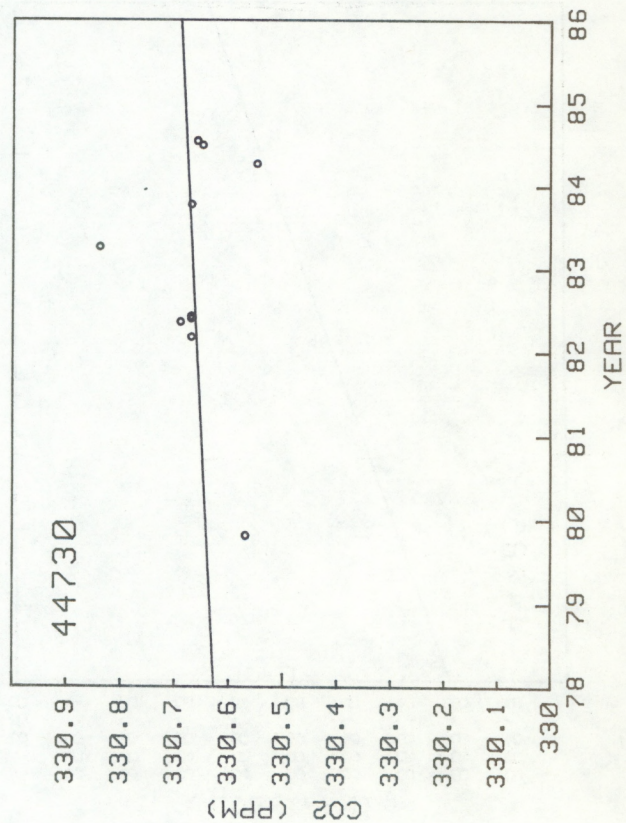
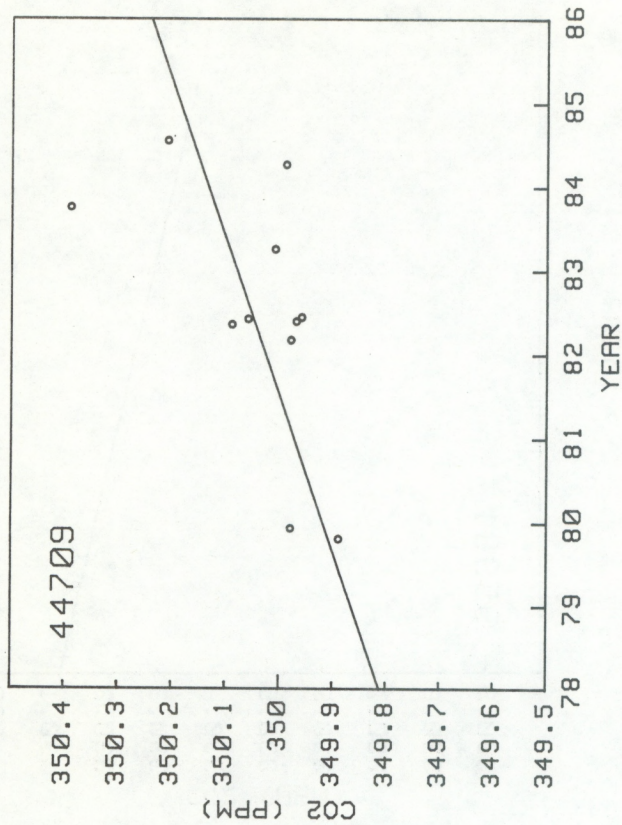
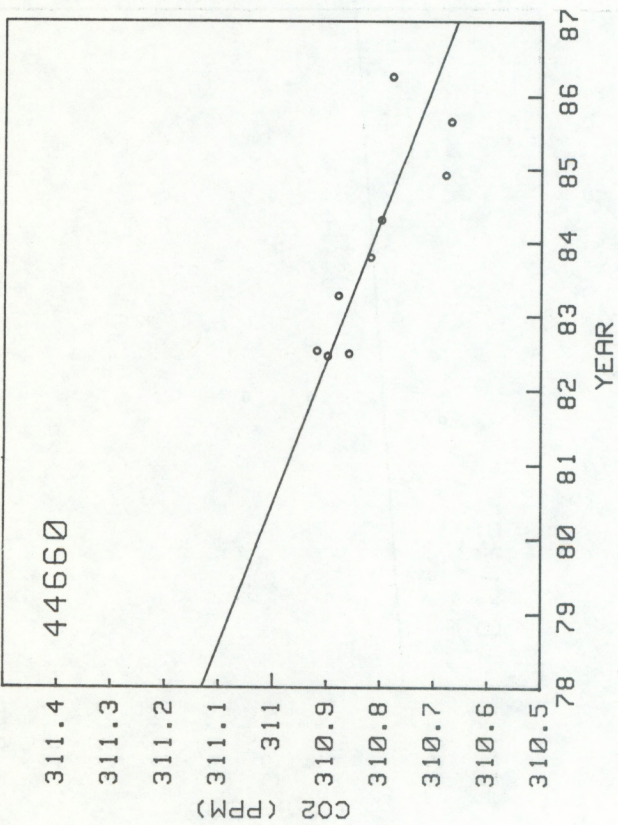


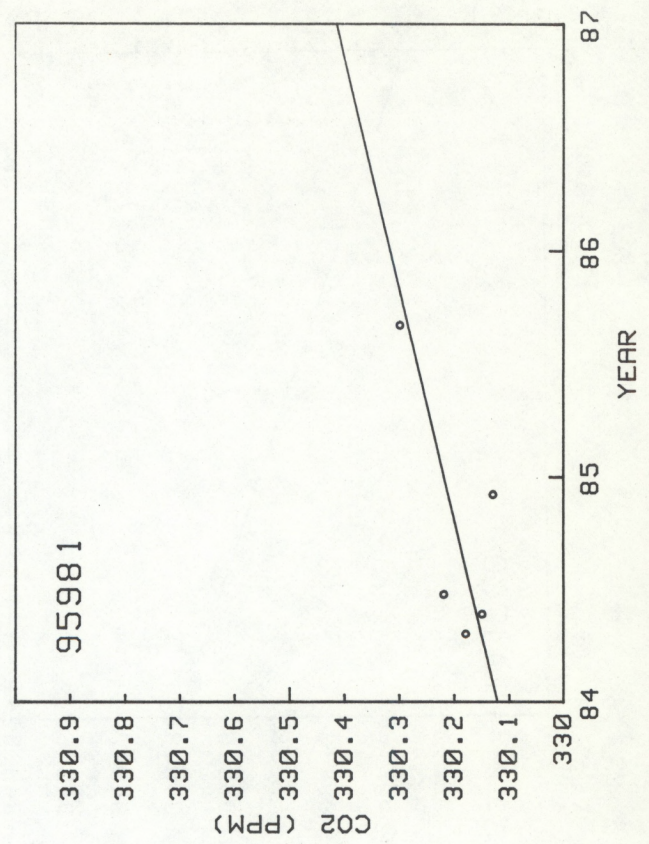
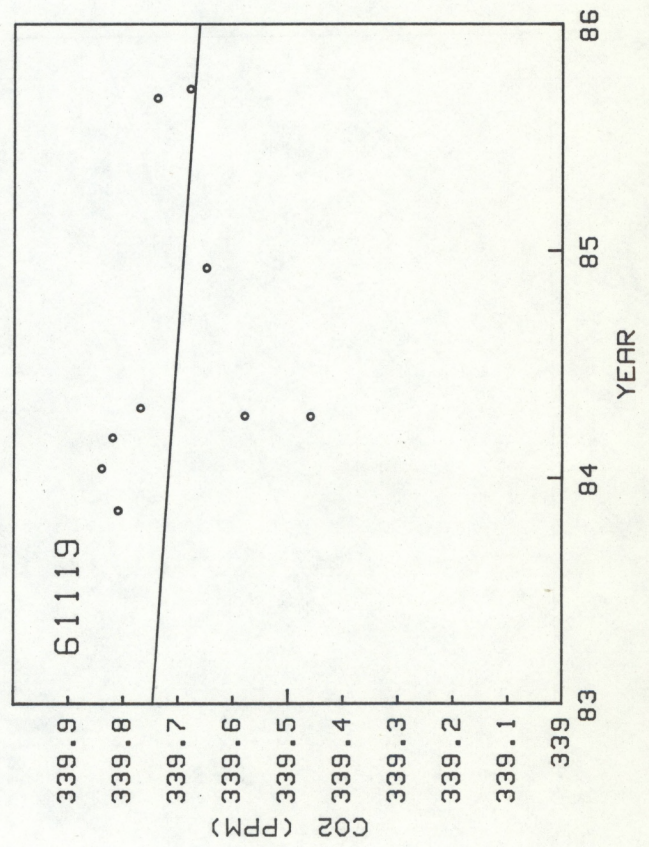
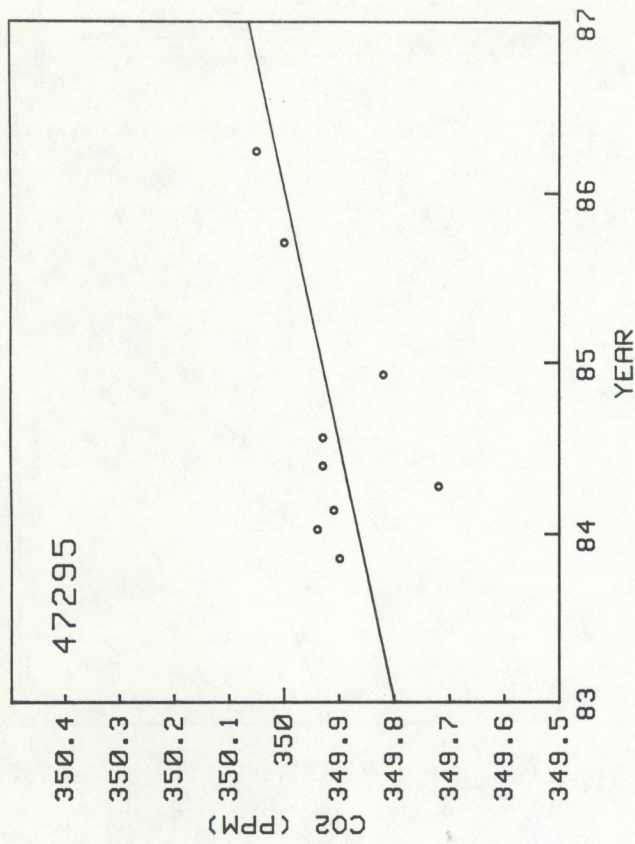
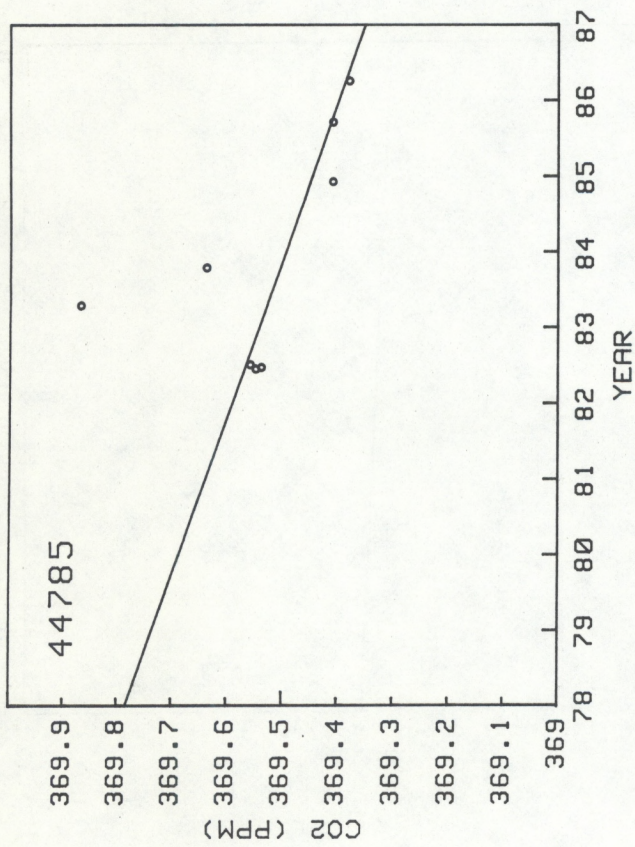


