APPENDICIES: TABLE OF CONTENTS

D Files: DJJJYY.nnn -- 'D' or Disk files are produced when the PD command has been issued, causing the software to 'print to disk'.

These files usually contain end-of-day summaries and/or test data.

B Files: BJJJYY.nnn -- 'B', or Brewer, files contain the raw data collected by the Brewer.
B files begin with the characters "version". The beginning of a B file contains three sections: the version string, the instrument constants, and a data header. Following is a description of the format of each B file section.

Data Header
Each B file begins with a data header.

Example	**Name**
Version=2	B file version number
Dh	Header
25	Day
11	Month
98	Year
Saskatoon	location name
52.108	latitude
106.713	Longitude
3.45	temperature in volts
Pr	Pressure header
1000	Mean Pressure

Temperature, in volts (TE%) - Read from the PMT thermistor. The temperature in °C is calculated using the equation:

$$Temp(C) = -33.27 + TE\% \times 18.64$$

Instrument Constants
This section of the B file starts with the header "inst". See Appendix B for the format of ICFJJJYY.nnn.

Dispersion constants
This section of the B file starts with the header "disp". See Appendix B for the format of DCFJJJYY.nnn.

Zenith Sky Constants
This section of the B file starts with the header "zeni". See Appendix B for the format of ZSFJJJYY.nnn.

Comment Block
Comments may be generated by the user with the CO command, and may also be automatically generated by some routines.

EXAMPLE	Name
Co	Comment header
13:20:14	Time comment was logged
User: text	Comment source: comment text

HG Calibration Data

Example	Name
Hg	Type of measurement
12:10:22	Time of measurement
.9995	Correlation value
287.1829	Calculated micrometer step
287	Micrometer set to this step #
190255	Peak intensity of the HG scan
28	Temperature (deg. C)

Correlation Value: - The corelation between the stored and measured spectra.
- Calculated Micrometer Step number
- The micrometer position of the HG peak

Standard Lamp Test Data

#	Example	Name
1	Sl	type of measurement
2	A	Filter
3	0	ND filter position of filterwheel #2 (in steps)
4	737.41	time – minutes since 00:00 hrs
5	0	Lower slit mask position (1=dark)
6	6	Upper slit mask position (6=slit 5)
7	20	# of cycles
8	625382	raw counts wavelength #0
9	43	dark count
10	644575	raw counts wavelength #1
11	710539	raw counts wavelength #2
12	839228	raw counts wavelength #3
13	914419	raw counts wavelength #4
14	981043	raw counts wavelength #5
15	Rat	ratios header
16	1543	single ratio #1 MS(4)
17	1116	single ratio #2 MS(5)
18	385	single ratio #3 MS(6)
19	300	single ratio #4 MS(7)

These lines are repeated for a total of 7 sets of data per SL test. This data is then averaged in the following summary.

#	Example	Name
1	Summary	Summary header
2	12:19:09	Time
3	mar	Month
4	08/	Day
5	98	Year
6	104.612	mean zenith angle during measurement
7	3.777	mean airmass
8	6	temperature (deg. C)
9	sl	type of measurement
10	0	ND filter position (in steps)
11	1523	mean single ratio #1 R1 MS(4)
12	662	mean single ratio #2 R2 MS(5)
13	-126	mean single ratio #3 R3 MS(6)
14	-783	mean single ratio #4 R4 MS(7)
15	4028	mean double ratio #1 R5 MS(8)
16	2056	mean double ratio #2 R6 MS(9)
17	824997.5	mean of counts from wavelength #1
18	971515.6	mean of counts from wavelength #5
19	2	standard deviation of single ratio #1
20	3	standard deviation of single ratio #2
21	4	standard deviation of single ratio #3
22	4	standard deviation of single ratio #4
23	13	standard deviation of double ratio #1
24	8	standard deviation of double ratio #2
25	387	standard deviation of counts wavelength #1
26	632	standard deviation of counts wavelength #5

Direct Sun Data

#	Example	Name
1	ds	type of measurement
2	a	Filter
3	64	ND filter position of #2 Filterwheel (in steps)
4	978.87	time - minutes since 00:00 hrs
5	0	lower slit mask position (1=dark)
6	6	upper slit mask position (6=slit 5)
7	20	# of cycles
8	625382	raw counts wavelength #0
9	11	dark count
10	13879	raw counts wavelength #1
11	345676	raw counts wavelength #2
12	437926	raw counts wavelength #3
13	728264	raw counts wavelength #4
14	805262	raw counts wavelength #5
15	rat	ratio header
16	15671	single ratio #1 MS(4)
17	8345	single ratio #2 MS(5)
18	2820	single ratio #3 MS(6)
19	1	single ratio #4 MS(7)

These lines are repeated for 5 DS measurements which are then averaged.