Appendix 2: Calibrations of NOAA/GMCC tertiary CO₂-in-air standards relative to the NOAA/GMCC secondary standards, expressed in the WMO 1985 mole fraction scale.

The solid lines are linear least squares regressions fitted to the data.







Appendix 3: SIO calibration data of NOAA/GMCC secondary CO₂
standards, expressed in the WMO 1985 mole fraction scale.

CYLINDER NUMBER # 3071

CO₂-IN-AIR CONCENTRATIONS (PPMV)

COMPARED CYLINDER NUMBER	DATE OF COMPARISONS YR/MO/DY	NUMBER OF COMPARISONS	ADJUSTED INDEX*	CO ₂ MOLE FRACTION**
4296	78/ 8/ 4	11	346.97	352.18
4296	78/ 9/ 1	10	347.02	352.24
75871	82/ 3/19	11	346.80	352.29
75871	82/ 3/31	10	346.89	352.39
75871	82/ 4/ 8	10	346.90	352.40
10074	82/11/ 9	10	346.86	352.47
10074	82/11/16	10	346.91	352.52
10074	82/11/23	10	346.87	352.49
34850	85/ 4/22	10	346.79	352.56
34850	85/ 6/17	12	346.86	352.64
34850	85/ 7/ 2	10	346.83	352.60

TOTAL 114 AVG. 346.88 352.43

SIGMA 0.15

MANO 82/11/17

352.40

CYLINDER NUMBER # 3074

4296	78/ 8/ 4	10	324.76	328.87
4296	78/ 9/ 1	12	324.77	328.90
75871	82/ 3/19	10	324.57	328.97
75781	82/ 3/31	14	324.61	329.01
75781	82/ 4/ 8	12	324.59	328.99
10074	82/11/ 9	12	324.62	329.11
10074	82/11/16	10	324.65	329.14
10074	82/11/23	10	324.59	329.08
34850	85/ 4/22	10	324.57	329.28
34850	85/ 7/ 2	10	324.51	329.22
34850	85/ 7/15	10	324.45	329.15

TOTAL 120 AVG. 324.61 329.06

SIGMA 0.13

MANO 82/11/16

329.08

CYLINDER NUMBER # 3080

136	79/ 7/ 5	10	296.84	301.17
136	79/ 7/30	13	297.00	301.34
136	79/ 8/10	11	296.96	301.31
75871	82/ 4/22	12	296.59	301.10
75781	82/ 5/18	10	296.61	301.12
75781	82/ 5/18	10	296.63	301.14
34850	85/ 6/ 7	10	296.42	301.31
34850	85/ 7/ 2	10	296.36	301.25
34850	85/ 7/15	10	296.39	301.28

TOTAL 96 AVG. 296.66 301.22

SIGMA 0.09

CYLINDER NUMBER # 3082
(PPMV)

CO₂-IN-AIR CONCENTRATIONS

COMPARED CYLINDER NUMBER	DATE OF COMPARISONS YR/MO/DY	NUMBER OF COMPARISONS	ADJUSTED INDEX*	CO ₂ MOLE FRACTION**
4296	78/ 8/ 4	14	312.24	316.19
4296	78/ 9/ 1	10	312.27	316.23
75871	82/ 3/19	10	312.05	316.29
75871	82/ 3/31	10	311.99	316.23
75871	82/ 4/ 8	10	311.97	316.22
10074	82/11/ 9	10	312.05	316.36
10074	82/11/16	10	312.03	316.35
10074	82/11/23	12	311.99	316.31
34850	85/ 5/29	10	311.91	316.50
34850	85/ 7/ 2	12	311.85	316.43
34850	85/ 7/15	10	311.86	316.44
TOTAL 118			AVG. 312.02	316.32
				SIGMA 0.10
MANO	82/11/15			316.32

CYLINDER NUMBER # 3087

136	79/ 7/16	12	373.80	381.78
136	79/ 7/30	12	373.66	381.61
136	79/ 8/10	10	373.77	381.74
75871	82/ 4/22	10	373.54	381.78
75871	82/ 5/18	8	373.51	381.77
75871	82/ 5/18	12	373.41	381.66
34850	85/ 6/ 7	10	373.34	381.85
34850	85/ 7/ 2	10	373.33	381.84
34850	85/ 7/15	10	373.24	381.74
TOTAL 94			AVG. 373.52	381.75
				SIGMA 0.08

CYLINDER NUMBER # 3089

136	79/ 7/16	10	385.98	395.68
136	79/ 7/30	12	385.89	395.58
136	79/ 8/10	10	385.95	395.65
75871	82/ 4/22	10	385.71	395.74
75871	82/ 5/18	10	385.70	395.74
75871	82/ 5/19	12	385.81	395.87
34850	85/ 6/ 7	10	385.55	395.88
34850	85/ 7/ 2	10	385.56	395.89
34850	85/ 7/15	10	385.53	395.85
TOTAL 94			AVG. 385.75	395.76
				SIGMA 0.11

CYLINDER NUMBER # **3091**
(PPMV)

CO₂-IN-AIR CONCENTRATIONS

COMPARED CYLINDER NUMBER	DATE OF COMPARISONS YR/MO/DY	NUMBER OF COMPARISONS	ADJUSTED INDEX*	CO ₂ MOLE FRACTION**
4296	78/ 8/ 4	12	336.77	341.35
4296	78/ 9/ 1	12	336.82	341.41
75871	82/ 3/19	12	336.49	341.34
75871	82/ 3/31	10	336.70	341.57
75871	82/ 4/ 8	10	336.69	341.56
10074	82/11/ 9	10	336.74	341.70
10074	82/11/16	10	336.75	341.72
10074	82/11/23	10	336.71	341.68
34850	85/ 5/10	10	336.69	341.84
34850	85/ 7/ 2	10	336.69	341.84
34850	85/ 7/15	10	336.63	341.77
		TOTAL 116	AVG. 336.70	341.60
				SIGMA 0.18
MANO	82/11/18			341.62

CYLINDER NUMBER # **3092**

136	79/ 7/16	11	360.23	366.66
136	79/ 7/30	12	360.21	366.63
136	79/ 8/10	10	360.29	366.73
75871	82/ 4/22	10	360.06	366.72
75871	82/ 5/18	10	360.07	366.75
75871	82/ 5/19	10	360.00	366.67
10074	82/11/ 9	10	360.01	366.78
10074	82/11/16	12	360.02	366.79
10074	82/11/23	10	360.00	366.77
34850	85/ 5/29	10	359.99	366.91
34850	85/ 7/ 2	10	359.95	366.87
34850	85/ 7/15	10	359.92	366.84
		TOTAL 125	AVG. 360.07	366.76
				SIGMA 0.09
MANO	82/11/19			366.63

* BASED ON 1959 MANOMETRIC CALIBRATION
(PREVIOUS PROVISIONAL SCALE)

** BASED ON 1985 MANOMETRIC CALIBRATION

Appendix 4: Summary of all GMCC CO₂-in-air reference gas calibrations for the years 1979 through 1985, expressed in the WMO 1985 mole fraction scale.

Note: The code character represents each new filling for that tank. "PRESS" is pressure of the tank in lbs/in².