#	Example	Name
1	Summary	Summary header
2	16:20:02	Time
3	mar	Month
4	08/	Day
5	92	Year
6	68.024	zenith angle
7	2.617	Airmass
8	-5	Temperature (deg. C)
9	ds	type of measurement
10	1	ND filter pos'n
11	15578	single ratio #1 MS(4)
12	8312	single ratio #2 MS(5)
13	2801	single ratio #3 MS(6)
14	-5	single ratio #4 MS(7)
15	15594	double ratio #1 MS(8)
16	6920	double ratio #2 MS(9)
17	.3	SO_2value MS(10)
18	404.4	O_3 value MS(11)
19	71	st'd dev. Single ratio #1
20	28	st'd dev. Single ratio #2
21	16	st'd dev. Single ratio #3
22	5	st'd dev. Single ratio #4
23	56	st'd dev. Double ratio #1
24	11	st'd dev. Double ratio #2
25	.4	SO_2 st'd dev.
26	.6	O_3 st'd dev.

Zenith Sky Data

#	Example	Name
1	zs	type of measurement
2	a	Filter
3	0	ND filter pos'n in filter wheel motor steps
4	974.43	time – minutes since 00:00 hrs
5	0	lower slit mask position
6	6	Upper slit mask position
7	20	# of cycles
8	625382	raw counts wavelength #0
9	4	dark count
10	10125	raw counts wavelength #1
11	48805	raw counts wavelength #2
12	164527	raw counts wavelength #3
13	306533	raw counts wavelength #4
14	311495	raw counts wavelength #5
15	Rat	ratio header
16	14857	Single ratio #1 MS(4)
17	8021	single ratio #2 MS(5)
18	2727	single ratio #3 MS(6)
19	79	single ratio #4 MS(7)

These lines are repeated for a total of 7 measurements, which are averaged.

#	Example	Name
1	Summary	Summary Header
2	16:16:09	Time
3	Mar	Month
4	08/	Day
5	92	Year
6	68.477	zenith angle
7	2.667	air mass
8	-5	Temperature (deg. C)
9	zs	type of measurement
10	0	ND filter position
11	14757	single ratio #1 MS(4)
12	8003	single ratio #2 MS(5)
13	2704	single ratio #3 MS(6)
14	72	single ratio #4 MS(7)
15	14526	double ratio #1 MS(8)
16	6528	double ratio #2 MS(9)
17	-48.6	SO_2 value MS(10)
18	404.8	O_3 value MS(11)
19	57	st'd dev. Single ratio #1
20	29	st'd dev. Single ratio #2
21	13	st'd dev. Single ratio #3
22	5	st'd dev. Single ratio #4
23	51	st'd dev. Double ratio #1
24	21	st'd dev. double ratio #2
25	3.2	SO_2 st'd dev.
26	2.1	O_3 st'd dev.

Umkehr Data

Umkehr data taken alternately at 5 'short' wavelengths and 5 'long' wavelengths. The short/long wavelength measurement sequence is repeated for as long as the UM command is engaged.

The following data is from a measurement at short wavelengths.

#	Example	Name
1	Um	type of measurement
2	25	Day
3	11	Month
4	98	Year
5	Saskatoon	location name
6	52.1	Latitude
7	106.7	Longitude
8	3.49	last temperature (volts)
9	pr	Pressure header
10	1000	Mean pressure (milli bars)
11	0	ND filter position
12	1157.87	time - minutes since 00:00 hrs.
13	1	lower slit mask position
14	6	upper slit mask
15	40	# of slitmask cycles
16	625382	raw counts wavelength #0
17	120	dark count
18	97706	raw counts wavelength #1
19	294523	raw counts wavelength #2

20	759956	raw counts wavelength #3
21	1087648	raw counts wavelength #4
22	962462	raw counts wavelength #5
23	rat	Ratio
24	105525	Single ratio #1 MS(4)
25	5722	Single ratio #2 MS(5)
26	1572	Single ratio #3 MS(6)
27	-574	Single ratio #4 MS(7)

S Files: SJJJYY.nnn – 'S', or Summary files contain summary information from each test and measurement contained within the B file for the same day

The data contained in the S file is essentially the same as the "summary" line of the B file.

SJJJYY.nnn files start with a "tc" and the 5 temperature coefficients which were in the instruments constants file when the SUM command was issued. The SUM command is normally performed as the first command in the ED end of day sequence. Each item in a S-file is separated with a carriage return and line feed, the end of the summary file is marked with "ef".

UV Files UVJJJYY.nnn - 'UV' files contain data data from UV scans, Including UV, UX, and UA.

#	Example	Name
1	UX integration time is 0.2294 seconds per cycle	(header for each scan).
2	dt 4.3E-08	Dead time
3	cy 1	# of cycles
4	Dh	Data header
5	26	Day
6	04	Month
7	92	Year
8	Saskatoon	Location
9	52.108	Latitude
10	106.713	Longitude
11	2.56	Temperature (volts)
12	Pr	Pressure header
12	960 dark	Pressure (mb) and dark count header
14	1	Dark count
15	825.9	Time (GMT) in minutes for 1st λ
16	2865	Wavelength for 1st λ
17	1263	Micrometer step # for 1st λ
18	11	raw counts for 1st λ
19		Lines 15 to 18 are repeated for each λ

In UX scans, lines 15 to 18 are repeated for wavelengths 286.5nm to 363.0nm in 0.5nm increments. In UV measurements the scan is from 290.0nm to 325.0nm then back to 290.0nm in 0.5nm increments and the number of cycles is 4 and counts for 4 cycles are recorded in the UV file.

Umkehr Files: UJJJYY.nnn -- As part of the End-of-Day process the Umkehr data in the B file is transferred into a U file which contains both morning and evening data if it has been collected.

XLJJJYY.nnn - Extended Lamp Scan

#	Example	Name
1	Integration time is 0.2294 seconds per cycle	Integration time
2	dt 3.4E-08	dead time
3	cy 1	number of slit mask cycles
4	le 154	Increments in the 290-325 nm region
5	ln 608	lamp serial number
6	di 5	distance between filament and teflon diffuser
7	dh	data header
8	15	Day
9	01	Month
10	99	Year
11	Saskatoon	Location
12	52.108	Latitude
13	106.713	Longitude
14	3.43	PMT temperature (Volts)
15	pr	Pressure header
16	960 Dark	Pressure (milli bars) and Dark Count Header
17	1	dark count
18	960.8	decimal minutes since 00:00 hours
19	2865	Wavelength (Angstrom)
20	256	micrometer step number
21	121.1	raw counts
22		lines 18-21 repeat for wavelengths from 2865A to 3630A in 5A increments
...		
633	end	end of measurement

A/D Values: -- A/D values are not stored in files (except HV and +5v and SL current), but they are very important in assessing the health of the Brewer, so they are included here for reference.

A/D Values for nov 15/98 at 17:03:05 for instrument number 159

Channel#	Name	Value (Lamps off)	Value (Lamps on)
0	PMT temp (deg C)	28.50	28.50
1	Fan temp (deg C)	27.83	27.83
2	Base temp (deg C)	28.21	28.21
3	H.T. voltage (V)	1487.05	1487.05
4	+12V power supply (V)	11.91	11.91
5	+ 5V power supply (V)	4.97	4.97
6	-12V power supply (V)	-11.99	-11.99
7	+24V power supply (V)	24.48	24.48
8	Rate meter (V)	0.00	0.00
9	Below Spectro temp (C)	27.07	27.07
10	Window area temp (C)	28.50	28.50
11	External temp (deg C)	27.55	27.55
12	+ 5V ss (V)	5.00	5.00
13	- 5V ss (V)	-4.91	-4.91
14	Std lamp current (A)	0.00	1.57
15	Std lamp voltage (V)	0.00	10.00
16	Mer lamp current (A)	0.00	0.36
17	Mer lamp voltage (V)	0.00	11.46
18	External 1 (V)	0.07	1.36
19	External 2 (V)	0.05	0.70
20	External 3 (V)	1.19	1.19
21	Humidity (g/m3)	3.74	3.74
22	External 4 (V)	0.02	0.12
23	External 5 (V)	0.03	0.13