Abbreviations:

BRW	Barrow Observatory, Barrow, Alaska (GMCC)
CONC	Co ₂ concentration, ppmv, 1985 mole fraction scale
CSIRO	Commonwealth Scientific and Industrial Research Organization, Australia
MLO	Mauna Loa Observatory, Hawaii (GMCC)
NBS	National Bureau of Standards
OGC	Oregon Graduate Center
PRESS	Tank pressure, lbs/in ²
SDEV	Standard deviation
SMO	Samoa Observatory, American Samoa (GMCC)
SPO	South Pole Observatory, Antarctica (GMCC)
SRM	Standard Reference Material
STD.	Standard
USGS	United States Geological Survey
WMO	World Meteorological Organization

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO2-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
79	17 DEC 79	—	A	342.63	1	342.63	0.000	FOR OGC
174	18 AUG 83	0420	A	340.57	2	340.57	0.000	CSIRO GC STD.
174	31 AUG 83	0400	A	340.57				
245	6 JUL 83	0375	A	343.68	2	343.75	.092	GMCC CH4 STD.
245	26 FEB 85	0200	A	343.81				
259	1 MAR 85	0390	A	339.40	1	339.40	0.000	GMCC CH4 STD.
511	14 DEC 79	—	A	338.90	1	338.90	0.000	FOR NBS
644	14 DEC 79	—	A	314.68	1	314.68	0.000	FOR NBS
1272	28 AUG 85	1850	A	332.56	1	332.56	0.000	FOR USGS
2232	5 JUN 85	1910	A	356.23	1	356.23	0.000	BRW WORKING TANK
2292	4 JUN 85	1980	A	356.48	1	356.48	0.000	BRW WORKING TANK
2308	17 SEP 85	1990	A	348.64	1	348.64	0.000	TERTIARY STD. BACKUP
2315	5 SEP 85	1990	A	341.15	2	341.14	.014	TERTIARY STD.
2315	19 SEP 85	1980	A	341.13				
2316	5 JUN 85	1930	A	366.92	1	366.92	0.000	TEST GAS
2331	4 JUN 85	2000	A	366.96	1	366.96	0.000	TEST GAS
3070	4 APR 80	—	A	324.64	2	324.61	.049	CO2-IN-NATURAL AIR
3070	25 OCT 83	1900	A	324.57				
3072	18 AUG 82	0880	A	329.80	1	329.80	0.000	GMCC HALOCARBON STD.
3073	7 APR 80	—	A	330.36	2	330.68	0.000	GMCC HALOCARBON STD.
3073	9 MAR 82	—	A	330.68				
3073	25 OCT 83	2120	A	330.66				
3073	28 MAR 85	2050	A	330.79				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO2-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
3073	28 MAR 85	2050	A	330.82	5	330.66	.182	CO2-IN-NATURAL AIR
3075	18 OCT 79	—	A	333.05				
3075	19 OCT 79	—	A	333.15				
3075	2 NOV 79	—	A	333.20				
3075	7 JAN 80	—	A	332.64				
3075	19 MAY 82	—	A	333.70				
3075	30 JUN 82	—	A	333.79				
3075	14 JUL 82	—	A	333.84				
3075	9 DEC 82	1100	A	333.79				
3075	13 OCT 83	0900	A	334.00				
3075	29 MAY 84	0530	A	334.27				
3075	27 MAR 85	0500	A	334.48	11	333.63	.557	FLASK ANALYSIS STD.
3076	4 APR 80	—	A	317.53				
3076	9 MAR 82	—	A	317.39				
3076	10 DEC 82	1800	A	317.49				
3076	27 OCT 83	1610	A	317.33				
3076	1 NOV 83	1620	A	317.40	5	317.43	.081	CO2-IN-NATURAL AIR
3077	1 NOV 79	—	A	333.07	1	333.07	0.000	FLASK ANALYSIS STD.
3077	16 NOV 81	—	B	347.30				
3077	5 OCT 82	1080	B	347.58				
3077	27 JAN 83	0600	B	347.90	3	347.59	.300	TEST GAS
3077	22 MAR 83	1740	C	343.08				
3077	17 JUN 83	0500	C	343.27	2	343.18	.134	TEST GAS
3081	1 NOV 79	—	A	349.37				
3081	20 MAY 82	—	A	349.80				
3081	9 DEC 82	0700	A	349.84	3	349.67	.261	FLASK ANALYSIS STD.
3085	2 NOV 79	—	A	318.52				
3085	19 MAY 82	—	A	318.51				
3085	10 DEC 82	1620	A	318.57				
3085	27 OCT 83	1520	A	318.56				
3085	1 NOV 83	1520	A	318.46	5	318.52	.044	FLASK ANALYSIS STD.
5188	14 NOV 84	0690	A	329.03	1	329.03	0.000	FOR UNIV. OF UTAH
6143	28 NOV 84	0350	A	373.55	1	373.55	0.000	FOR UNIV. OF UTAH

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
6493	27 AUG 85	0610	A	348.99	1	348.99	0.000	FOR USGS
8334	24 AUG 84	1150	A	375.00	1	375.00	0.000	FOR WASH. STATE UNIV.
8336	8 SEP 83	1390	A	374.70	1	374.70	0.000	FOR WASH. STATE UNIV.
8358	7 NOV 84	0380	A	350.57	1	350.57	0.000	FOR UNIV. OF UTAH
10932	24 SEP 82	2100	A	334.93	2	335.08	.205	SPO WORKING TANK
10932	22 FEB 85	0270	A	335.22				
10932	22 AUG 85	1900	B	358.73	1	358.73	0.000	FLASK ANALYSIS BACKUP STD.
11003	23 AUG 84	1890	A	310.99	1	310.99	0.000	FOR COLORADO STATE UNIV.
11017	30 SEP 82	1810	A	343.55	1	343.55	0.000	BRW WORKING TANK
11017	3 AUG 83	2120	B	343.55	1	343.55	0.000	TEST GAS
11028	5 OCT 82	1890	A	326.03	3	326.03	0.000	BRW STATION STD.
11028	19 NOV 84	1890	A	326.03				
11028	26 DEC 84	1820	A	326.03				
11039	1 OCT 82	2080	A	344.72	2	344.95	.325	SPO WORKING TANK
11039	30 NOV 84	0520	A	345.18				
11039	22 MAY 85	2010	B	345.58	1	345.58	0.000	BRW WORKING TANK
11066	28 SEP 82	—	A	333.96	2	334.86	1.266	SPO WORKING TANK
11066	27 DEC 84	0490	A	335.75				
11066	2 OCT 85	1930	B	348.93	1	348.93	0.000	SPO WORKING TANK
11077	29 SEP 82	—	A	337.29	2	338.25	1.358	SPO WORKING TANK
11077	25 FEB 85	0350	A	339.21				
11077	20 MAY 85	2100	B	323.92				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
11077	19 JUL 85	2020	B	323.94				
11077	29 JUL 85	—	B	323.97	3	323.94	.025	SPO STATION STD.
11078	24 SEP 82	2080	A	349.11				
11078	23 JAN 84	0320	A	349.52	2	349.32	.290	BRW WORKING TANK
11078	7 FEB 84	2000	B	344.13				
11078	22 FEB 84	2000	B	344.30				
11078	3 MAY 84	1310	B	344.40	3	344.28	.137	TEST GAS
11078	21 DEC 84	2000	C	341.11	1	341.11	0.000	TEST GAS
11078	30 SEP 85	1890	D	349.99	1	349.99	0.000	SPO WORKING TANK
11081	29 SEP 82	—	A	343.59	1	343.59	0.000	BRW WORKING TANK
11081	13 JUL 83	2100	B	343.77	1	343.77	0.000	SPO WORKING TANK
12847	13 APR 84	1480	A	346.59	1	346.59	0.000	FOR COLORADO STATE UNIV.
13558	30 SEP 82	2090	A	346.60				
13558	13 FEB 85	0310	A	347.77	2	347.19	.827	SPO WORKING TANK
13558	25 APR 85	1750	B	327.54				
13558	13 MAY 85	1750	B	327.55				
13558	29 JUL 85	—	B	327.55	3	327.55	.006	FLASK ANALYSIS STD.
13563	28 SEP 82	—	A	345.08	1	345.08	0.000	SPO WORKING TANK
13604	1 OCT 82	2110	A	346.47				
13604	26 FEB 85	0320	A	347.15	2	346.81	.481	SPO WORKING TANK
13604	27 AUG 85	1980	B	357.73				
13604	18 SEP 85	1960	B	357.77	2	357.75	.028	TERTIARY STD. BACKUP
13629	27 SEP 82	—	A	337.37				
13629	26 DEC 84	0100	A	340.12	2	338.75	1.945	SPO WORKING TANK

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO2-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
13629	26 APR 85	1820	B	340.03				
13629	9 MAY 85	1830	B	340.00				
13629	13 AUG 85	1790	B	339.99	3	340.01	.021	FLASK ANALYSIS STD.
18017	3 NOV 83	2080	A	350.91				
18017	26 JUN 84	1920	A	350.99				
18017	27 JUN 84	1820	A	350.80				
18017	16 SEP 85	1710	A	350.78	4	350.87	.098	NBS SRM
18035	6 JUL 83	1800	A	335.96				
18035	25 APR 84	1650	A	336.13				
18035	6 SEP 85	1510	A	335.88	3	335.99	.128	NBS SRM
18508	3 NOV 83	1810	A	342.71				
18508	6 JUN 84	1810	A	342.83				
18508	6 SEP 85	1730	A	342.73	3	342.76	.064	NBS SRM
24193	25 FEB 81	—	A	316.84				
24193	3 MAR 81	—	A	318.45				
24193	1 APR 81	—	A	318.73	3	318.01	1.020	FOR USSR
24210	27 FEB 81	—	A	331.30				
24221	27 FEB 81	—	A	341.99	1	331.30	0.000	FOR USSR
24296	2 MAR 81	—	A	354.72	1	341.99	0.000	FOR USSR
24319	25 FEB 81	—	A	345.86				
24319	3 MAR 81	—	A	345.98	2	345.92	.085	FOR USSR
25087	1 APR 81	—	A	334.06	1	334.06	0.000	FOR USSR
25096	26 FEB 81	—	A	333.95	1	333.95	0.000	FOR USSR
25097	26 FEB 81	—	A	322.98				
25097	2 MAR 81	—	A	323.00	2	322.99	0.014	FOR USSR
30357	18 APR 84	1970	A	346.90	1	346.90	0.000	SPO WORKING TANK