PO Values: -- The PO command generates the following.

```
                          MKIII BREWER INSTRUMENT #159
                          ----------------------------
                           01-05-1998  17:02:42

*****************************************************************************
*
* Ozone Values   *    1    *    2    *    3    *    4    *    5    *    hg
*
*****************************************************************************
*
  Wavelength(nm) * 306.289   310.035   313.486   316.787   319.978   303.184
  Temp. Coeff    *  0.0000   -0.2473   -0.6914   -0.6902   -1.2794    0.0000
  Disp. Coeff #1 * 2856.960  2896.561  2933.527  2968.578  3003.310  2823.907
  Disp. Coeff #2 * 0.076746  0.076004  0.075101  0.074407  0.073260  0.077476
  Disp. Coeff #3 *-0.725E-6 -0.739E-6 -0.734E-6 -0.751E-6 -0.707E-6 -0.726E-6
*****************************************************************************
*
```

ETC Values : O_3 = 1690 ; SO_2 = 215

O_3 Absn Coeffs : O_3 = 0.3446 ; SO_2 = 1.1533
SO_2 Absn Coeffs : O_3 = 0 ; SO_2 = 2.3500

Micrometer steps/deg	=	0.00	WL cal step number	=	286
Micrometer Zero	=	2469	Umkehr offset	=	1688
Iris Open Steps	=	250	Zenith steps/rev	=	2972
Micrometer 1 Offset O_3	=	0	Micrometer 2 Offset	=	0
Grating Slope	=	1	Grating Intercept	=	10
Filterwheel 3 Offset O_3	=	242			
Dead Time(ns)	=	40	Buffer Delay(s)	=	0.6
Zenith UVB Dome Position	=	2223			

Note: Faster Processors May Require a Longer Buffer Delay
(Typically 0.2 to 0.8 Seconds)

Average files: ???AVG.nnn and OZOAVGYY.nnn

The Brewer is a ‘statistical’ instrument, and instantaneous deviations from the norm are not uncommon. The purpose of average files is to provide a daily value for a specific measurement or test result. It is normal to plot the data in average files vs time (days) to observe trends in data and test results.

APOAVG.nnn - Analog Printout Log
The values should be monitored for power supply stability.

1	2	3	4
08591	1566.80	5.17	1.61
08691	1555.86	5.17	1.61

1. Julian Day (dddyy)
2. H.T. voltage
3. +5V
4. standard lamp current

DTOAVG.nnn - Dead Time Log

1	2	3
04991	41.66	43.375
05991	41.69	43.276

1. Julian Day (dddyy)
2. dead time for high intensities
3. dead time for low intensities

FMOAVG.nnn - FM Average

1	2	3	4	5	6	7	8	9
05791	425.9	+4.8	3152.5	-0.2	1.3	189001.4	4	33
05891	403.1	+5.3	2909.1	2.6	4.8	1788953	3	34

1. Julian Day (dddyy)
2. daily mean ozone
3. standard deviation of daily mean ozone
4. ETC
5. daily mean SO_2
6. standard deviation of daily mean SO_2.
7. ETC,
8. number of good observations
9. number of total observations.

H2OAVG.nnn Humidity Log File

The file is updated during the AP command at the End-of-Day.

1	2	3	4	5	6
29098 29198	23.939 25.648	21.186 25.458	24.793 25.078	3.60 2.68	19.4 11.3

1. Julian day (jjjyy)
2. Temperature at the PMT (°C)
3. ‘Fan’ Temperature in °C - used in the absolute humidity calculation.
4. Temp of base plate (°C)
5. Moisture measured in grams of water per cubic meter of air.
6. Relative Humidity (%)

HGOAVG.nnn

1	2	3	4
08391	2592	33	18
08491	2330	25	20
08591	2483	34	22

1. Julian Day (jjjyy)
2 maximum lamp intensity of the days scans
3. high Brewer temperature of the days scans
4. number of scans.