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
30416	30 AUG 84	1970	A	347.61	1	347.61	0.000	SPO WORKING TANK
30461	9 MAY 83	1300	A	318.70				
30461	9 JUN 83	1220	A	318.67				
30461	8 JUL 83	1220	A	318.72				
30461	4 APR 85	0610	A	318.60				
30461	16 APR 85	0610	A	318.63				
30461	14 MAY 85	0660	A	318.60	6	318.65	.051	SPO STATION STD.
30463	3 AUG 82	2120	A	319.00	1	319.00	0.000	SPO ZERO GAS
30466	9 SEP 81	—	A	342.62				
30466	27 DEC 84	0580	A	343.10	2	342.86	.339	SPO WORKING TANK
30466	4 OCT 85	1930	B	340.37	1	340.37	0.000	SPO WORKING TANK
32611	15 MAR 84	2010	A	316.63	1	316.63	0.000	FOR UNIV. OF COLORADO
32977	14 SEP 82	1760	A	309.64				
32977	21 SEP 82	1780	A	309.58				
32977	30 JAN 84	1510	A	309.40				
32977	28 AUG 85	1470	A	310.00	4	309.66	.252	FOR UNIV. OF NEBRASKA
33158	13 SEP 82	1900	A	349.43				
33158	21 SEP 82	1970	A	349.40				
33158	18 JAN 84	1750	A	349.46				
33158	20 AUG 85	1700	A	350.07	4	349.59	.321	FOR UNIV. OF NEBRASKA
36684	24 JAN 84	2000	A	325.12				
36684	18 MAY 84	1980	A	325.43				
36684	29 MAY 84	1980	A	325.08				
36684	25 FEB 85	2000	A	325.41				
36684	13 MAR 85	1880	A	325.41	5	325.29	.174	FOR WMO COMPARISON
36736	31 JAN 84	1800	A	341.33	1	341.33	0.000	MLO GC STD.
36737	18 JAN 84	1850	A	342.21				
36737	22 MAY 84	1380	A	342.66	2	342.44	.318	GC STD.
36737	13 FEB 85	1940	B	343.25				
36737	13 MAR 85	1920	B	343.29	2	343.27	.028	FOR WMO COMPARISON

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
36738	27 FEB 85	2000	A	362.60				
36738	26 MAR 85	1980	A	362.63	2	362.62	.021	FOR WMO COMPARISON
36770	24 JAN 84	2000	A	324.94	1	324.94	0.000	MLO GC STD.
39278	21 FEB 80	—	A	343.21				
39278	16 JUN 82	—	A	344.12				
39278	2 JUL 82	1300	A	344.08				
39278	14 JUL 82	1470	A	344.17				
39278	29 APR 85	0310	A	345.10				
39278	7 MAY 85	0310	A	345.09				
39278	6 AUG 85	0300	A	345.20	7	344.42	.736	BRW STATION STD.
39281	22 FEB 80	—	A	335.06	1	335.06	0.000	BRW WORKING TANK
39281	2 FEB 83	2100	B	336.37				
39281	23 FEB 84	0320	B	336.85	2	336.61	.339	SMO WORKING TANK
39281	4 SEP 84	1910	C	347.62				
39281	1 MAY 85	0430	C	347.71	2	347.67	.064	BRW WORKING TANK
39281	4 OCT 85	1990	D	350.40	1	350.40	0.000	SPO WORKING TANK
39314	11 MAY 83	2150	A	354.22				
39314	8 SEP 83	2080	A	354.34				
39314	21 JUN 84	—	A	354.59	3	354.38	.189	BRW WORKING TANK
39314	29 JAN 85	1980	B	338.51	1	338.51	0.000	MLO WORKING TANK
39319	17 APR 84	2010	A	349.31	1	349.31	0.000	BRW WORKING TANK
39348	22 FEB 80	—	A	320.43	1	320.43	0.000	TEST GAS
39348	4 MAY 81	—	B	334.63				
39348	30 OCT 81	—	B	334.82				
39348	27 AUG 82	2000	B	334.89				
39348	7 FEB 83	1850	B	334.89	4	334.81	.123	TEST GAS
39349	16 JUN 82	1890	A	325.24				
39349	24 JUN 82	—	A	325.24				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
39349	8 JUL 82	—	A	325.35				
39349	4 MAY 84	0880	A	325.39				
39349	19 NOV 84	0860	A	325.42				
39349	28 DEC 84	0850	A	325.46				
39349	4 MAR 85	0880	A	325.40	7	325.36	.087	SMO STATION STD.
39372	11 JUN 81	—	A	346.59	1	346.59	0.000	BRW WORKING TANK
39372	10 SEP 81	—	B	342.24	1	342.24	0.000	SPO WORKING TANK
39376	26 APR 83	1310	A	331.98				
39376	9 JUN 83	1280	A	331.97				
39376	8 JUL 83	1370	A	332.04				
39376	4 APR 85	1000	A	331.96				
39376	16 APR 85	1000	A	331.97				
39376	10 MAY 85	1000	A	331.93				
39376	22 JUL 85	—	A	331.90	7	331.96	.044	SPO STATION STD.
39395	15 JUL 83	2000	A	333.93				
39395	31 OCT 84	0480	A	334.24	2	334.09	.219	BRW WORKING TANK
39395	31 JAN 85	1800	B	337.74	1	337.74	0.000	MLO WORKING TANK
39399	16 APR 84	1880	A	334.95				
39399	23 MAY 84	1910	A	335.07				
39399	13 SEP 84	1880	A	335.19				
39399	31 DEC 84	1810	A	335.15				
39399	17 JUL 85	1860	A	335.24	5	335.12	.114	MLO STATION STD.
39415	28 MAR 83	2100	A	314.00	1	314.00	0.000	ZERO GAS
39432	13 APR 84	1990	A	352.85				
39432	22 MAY 84	2000	A	352.93				
39432	28 NOV 84	1950	A	352.90				
39432	21 FEB 85	1970	A	352.92	4	352.90	.036	BRW STATION STD.
39442	28 MAY 81	—	A	332.94				
39442	6 JAN 82	—	A	334.61				
39442	26 MAR 82	—	B	339.80	2	333.78	1.181	BRW WORKING TANK
39442	8 APR 82	—	B	339.64				
39442	18 JUN 82	—	B	339.87				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO2-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
39442	2 FEB 84	0410	B	342.13	4	340.36	1.184	BRW WORKING TANK
39442	26 APR 84	2060	C	331.68	1	331.68	0.000	BRW WORKING TANK
39444	26 APR 83	1380	A	344.14				
39444	1 JUN 83	1310	A	344.17				
39444	7 JUL 83	1300	A	344.05				
39444	3 APR 85	0910	A	344.04				
39444	29 APR 85	0970	A	344.05				
39444	7 MAY 85	0940	A	344.06				
39444	24 JUL 85	—	A	344.04				
39454	27 FEB 80	—	A	345.62	7	344.08	.053	SPO STATION STD.
39454	10 JUN 81	—	B	334.37	1	345.62	0.000	TEST GAS
39454	10 DEC 81	—	C	344.37	1	334.37	0.000	TEST GAS
39454	6 MAY 83	2080	C	344.49				
39454	18 AUG 83	1890	C	344.50				
39454	2 MAR 84	1510	C	344.60	4	344.49	.094	TEST GAS
39454	21 DEC 84	1940	D	343.72	1	343.72	0.000	TEST GAS
39454	13 AUG 85	2010	E	345.71	1	345.71	0.000	TEST GAS
44580	23 OCT 79	—	A	340.13				
44580	8 MAR 82	—	A	340.11				
44580	14 MAY 82	—	A	340.17				
44580	28 MAY 82	—	A	340.12				
44580	7 JUN 82	—	A	340.14				
44580	7 APR 83	1200	A	340.25				
44580	7 OCT 83	0620	A	340.07				
44580	9 APR 84	0510	A	340.06				
44580	10 APR 84	0510	A	340.14	9	340.13	.056	TERTIARY STD.
44580	20 MAY 85	1980	B	329.00				
44580	4 SEP 85	1920	B	329.06	2	329.03	.042	TERTIARY STD. BACKUP
44591	8 MAR 82	—	A	319.64				
44591	13 MAY 82	—	A	319.61				
44591	28 MAY 82	—	A	319.57				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO2-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
44591	7 JUN 82	—	A	319.56	9	319.57	.070	TERTIARY STD.
44591	8 APR 83	1520	A	319.42				
44591	21 OCT 83	1290	A	319.65				
44591	24 APR 84	—	A	319.60				
44591	3 DEC 84	0910	A	319.52				
44591	30 AUG 85	0720	A	319.58				
44631	24 OCT 79	—	A	359.51	10	359.51	.065	TERTIARY STD.
44631	10 DEC 79	—	A	359.52				
44631	15 JUN 82	—	A	359.47				
44631	22 JUN 82	—	A	359.58				
44631	6 JUL 82	—	A	359.59				
44631	14 APR 83	1690	A	359.42				
44631	18 OCT 83	1600	A	359.62				
44631	12 APR 84	1560	A	359.48				
44631	6 DEC 84	1200	A	359.45				
44631	18 SEP 85	0820	A	359.50				
44634	7 JAN 82	—	A	325.93	3	325.88	.090	TEST GAS
44634	13 APR 83	1780	A	325.94				
44634	6 JUN 84	1720	A	325.78				
44660	18 JUN 82	—	A	310.90	8	310.82	.096	TERTIARY STD.
44660	30 JUN 82	—	A	310.86				
44660	14 JUL 82	—	A	310.92				
44660	13 APR 83	1900	A	310.88				
44660	21 OCT 83	1790	A	310.82				
44660	24 APR 84	1780	A	310.80				
44660	3 DEC 84	1660	A	310.68				
44660	30 AUG 85	1610	A	310.67				
44709	24 OCT 79	—	A	349.89				
44709	10 DEC 79	—	A	349.98				
44709	8 MAR 82	—	A	349.98	11	350.05	.141	TERTIARY STD.
44709	14 MAY 82	—	A	350.09				
44709	28 MAY 82	—	A	349.97				
44709	7 JUN 82	—	A	350.06				
44709	15 JUN 82	—	A	349.96				
44709	7 APR 83	1210	A	350.01				
44709	7 OCT 83	1110	A	350.39				
44709	11 APR 84	0910	A	349.99				
44709	24 JUL 84	0430	A	350.21				
44709	5 SEP 85	1930	B	339.31	1	339.31	0.000	TERTIARY STD. BACKUP
44730	23 OCT 79	—	A	330.57				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
44730	8 MAR 82	—	A	330.67	10	330.66	.077	TERTIARY STD.
44730	13 MAY 82	—	A	330.69				
44730	28 MAY 82	—	A	330.67				
44730	7 JUN 82	—	A	330.67				
44730	8 APR 83	1230	A	330.84				
44730	13 OCT 83	1100	A	330.67				
44730	11 APR 84	0800	A	330.55				
44730	6 JUL 84	0580	A	330.65				
44730	24 JUL 84	0350	A	330.66				
44730	16 SEP 85	1930	B	349.25	1	349.25	0.000	FLASK ANALYSIS STD. BACKUP
44759	16 JUN 82	—	A	379.82	7	379.76	.104	TERTIARY STD.
44759	24 JUN 82	—	A	379.74				
44759	7 JUL 82	—	A	379.78				
44759	19 APR 83	2060	A	379.92				
44759	19 OCT 83	2050	A	379.82				
44759	7 DEC 84	1980	A	379.65				
44759	20 SEP 85	1930	A	379.62				
44785	16 JUN 82	—	A	369.55				
44785	24 JUN 82	—	A	369.54				
44785	7 JUL 82	—	A	369.56				
44785	19 APR 83	1970	A	369.87	7	369.57	.157	TERTIARY STD.
44785	19 OCT 83	1820	A	369.64				
44785	7 DEC 84	1710	A	369.41				
44785	20 SEP 85	1620	A	369.41				
45602	11 JUN 81	—	A	329.25	1	329.25	0.000	BRW WORKING TANK
45602	9 SEP 81	—	B	330.51	1	330.51	0.000	SPO WORKING TANK
45602	22 JUL 83	2050	C	343.04	2	343.19	.212	BRW WORKING TANK
45602	23 JAN 84	0450	C	343.34				
45602	7 FEB 84	2000	D	336.16				
45602	22 FEB 84	1980	D	336.31				
45604	3 SEP 81	—	A	347.73				
45604	16 NOV 81	—	A	347.75				
45604	21 JUL 82	2100	B	345.03				
45604	8 SEP 82	2050	B	345.07				
45604	3 SEP 81	—	A	347.73				
45604	16 NOV 81	—	A	347.75				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
45604	31 AUG 83	1350	B	345.12				
45604	2 MAR 84	0290	B	345.16	4	345.10	.057	TEST GAS
45604	5 SEP 84	1910	C	359.45				
45604	19 SEP 84	1930	C	359.50				
45604	12 OCT 84	1930	C	359.50				
45604	18 OCT 85	1780	C	359.57	4	359.51	.049	FLASK ANALYSIS STD.
45625	9 APR 82	—	A	327.17				
45625	28 APR 82	—	A	327.17				
45625	4 JUN 82	—	A	327.24				
45625	8 JUN 82	—	A	327.17				
45625	26 APR 85	1520	A	327.27				
45625	13 MAY 85	1520	A	327.31	6	327.22	.061	BRW SURVEILLANCE TANK
45790	24 APR 84	1900	A	337.09				
45790	26 NOV 85	0450	A	337.65	2	337.37	.396	SMO WORKING TANK
45796	28 APR 83	0500	A	355.89				
45796	1 JUN 83	0500	A	355.96				
45796	10 AUG 83	0450	A	356.11	3	355.99	.112	SPO STATION STD.
45796	26 JAN 84	1910	B	325.65				
45796	13 MAR 84	1920	B	325.74				
45796	21 MAY 84	1910	B	325.98				
45796	27 JUL 84	1890	B	326.14	4	325.88	.224	SPO STATION STD.
45803	26 JUL 83	1980	A	334.23	1	334.23	0.000	SPO WORKING TANK
45854	24 APR 84	1970	A	347.26				
45854	22 NOV 85	0380	A	347.64	2	347.45	.269	SMO WORKING TANK
45870	18 MAR 82	—	A	346.05	1	346.05	0.000	SMO WORKING TANK
45870	2 FEB 83	1960	B	328.45				
45870	16 MAR 84	0480	B	328.42	2	328.44	.021	BRW WORKING TANK
45870	31 AUG 84	1980	C	356.05				
45870	7 MAR 85	0500	C	356.31	2	356.18	.184	BRW WORKING TANK
45878	27 AUG 80	—	A	333.09	1	333.09	0.000	SPO WORKING TANK