MIOAVG.nnn - Micrometer Log

A new entry is generated each time the FR routine is run.

1	2	3	4	5	6	7
33898 o_3	28	286	-2	0	0	0
33998 o_3	27	286	0	0	0	0
34098 o_3	26	286	0	0	2	0

1. Julian day followed by O_3 to indicate this is an ozone operation
2. Temperature at time of test
3. wavelength offset step number
4. Micrometer #1 steps from operating position to zero sensor.
5. Micrometer #1 offset constant from the ICF file.
6. Micrometer #2 steps from operating position to zero sensor.
7. Micrometer #2 offset constant from the ICF file.

OPAVG.nnn -- Operating Constants Log

Used to keep a record of changes to the operating constants used in the Brewer. Updated during the ED or when the CF or IC routine is used.

The first column of the file is the routine that generated the entry in the operating constants log (IC, CF or ED). The rest of the entries are identical to the OP_ST.nnn file. See Appendix B.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ED	159	c:\bdata\	icf31098	zsf13998	dcf11798	07	12	98	Saskatoon	52	107	1000	3.220544
IC	159	c:\bdata\	icf31098	zsf13998	dcf11798	07	12	98	Saskatoon	52	107	1000	3.286822

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
10	0	14696	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	Skc	o_3	epa96	03:31:16
10	0	14696	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1		o_3		19:43:56

OZOAVGYY.nnn - Ozone Average File

Used to monitor the daily average ozone measurements collected by the Brewer

.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
08398	452.1	+2.4	-0.6	0.6	16/29	185	20	445.2	+5.2	-12.3	26.4	19/22	199	19
08498	472.8	+2.1	-.08	1.2	22/35	185	19	465.5	+5.8	-7.3	25.1	16/20	190	19
08598	458.8	+9.3	-0.7	0.6	12/35	192	18	461.7	+7.2	-5.7	23.2	16/20	184	19

Direct Sun (DS) Ozone Data

1. julian day & year
2. mean daily total column DS ozone
3. DS ozone standard deviation
4. mean daily total column DS sulphur dioxide
5. DS SO_2 standard deviation
6. number of good DS observations / number of total DS observations
7. harmonic mean of airmass for the DS measurements.
8. hour that best represents the mean time for the mean DS daily ozone

Zenith Sky (ZS) Ozone Data

9. mean daily total column ZS ozone
10. ZS ozone standard deviation
11. mean daily total column ZS sulphur dioxide
12. ZS SO_2 standard deviation
13. number of good ZS observations / number of total ZS observations
14. harmonic mean of airmass for the ZS measurements.
15. hour that best represents the mean time for the mean zs daily ozone

FZOAVG.nnn

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
17897	326.3	+11	-3.1	+1.2	31/	77	192	12	44.7	+13.5	-28.6	+12.8	7/	7	508	8
17997	342.3	+3.3	-3.1	+1.0	13/	56	179	13	0.0	+0.0	+0.0	+0.0	0/	3	0	0
18097	323.6	+2.9	-2.9	+0.9	9/	55	190	14	332.6	+0.8	-25.3	+6.8	2/	5	556	12

1. Julian day
2. DS ozone
3. Standard deviation
4. DS SO_2
5. Standard deviation
6. Good Observations
7. Total Observations
8. Harmonic mean of mu
9. Representative hour

10. FZ ozone
11. Standard deviation
12. FZ SO_2
13. Standard Deviation
14 Good Observations
15. Total Observations
16. Harmonic mean of mu
17. Representative hour

RSOAVG.nnn - Run / Stop Log

Used to monitor the operation of the slitmask. The values of colums 2,4,5,6,7,8, and 9 should be 1±0.003

1	2	3	4	5	6	7	8	9
08391	1.0006	1.1667	1.0003	.9995	1.0005	.9999	.9991	.9997
08491	1.0020	.9024	.9989	.9994	1.0001	.9992	.9998	.9996

1.dddyy

2-9 run/stop ratio for slit mask positions 0 through 7.

SCOAVG.nnn - Sun Scan Average File

1	2	3	4	5	6	7	8	9
07590	22	1.971933	1	133.6	440.1	131.7	-.3	135
07991	21	1.889433	2	134.5	418.1	131.3	.1	137
08791	30	1.804133	2	136.9	404.7	133.6	-.6	135

1. dddyy
2. temperature
3. airmass
4. neutral density filter used
5. maximum step of scan
6. Maximum Ozone
7. Minimum step of scan

8, Minimum SO_2

9. HG calibration point

SLOAVG.nnn - Standard Lamp Log

Used to monitor the stability of the Brewer's ozone measureing stability..

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
06791	14	32	5	1705	815	-29	-702	3952	2023	581925	1	1	1	2	4	2	10848
06891	24	35	4	1707	815	-29	-703	3957	2026	572599	4	2	2	1	1	1	6619
06991	25	31	2	1706	815	-30	-700	3948	2021	576789	1	1	0	1	2	1	6873

1. dddyy
2. low temperature of the SL test
3. high temperature of the SL test
4. number of sl tests
5. ratio 1
6. ratio 2
7. Ratio 3
8. Ratio 4
9. Ratio 5
10. Ratio 6
11. Lamp intensity

12-18. Standard Deviations

DUVJJJYY.nnn: Gives the Daily DUV.

Time	DUV
6.1860	4.402109
8.5610	65.338420
9.8725	132.457100
12.7702	219.891700
15.7105	105.198000
16.3337	69.199570
17.1518	40.585530
17.9707	16.680470
18.7878	5.160622
19.6043	0.597062

Time is in decimal hours from 00:00:00 GMT
DUV is in $mW/m^2/nm$

UVOAVG.nnn

1	**2**	**3**	**4**	**5**	**6**
20898 20998	2073.4 3559.2	14 14	21 27	20 20	uvr13398.159 uvr13398.159

1. Julian day and year
2. daily weighted Diffey UV, Joules
3. length of day; hours between the first and last scan in the UV data file
4. the number of scans in the UV file
5. representative hour
6. UVRJJJYY file in use

UVBJJJYY.nnn: produced from UV scans by AB_UVDAT.EXE
First row - decimal hours from 00:00 (GMT)
First column - wavelength (angstroms)
Other columns : one per scan taken - irradiance ($W/m^2/nm$)
Second last row - scan weighted (Erythema) UV (mW/m^2)
Last row - scan weighted (Diffey) UV (mW/m^2)

DUVJJJYY.nnn: produced from UV scans by AB_UVDAT.EXE)
First column - decimal hours from 00:00 (GMT)
Row 1 column 2 - daily weighted (Erythema) UV (J/m^2)
Row 1 column 3 - daily weighted (Diffey) UV (J/m^2)
Remainder of column 2 - scan weighted (Erythema) UV (mW/m^2)
Remainder of column 3 - scan weighted (Diffey) UV (mW/m^2)

LAMP_LLL.nnn - Lamp File

The Lamp file is created at the factory by an initial Quick Scan. Subsequent QS scans append data to LAMP_LLL.nnn.

Column	Description
1	Julian date
2	Distance from lamp filament to teflon diffuser
3	pmt temperature
4	Dark count
5-15	Intensities at 11 wavelengths
16	DUV calculation based on the lamp intensities

LAMPLLL.IRX - Lamp Irradiance File

Lamp Irradiance files, generated at the factory, tabulate the UV irradiance of the UV test lamps.

First row - lamp identification number
Second row - distance between lamp filament and teflon diffuser
Now the file splits into 2 columns:

First column - wavelength in Angstroms from 2865A to 3630A in 0.6nm Increments.
Second column - irradiance in milli watts per square metre.

PUX, PUF, PUV, PUA: Processed UV files

First row - decimal hours from 00:00 (GMT) Header for each scan includes date, starting time (hour), ending time (hour), zenith angle, latitude, longitude, location name, instrument # and measurement type, Row 2 column 1 - GMT time in minutes, column 2 - Wavelength (Angstroms), column 3 - irradiance ($W/m^2/nm$ or $mW/m^2/nm$, depending on selection during processing).