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
45878	18 MAR 82	—	B	335.83	1	335.83	0.000	SMO WORKING TANK
45878	27 JAN 83	1980	C	344.85				
45878	1 MAR 84	0910	C	344.94	2	344.90	.064	SMO WORKING TANK
45878	29 JAN 85	2000	D	348.66	1	348.66	0.000	MLO WORKING TANK
45910	23 JUN 82	—	A	334.36	1	334.36	0.000	SMO WORKING TANK
45910	26 JAN 84	2000	B	323.40				
45910	13 MAR 84	1920	B	323.60				
45910	21 MAY 84	1950	B	323.96				
45910	26 JUL 84	1900	B	324.28				
45910	31 DEC 84	1940	B	324.92				
45910	4 MAR 85	1900	B	325.04				
45910	17 JUL 85	1910	B	325.59	7	324.40	.811	SPO ZERO GAS
45918	21 FEB 80	—	A	318.32				
45918	28 FEB 80	—	A	318.20				
45918	24 JUN 82	—	A	318.19				
45918	15 JUL 82	1400	A	318.15				
45918	22 JUL 82	1390	A	318.20				
45918	24 APR 85	0390	A	318.04				
45918	14 MAY 85	0390	A	318.05				
45918	19 JUL 85	0380	A	318.12	8	318.16	.091	BRW STATION STD.
45918	7 OCT 85	1960	B	325.91				
45918	22 OCT 85	1960	B	325.85				
45918	4 NOV 85	1950	B	325.87	3	325.88	.031	MLO STATION STD.
45922	15 JUL 83	2050	A	345.34				
45922	12 AUG 85	0590	A	345.56	2	345.45	.156	MLO WORKING TANK
45957	1 OCT 81	—	A	340.15				
45957	8 OCT 81	—	A	340.09	2	340.12	.042	BRW WORKING TANK
45957	3 AUG 82	2060	B	327.46	1	327.46	0.000	TEST GAS
45957	3 FEB 83	2090	C	335.61	1	335.61	0.000	SMO WORKING TANK
45958	10 SEP 81	—	A	330.56	1	330.56	0.000	SPO WORKING TANK

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
45958	19 JUL 83	1980	B	334.02	1	334.02	0.000	SPO WORKING TANK
45984	23 MAY 85	1960	A	349.56	1	349.56	0.000	BRW WORKING TANK
46013	17 JUN 82	—	A	331.79				
46013	18 JUN 82	1870	A	331.87				
46013	18 JUN 82	—	A	331.88				
46013	1 JUL 82	1980	A	331.66				
46013	19 JUL 82	1910	A	332.02				
46013	28 JUL 82	1900	A	331.88				
46013	19 JUL 84	1150	A	331.98				
46013	22 AUG 84	1130	A	331.97				
46013	17 DEC 84	1140	A	331.98				
46013	20 DEC 84	1150	A	331.99	10	331.90	.111	MLO STATION STD.
46046	15 JUN 84	2000	A	319.84	1	319.84	0.000	ZERO GAS
46117	11 JUN 82	2000	A	346.25				
46117	21 JUN 82	—	A	346.36	2	346.31	.078	MLO WORKING TANK
46117	22 SEP 83	2100	B	337.71				
46117	21 JUN 84	—	B	337.81	2	337.76	.071	BRW WORKING TANK
46117	1 FEB 85	1920	C	348.51	1	348.51	0.000	MLO WORKING TANK
46124	6 AUG 82	2090	A	323.00				
46124	18 AUG 82	2070	A	323.12				
46124	27 AUG 82	2060	A	323.11				
46124	8 SEP 82	2070	A	323.14				
46124	20 SEP 83	1650	A	323.10	5	323.09	.055	TRAVELLING STATION STD.
46150	28 JUL 83	1930	A	334.35	1	334.35	0.000	SPO WORKING TANK
47266	5 APR 83	1850	A	324.39				
47266	21 APR 83	1790	A	324.17				
47266	5 MAY 83	1780	A	324.24	3	324.27	.112	SPO STATION STD.
47269	29 MAY 85	2000	A	349.31	1	349.31	0.000	SPO WORKING TANK
47271	21 FEB 80	—	A	354.08				
47271	28 JUN 82	0900	A	354.68				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
47271	9 JUL 82	0900	A	354.76				
47271	16 JUL 82	0890	A	354.66				
47271	22 MAR 83	0810	A	354.95				
47271	11 MAY 83	0720	A	354.85				
47271	17 JUN 83	0790	A	354.97				
					7	354.71	.302	BRW STATION STD.
47271	3 AUG 83	2060	B	351.34				
47271	25 NOV 85	0150	B	352.66				
					2	352.00	.933	SMO WORKING TANK
47272	27 AUG 80	—	A	333.89				
					1	333.89	0.000	SPO WORKING TANK
47272	22 JUN 82	—	B	335.82				
47272	15 JUL 82	2030	B	335.93				
47272	22 JUL 82	2000	B	335.78				
47272	6 AUG 82	2000	B	335.77				
47272	20 SEP 83	1700	B	335.76				
					5	335.81	.070	TRAVELLING STATION STD.
47276	18 OCT 79	—	A	337.73				
47276	19 OCT 79	—	A	337.68				
47276	8 APR 82	—	A	337.74				
47276	27 APR 82	—	A	337.73				
47276	9 JUN 82	—	A	337.73				
47276	22 FEB 85	0210	A	337.92				
					6	337.76	.084	SPO SURVEILLANCE STD.
47277	21 FEB 80	—	A	331.51				
47277	28 FEB 80	—	A	331.44				
47277	16 JUN 82	—	A	332.07				
47277	2 JUL 82	1400	A	331.95				
47277	14 JUL 82	1380	A	332.07				
47277	25 APR 85	0230	A	332.65				
47277	10 MAY 85	0210	A	332.68				
47277	22 JUL 85	—	A	332.80				
					8	332.15	.524	BRW STATION STD.
47277	3 OCT 85	1980	B	340.65				
					1	340.65	0.000	SPO WORKING TANK
47281	11 JUN 82	2100	A	348.60				
47281	22 JUN 82	—	A	348.66				
47281	12 JUL 82	2080	A	348.70				
47281	9 AUG 82	2020	A	348.50				
47281	19 SEP 83	1690	A	348.64				
					5	348.62	.076	TRAVELLING STATION STD.
47282	19 JUL 83	2080	A	344.17				
47282	28 FEB 85	0530	A	344.37				
					2	344.27	.141	MLO WORKING TANK

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
47282	3 JUN 85	1980	B	356.35	1	356.35	0.000	BRW WORKING TANK
47284	16 APR 84	1920	A	347.56	1	347.56	0.000	SPO WORKING TANK
47285	20 MAY 83	2020	A	366.26	4	366.27	.048	CO ₂ -IN-NATURAL AIR
47285	18 OCT 83	1970	A	366.34				
47285	24 FEB 84	1890	A	366.25				
47285	26 MAR 85	1910	A	366.23				
47286	7 JAN 80	—	A	346.90	2	347.05	.212	TEST GAS
47286	7 APR 80	—	A	347.20				
47286	5 APR 83	1800	B	334.50	3	334.55	.042	SMO STATION STD.
47286	21 APR 83	1760	B	334.56				
47286	5 MAY 83	1750	B	334.58				
47287	1 OCT 81	—	A	353.69	6	353.61	.090	TEST GAS
47287	8 OCT 81	—	A	353.67				
47287	21 JUN 83	2110	A	353.60				
47287	4 OCT 83	2020	A	353.70				
47287	20 MAR 84	1900	A	353.51				
47287	27 JUN 84	1840	A	353.50				
47287	30 SEP 85	1900	B	344.44	2	344.44	.007	BRW STATION STD.
47287	22 OCT 85	2000	B	344.43				
47288	22 JUN 82	—	A	334.71	1	334.71	0.000	BRW WORKING TANK
47288	20 JUL 83	2010	B	335.80	2	335.80	0.000	MLO WORKING TANK
47288	12 AUG 85	0580	B	335.80				
47289	27 JUL 83	2040	A	345.02	2	345.07	.071	MLO WORKING TANK
47289	24 OCT 84	0410	A	345.12				
47289	4 FEB 85	1800	B	338.45	1	338.45	0.000	MLO WORKING TANK
47290	3 OCT 85	1980	A	350.50	1	350.50	0.000	MLO WORKING TANK
47291	21 MAY 85	2000	A	339.12	1	339.12	0.000	SMO WORKING TANK

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
47293	13 SEP 79	—	A	330.60				
47293	14 SEP 79	—	A	330.53				
47293	3 FEB 81	—	A	330.66				
47293	28 AUG 81	—	A	330.59	4	330.60	.053	FLASK ANALYSIS STD.
47293	25 JUN 82	—	B	357.44				
47293	9 JUL 82	2080	B	357.58				
47293	16 JUL 82	2030	B	357.61				
47293	10 DEC 84	1460	B	357.60				
47293	2 JAN 85	1430	B	357.60				
47293	5 MAR 85	1430	B	357.63	6	357.58	.069	SPO STATION STD.
47294	28 AUG 80	—	A	343.18	1	343.18	0.000	SPO WORKING TANK
47294	18 MAR 82	—	B	334.58				
47294	22 NOV 82	0300	B	334.81	2	334.70	.163	BRW WORKING TANK
47294	24 JAN 83	2110	C	344.58				
47294	11 JUN 84	—	C	344.85	2	344.72	.191	MLO WORKING TANK
47294	31 AUG 84	2000	D	345.65				
47294	7 MAR 85	0480	D	345.74	2	345.70	.064	BRW WORKING TANK
47294	2 OCT 85	1970	E	344.37	1	344.37	0.000	MLO WORKING TANK
47295	22 JUN 82	—	A	345.63	1	345.63	0.000	SNO WORKING TANK
47295	9 NOV 83	2000	B	349.90				
47295	11 JAN 84	2010	B	349.94				
47295	21 FEB 84	2000	B	349.91				
47295	12 APR 84	1960	B	349.72				
47295	25 MAY 84	1980	B	349.93				
47295	24 JUL 84	1940	B	349.93				
47295	6 DEC 84	1700	B	349.82				
47295	17 SEP 85	1230	B	350.00	8	349.89	.086	TERTIARY STD.
53879	9 AUG 82	2080	A	360.56				
53879	16 AUG 82	2050	A	360.71				
53879	17 AUG 82	2030	A	360.65				
53879	30 AUG 82	2010	A	360.73				
53879	7 SEP 82	2000	A	360.67				
53879	19 SEP 83	1740	A	360.73	6	360.68	.065	TRAVELLING STATION STD.

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
53880	25 MAR 82	—	A	346.20	1	346.20	0.000	SMO WORKING TANK
53880	13 JUL 83	2000	B	335.29				
53880	24 OCT 84	0200	B	335.30	2	335.30	.007	MLO WORKING TANK
53880	31 JAN 85	1980	C	349.83	1	349.83	0.000	MLO WORKING TANK
53891	7 OCT 85	2000	A	339.78	1	339.78	0.000	SPO WORKING TANK
53896	9 APR 82	—	A	335.31				
53896	28 APR 82	—	A	335.31				
53896	9 JUN 82	—	A	335.37				
53896	27 NOV 85	0880	A	335.30	4	335.32	.032	SMO SURVEILLANCE TANK
53899	16 AUG 82	2090	A	354.38				
53899	17 AUG 82	2090	A	354.38				
53899	30 AUG 82	2090	A	354.33				
53899	7 SEP 82	2080	A	354.36				
53899	27 SEP 82	—	A	354.36				
53899	30 APR 85	1080	A	354.69				
53899	8 MAY 85	1050	A	354.70				
53899	6 AUG 85	1010	A	354.71	8	354.49	.176	BRW STATION STD.
53905	28 AUG 80	—	A	344.06	1	344.06	0.000	SPO WORKING TANK
53905	25 JUN 82	—	B	359.71				
53905	28 JUN 82	1950	B	359.80				
53905	12 JUL 82	2000	B	359.81				
53905	20 JUL 82	1980	B	359.83				
53905	25 JUL 84	1210	B	359.96				
53905	24 AUG 84	1190	B	359.91				
53905	14 DEC 84	1200	B	359.98				
53905	23 OCT 85	1210	B	359.99	8	359.87	.101	MLO STATION STD.
53906	23 MAR 83	1190	A	355.02				
53906	6 APR 83	1110	A	355.19				
53906	15 APR 83	1010	A	355.08	3	355.10	.086	SMO STATION STD.
53913	21 JUN 82	—	A	334.82	1	334.82	0.000	MLO WORKING TANK
53913	4 AUG 83	2000	B	336.91				
53913	6 MAR 85	1450	B	337.06	2	336.99	.106	TEST GAS

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
53926	8 SEP 81	—	A	342.50	1	342.50	0.000	SPO WORKING TANK
53926	7 JUL 83	2090	B	353.30				
53926	4 AUG 83	2030	B	353.28				
53926	22 AUG 83	1910	B	353.12				
53926	3 APR 85	1650	B	353.15				
53926	30 APR 85	1680	B	353.15				
53926	8 MAY 85	1560	B	353.14				
53926	24 JUL 85	—	B	353.10	7	353.18	.079	SPO STATION STD.
53928	27 JUN 80	—	A	346.58				
53928	28 APR 83	1850	A	346.52				
53928	6 MAR 85	1280	A	346.55	3	346.55	.030	TEST GAS
53928	4 NOV 85	2020	B	346.18	1	346.18	0.000	TEST GAS
53929	27 FEB 80	—	A	335.74	1	335.74	0.000	FOR USSR
53932	25 MAR 82	—	A	335.47	1	335.47	0.000	SNO WORKING TANK
53932	20 JUL 83	2110	B	344.08	1	344.08	0.000	SPO WORKING TANK
53937	28 MAY 81	—	A	320.39				
53937	6 JAN 82	—	A	320.38	2	320.39	.007	BRW WORKING TANK
53937	18 MAR 82	—	B	324.03	1	324.03	0.000	BRW WORKING TANK
53937	3 FEB 83	2020	C	334.49				
53937	15 NOV 83	0420	C	336.19	2	335.34	1.202	MLO WORKING TANK
53937	17 APR 84	1990	D	335.61	1	335.61	0.000	SPO WORKING TANK
53944	27 JUN 80	—	A	342.21				
53944	4 FEB 81	—	A	343.29	2	342.75	.764	TEST GAS
53944	21 FEB 81	—	B	326.81	1	326.81	0.000	BRW WORKING TANK
53944	2 DEC 82	1900	C	330.35				
53944	4 JAN 83	1810	C	330.23				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
53944	17 AUG 83	1110	C	330.49				
53944	13 FEB 84	0730	C	330.41				
53944	3 AUG 84	0480	C	330.63	5	330.42	.150	FLASK ANALYSIS STD.
53944	7 FEB 85	2010	D	356.03	1	356.03	0.000	BRW WORKING TANK
58635	6 FEB 81	—	A	345.40	1	345.40	0.000	TEST GAS
58635	7 NOV 83	2000	B	339.83				
58635	31 JAN 84	1990	B	340.07				
58635	23 APR 84	1980	B	339.93				
58635	26 JUN 84	1970	B	339.94				
58635	11 DEC 84	1760	B	340.00				
58635	17 OCT 85	0420	B	340.03	6	339.97	.085	FLASK ANALYSIS STD.
58682	13 SEP 79	—	A	339.27				
58682	14 SEP 79	—	A	339.35				
58682	17 DEC 79	—	A	339.31				
58682	3 FEB 81	—	A	339.46				
58682	5 MAY 81	—	A	339.38	5	339.35	.072	FLASK ANALYSIS STD.
58682	17 JUN 82	—	B	320.84				
58682	18 JUN 82	2080	B	320.79				
58682	18 JUN 82	—	B	320.85				
58682	8 JUL 82	—	B	321.10				
58682	19 JUL 82	2010	B	321.15				
58682	28 JUL 82	2000	B	321.14				
58682	26 JUL 84	1310	B	323.39				
58682	23 AUG 84	1330	B	323.47				
58682	17 DEC 84	1290	B	323.60				
58682	20 DEC 84	1300	B	323.63	10	322.00	1.321	MLO STATION STD.
58698	8 SEP 81	—	A	330.26	1	330.26	0.000	SPO WORKING TANK
58698	14 JUL 83	2010	B	335.08				
58698	28 FEB 85	0410	B	335.17	2	335.13	.064	MLO WORKING TANK
58698	21 MAY 85	1950	C	338.92	1	338.92	0.000	SNO WORKING TANK
58700	11 JUN 82	2000	A	347.78				
58700	30 JUN 82	2100	A	347.81				
58700	13 JUL 82	2010	A	347.80				
58700	3 MAY 84	1150	A	347.83				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
58700	6 SEP 84	1130	A	347.83				
58700	7 NOV 84	1120	A	347.87				
58700	5 MAR 85	1090	A	347.81	7	347.82	.029	SPO STATION STD.
58701	27 JUL 83	1930	A	334.26	1	334.26	0.000	SPO WORKING TANK
58703	14 APR 83	2180	A	350.36				
58703	20 MAY 83	2110	A	350.35				
58703	1 JUL 83	2100	A	350.46				
58703	7 SEP 83	2140	A	350.54				
58703	24 FEB 84	1690	A	350.55				
58703	13 NOV 84	0980	A	350.59				
58703	2 JAN 85	0720	A	350.67				
58703	27 MAR 85	0480	A	350.76				
58703	9 MAY 85	0480	A	350.76	9	350.56	.153	FLASK ANALYSIS STD.
58706	23 JUN 82	—	A	337.03	1	337.03	0.000	BRW WORKING TANK
58706	25 JAN 83	2080	B	346.32				
58706	26 NOV 85	0110	B	347.58	2	346.95	.891	SMO WORKING TANK
58710	18 APR 84	1990	A	336.84				
58710	22 NOV 85	0200	A	337.76	2	337.30	.651	SMO WORKING TANK
58711	19 APR 84	1990	A	346.73				
58711	21 NOV 85	0350	A	347.54	2	347.13	.573	SMO WORKING TANK
58732	20 APR 84	1980	A	346.94				
58732	27 NOV 85	0210	A	347.83	2	347.39	.629	SMO WORKING TANK
58733	5 FEB 81	—	A	346.05				
58733	10 JUN 81	—	A	346.22	2	346.13	.120	TEST GAS
58733	7 JAN 82	—	B	339.87				
58733	3 JAN 83	1800	B	340.12				
58733	4 JAN 83	1790	B	340.19				
58733	10 AUG 83	0790	B	340.33				
58733	6 OCT 83	0300	B	340.41	5	340.18	.209	FLASK ANALYSIS STD.
58733	17 JAN 84	2020	C	317.69				
58733	21 FEB 84	2020	C	317.81				
58733	6 MAR 84	2020	C	317.83				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
58733	25 APR 84	2010	C	317.67	5	317.74	.072	TERTIARY STD. BACKUP
58733	3 SEP 85	1960	C	317.72				
58738	19 APR 84	1960	A	335.85	2	336.59	1.047	SMO WORKING TANK
58738	21 NOV 85	0380	A	337.33				
58739	8 APR 82	—	A	336.00	7	336.07	.063	MLO SURVEILLANCE TANK
58739	27 APR 82	—	A	336.00				
58739	4 JUN 82	—	A	336.02				
58739	8 JUN 82	—	A	336.09				
58739	24 JUL 84	1610	A	336.12				
58739	25 JUL 84	1580	A	336.12				
58739	13 SEP 84	1600	A	336.15				
58743	16 JUN 82	1900	A	335.90	6	336.24	.305	SPO STATION STD.
58743	30 JUN 82	2000	A	335.93				
58743	13 JUL 82	2000	A	336.06	1	313.15	0.000	ZERO GAS TANK
58743	10 DEC 84	1400	A	336.48				
58743	28 DEC 84	1410	A	336.53	2	334.52	.113	TEST GAS
58743	1 MAR 85	1400	A	336.52				
58753	9 MAY 83	1710	A	313.15	1	321.72	0.000	BRW ZERO GAS TANK
58757	28 MAR 83	2180	A	334.60				
58757	17 AUG 83	1950	A	334.44	1	343.90	0.000	SPO WORKING TANK
58757	14 NOV 84	2000	B	321.72				
58758	28 JUL 83	2020	A	343.90	7	342.30	.145	FLASK ANALYSIS STD.
58760	26 JUL 83	2100	A	342.15				
58760	7 SEP 83	1980	A	342.09				
58760	13 FEB 84	1460	A	342.53				
58760	16 MAR 84	1380	A	342.33				
58760	23 APR 84	1190	A	342.28				
58760	3 AUG 84	0870	A	342.35				
58760	31 OCT 84	0480	A	342.35	1	338.93	0.000	SMO WORKING TANK
58760	22 MAY 85	2020	B	338.93				
61072	10 DEC 81	—	A	331.03	1	331.03	0.000	TEST GAS

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
61072	21 JUL 82	2100	B	340.09				
61072	13 SEP 82	1710	B	340.11				
61072	21 JUN 83	0520	B	340.28				
61072	4 OCT 83	0490	B	340.12	4	340.15	.088	TEST GAS
61075	5 FEB 81	—	A	349.68				
61075	4 MAY 81	—	A	349.75				
61075	30 OCT 81	—	A	349.71				
61075	7 FEB 83	1870	A	349.58	4	349.68	.073	TEST GAS
61080	17 SEP 79	—	A	349.82				
61080	18 SEP 79	—	A	349.70				
61080	19 SEP 79	—	A	349.84				
61080	20 SEP 79	—	A	349.91				
61080	6 FEB 81	—	A	349.83				
61080	31 AUG 81	—	A	349.95				
61080	28 JUN 82	—	A	349.91				
61080	6 JUL 82	—	A	349.99	8	349.87	.091	FLASK ANALYSIS STD.
61080	22 JUL 83	2000	B	333.35				
61080	15 MAR 84	1990	B	333.53				
61080	23 MAY 84	1970	B	333.47				
61080	27 JUL 84	2000	B	333.45	4	333.45	.075	SPO STATION STD.
61084	23 MAR 83	1580	A	345.18				
61084	6 APR 83	1500	A	345.34				
61084	15 APR 83	1540	A	345.36	3	345.29	.099	SMO STATION STD.
61092	29 MAY 85	2000	A	348.95	1	348.95	0.000	SMO WORKING TANK
61119	5 MAY 81	—	A	342.98				
61119	28 AUG 81	—	A	343.05				
61119	3 JAN 83	0500	A	343.10	3	343.04	.060	FLASK ANALYSIS STD.
61119	9 NOV 83	2000	B	339.81				
61119	17 JAN 84	2000	B	339.84				
61119	6 MAR 84	2000	B	339.82				
61119	9 APR 84	1890	B	339.46				
61119	10 APR 84	1890	B	339.58				
61119	23 APR 84	1990	B	339.77				
61119	4 DEC 84	1530	B	339.65				
61119	4 SEP 85	0500	B	339.74				
61119	19 SEP 85	0500	B	339.68	9	339.71	.126	TERTIARY STD.

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
61146	17 SEP 79	—	A	361.65	10	362.09	.173	FLASK ANALYSIS STD.
61146	18 SEP 79	—	A	362.24				
61146	19 SEP 79	—	A	362.07				
61146	20 SEP 79	—	A	362.09				
61146	31 AUG 81	—	A	362.26				
61146	22 JUN 82	—	A	362.07				
61146	28 JUN 82	—	A	362.04				
61146	4 JAN 83	2100	A	362.17				
61146	5 JAN 83	2100	A	362.15				
61146	22 AUG 83	1980	A	362.20				
61146	28 AUG 84	1970	B	346.00	3	345.97	.052	SPO STATION STD.
61146	14 SEP 84	1960	B	345.91				
61146	25 SEP 84	—	B	346.00				
61192	24 JAN 83	2090	A	345.70	2	345.85	.205	MLO WORKING TANK
61192	15 NOV 83	0470	A	345.99				
61192	20 APR 84	1950	B	337.10	1	337.10	0.000	SPO WORKING TANK
69023	13 NOV 84	0210	A	352.31	1	352.31	0.000	FOR UNIV. OF UTAH
74233	6 MAY 83	1600	A	331.04	1	331.04	0.000	TEST GAS
74233	24 APR 85	1920	B	323.97	1	323.97	0.000	ZERO GAS
74240	23 MAY 85	1900	A	349.30	1	349.30	0.000	SPO WORKING TANK
74311	3 SEP 81	—	A	329.83	4	329.94	.138	FLASK ANALYSIS STD.
74311	20 MAY 82	—	A	329.82				
74311	22 NOV 82	0490	A	330.01				
74311	2 DEC 82	0480	A	330.10				
74311	1 FEB 83	1980	B	335.05	2	335.26	.290	MLO WORKING TANK
74311	11 JUN 84	—	B	335.46				
74311	30 AUG 84	1910	C	337.16	1	337.16	0.000	SPO WORKING TANK
74434	23 JUN 82	—	A	336.38	2	336.54	.226	BRW WORKING TANK
74434	2 FEB 84	0400	A	336.70				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
74434	27 APR 84	1890	B	340.41				
74434	30 APR 84	1890	B	340.48				
74434	30 MAY 84	1780	B	340.51				
74434	1 JUN 84	—	B	340.47				
74434	2 JUL 84	—	B	340.47				
74434	3 JUL 84	1590	B	340.55				
74434	6 JUL 84	1600	B	340.70	7	340.51	.093	TEST GAS
74449	25 MAR 82	—	A	329.64				
74449	8 APR 82	—	A	329.26	2	329.45	.269	TEST GAS
74449	23 JUN 82	—	B	334.11				
74449	30 JAN 84	0450	B	336.17	2	335.14	1.457	BRW WORKING TANK
74449	27 APR 84	1790	C	348.15				
74449	30 APR 84	1790	C	348.16				
74449	30 MAY 84	1740	C	348.06				
74449	1 JUN 84	—	C	348.06				
74449	2 JUL 84	—	C	348.02				
74449	3 JUL 84	1720	C	348.00	6	348.08	.066	TEST GAS
74484	15 JUN 84	2010	A	324.11	1	324.11	0.000	SMO ZERO GAS TANK
74502	4 FEB 81	—	A	327.49	1	327.49	0.000	TEST GAS
74502	21 FEB 81	—	B	349.19	1	349.19	0.000	BRW WORKING TANK
74502	3 JAN 83	1480	C	350.41				
74502	3 JAN 83	1500	C	350.49				
74502	4 JAN 83	1500	C	350.30				
74502	5 JAN 83	1470	C	350.39				
74502	1 JUL 83	0780	C	350.52				
74502	6 OCT 83	0480	C	350.79	6	350.48	.169	FLASK ANALYSIS STD.
74502	7 NOV 83	1980	D	350.32	1	350.32	0.000	BRW WORKING TANK
74502	28 JAN 85	2020	E	349.91				
74502	11 FEB 85	2000	E	349.87				
74502	27 FEB 85	2020	E	349.89				
74502	18 OCT 85	1170	E	349.94	4	349.90	.030	FLASK ANALYSIS STD.
74506	9 SEP 81	—	A	330.39				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
74506	4 MAY 84	0500	A	330.83	2	330.61	.311	SPO WORKING TANK
74506	4 SEP 84	1910	B	357.91				
74506	1 MAY 85	0390	B	357.99	2	357.95	.057	BRW WORKING TANK
74526	11 JUN 82	2100	A	346.72				
74526	1 JUL 82	2080	A	346.68				
74526	20 JUL 82	2070	A	346.75				
74526	19 JUL 84	1410	A	346.85				
74526	22 AUG 84	1390	A	346.90				
74526	14 DEC 84	1330	A	346.89				
74526	23 OCT 85	1380	A	346.82	7	346.80	.086	MLO STATION STD.
74534	9 SEP 81	—	A	342.38	1	342.38	0.000	SPO WORKING TANK
74534	14 JUL 83	2100	B	343.76	1	343.76	0.000	SPO WORKING TANK
76977	20 MAR 84	2010	A	376.65	1	376.65	0.000	FOR UNIV. OF COLORADO
95954	25 APR 84	1910	A	341.84				
95954	30 NOV 84	0410	A	342.02	2	341.93	.127	BRW WORKING TANK
95954	3 JUN 85	2000	B	354.60	1	354.60	0.000	TEST GAS
95973	25 MAR 82	—	A	346.77	1	346.77	0.000	MLO WORKING TANK
95973	1 FEB 83	2090	B	334.51				
95973	23 FEB 84	0370	B	334.76	2	334.64	.177	SPO WORKING TANK
95973	28 AUG 84	1970	C	356.16				
95973	14 SEP 84	1960	C	356.11				
95973	25 SEP 84	—	C	356.12	3	356.13	.026	SPO STATION STD.
95981	23 APR 84	1990	A	330.18				
95981	25 MAY 84	1950	A	330.15				
95981	26 JUN 84	1920	A	330.22				
95981	4 DEC 84	1680	A	330.13				
95981	3 SEP 85	1240	A	330.30	5	330.20	.067	TERTIARY STD.
95987	4 AUG 81	—	A	324.61				

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
95987	21 AUG 81	—	A	324.51				
95987	1 SEP 81	—	A	324.59				
95987	30 DEC 82	1850	A	324.65				
95987	11 JAN 83	1800	A	324.93				
95987	12 JAN 83	1810	A	324.81				
95987	13 JAN 83	1790	A	324.80	7	324.70	.149	TRAVELLING STATION STD.
95987	25 APR 84	2010	B	340.98				
95987	6 SEP 84	0440	B	341.07				
95987	7 FEB 85	1920	C	346.24	2	341.03	.064	BRW WORKING TANK
96002	14 SEP 82	2100	A	317.51	1	346.24	0.000	BRW WORKING TANK
96002	28 JAN 85	1990	B	338.68	1	317.51	0.000	ZERO GAS TANK
96002	11 FEB 85	1920	B	338.66				
96002	21 FEB 85	1930	B	338.67	3	338.67	.010	BRW STATION STD.
96079	26 APR 84	1910	A	331.05				
96079	18 MAY 84	1970	A	331.08				
96079	26 JUN 84	1890	A	331.09				
96079	11 DEC 84	1550	A	331.22				
96079	17 OCT 85	1320	A	331.31	5	331.15	.111	FLASK ANALYSIS STD.
96081	5 AUG 81	—	A	344.20				
96081	20 AUG 81	—	A	344.21				
96081	1 SEP 81	—	A	344.26				
96081	30 DEC 82	1700	A	344.29				
96081	11 JAN 83	1690	A	344.67				
96081	12 JAN 83	1690	A	344.55				
96081	13 JAN 83	1690	A	344.48	7	344.38	.186	TRAVELLING STATION STD.
96081	23 OCT 84	1870	B	354.74				
96081	22 MAR 85	1700	B	354.83	2	354.79	.064	TEST GAS
96101	22 SEP 83	1920	A	337.70				
96101	25 NOV 85	0100	A	339.27	2	338.49	1.110	SMO WORKING TANK
96105	26 MAR 82	—	A	336.00	1	336.00	0.000	MLO WORKING TANK
96105	25 JAN 83	2000	B	346.37				
96105	1 MAR 84	0380	B	346.55	2	346.46	.127	SMO WORKING TANK

BOULDER CALIBRATIONS

CALIBRATION SUMMARY FOR CO₂-IN-AIR REFERENCE GASES
25 APR 1986

SERIAL #	DATE	PRESS	CODE	CONC.	NUMBER	AVERAGE	SDEV	COMMENTS
96105	5 SEP 84	1960	C	365.35				
96105	19 SEP 84	1970	C	365.36				
96105	12 OCT 84	1920	C	365.36	3	365.36	.006	BRW STATION STD.
96111	5 AUG 81	—	A	354.52				
96111	20 AUG 81	—	A	354.56				
96111	1 SEP 81	—	A	354.62				
96111	30 DEC 82	1880	A	354.53				
96111	11 JAN 83	1880	A	354.85				
96111	12 JAN 83	1880	A	354.75				
96111	13 JAN 83	1880	A	354.64	7	354.64	.122	TRAVELLING STATION STD.
96111	23 OCT 84	1820	B	344.61				
96111	22 MAR 85	1500	B	344.56	2	344.59	.035	TEST GAS
96117	4 AUG 81	—	A	334.17				
96117	21 AUG 81	—	A	334.10				
96117	1 SEP 81	—	A	334.08				
96117	30 DEC 82	1610	A	334.17				
96117	11 JAN 83	1600	A	334.61				
96117	12 JAN 83	1610	A	334.51				
96117	13 JAN 83	1600	A	334.43	7	334.30	.216	TRAVELLING STATION STD.
96117	1 FEB 85	1800	B	339.64	1	339.64	0.000	BRW WORKING TANK
96128	4 FEB 85	1820	A	339.50	1	339.50	0.000	BRW WORKING TANK
99497	9 JUL 85	2000	A	354.70	1	354.70	0.000	FOR PERU
99507	9 JUL 85	2000	A	341.00	1	341.00	0.000	FOR PERU
535799	22 AUG 85	0980	A	375.87	1	375.87	0.000	FOR UNIV. OF NEBRASKA
577674	20 AUG 85	2580	A	330.89	1	330.89	0.000	FOR UNIV. OF NEBRASKA