PXL: Processed lamp files

First row - Lamp Number
Row 2 - distance in centimeters
Column 1 Row 3 - Wavelength (Angstroms)
Row 4 - irradiance ($mW/m^2/nm$)

Appendix B Configuration Files

ICFJJJYY.nnn - Instrument Constants

#	Example	Name
1	Inst	Instrument constants header
2	0	Ozone temperature coefficient for slit 1
3	-.2473	Ozone temperature coefficient for slit 2
4	-.6914	Ozone temperature coefficient for slit 3
5	-.6902	Ozone temperature coefficient for slit 4
6	-.2794	Ozone temperature coefficient for slit 5
7	0	Micrometer steps per degree
8	.3446	Ozone on ozone ratio
9	2.35	SO_2 on SO_2 ratio
10	1.1533	Ozone on SO_2 ratio
11	1690	ETC on ozone ratio
12	215	ETC on SO_2 ratio
13	4E-08	Dead time (seconds)
14	286	Wavelength calibration step number
15	14	Slit mask motor delay
16	1688	Umkehr offset
17	0	Neutral density of filter 0
18	5000	Neutral density of filter 1
19	10000	Neutral density of filter 2
20	15000	Neutral density of filter 3
21	20000	Neutral density of filter 4
22	25000	Neutral density of filter 5
23	2972	Zenith motor steps per revolution
24	Mkiii	Brewer model type
25	1	COM port number
26	0	ozone temperature coefficient for mercury exit slit
27-32	-	Not Used
33	0	ozone micrometer #1 offset
34	2310	ozone micrometer #2 offset
35-41	-	Not Used
42	.998	grating slope
43	1.901	grating intercept
44	2469	Micrometer zero position
45	250	number of motor steps to open iris
46	0.8	Computer buffer delay (larger numbers for faster computers)
47	-	Not Used
48	256	ozone filterwheel #1 position
49	0	filterwheel #2 position
50	64	UV filterwheel #2 position
51	40	steps from zenith sensor to the hard stop
52	2223	Zenith UV position
53	1 Jan 99	Release Date

OP_ST.nnn - Operating State File

The operating state file controls many of the operating parameters of the Brewer. The left column lists the actual value written in the OP_ST.nnn file. The middle column is the BASIC variable name used in the Brewer software to contain this value, and the right column is a description of the value's meaning.

#	**Sample**	**SW Variable**	**Explanation**
1	046	NO$	Brewer ID number
2	\BDATA	DD$	Data Directory
3	ICFjjjyy	ICF$	instrument constants file
4	ZSFjjjyy	ZSF$	zenith sky coefficients file
5	DCFjjjyy	DCF$	dispersion constants file
6	UVRjjjyy	UVR$	UV response file
7	01	DA$	Current day
8	01	MO$	Current month
9	99	YE$	Current year
10	Saskatoon	LO$	Location of Brewer instrument
11	52.108	L1$	Latitude of instrument
12	106.713	L2$	Longitude of instrument
13	960	L3$	Average climatic station pressure (millibars)
14	1.8	TE$	Voltage representation of Brewer temperature
15	215	NC%	Azimuth north correction
16	0	HC%	Zenith horizon correction
17	14689	SR%	Azimuth steps per revolution
18	1	Q1%	Zenith drive motor
19	1	Q2%	Azimuth drive motor
20	1	Q3%	Iris drive motor
21	1	Q4%	Filterwheel #1 drive motor
22	1	Q5%	Filterwheel #2 drive motor
23	1	Q6%	Clock board
24	1	Q7%	A/D board
25	1	Q8%	UVB port
26	1	Q9%	Filterwheel #3 drive motor
27	1	Q10%	New or old temperature circuit. Set to 1 for a new temperature circuit and 0 for an old circuit.
28	1	Q11%	Second film polarizer
29	0	Q12%	Set to 1 to enable NOBREW operation
30	1	Q13%	Wide HG slit present. Always set this to 1.
31	1	Q14%	New Brewer electronics board
32	0	Q15%	Humidity Sensor
33	skc/menu	DI$	Schedule or menu indicator
34	O_3	MDD$	Mode
35	UMKNO2	SK$	Schedule name

DCFJJJ.nnn - Dispersion constants

The Dispersion Constants are used to calculate the ozone wavelength of the exit slits.

#	Example	Name
1	Disp	Header
2	2856.96	intercept for slit 1
3	7.674577E-02	slope for slit 1
4	-7.251786E-07	quadratic for slit 1
5	2896.561	intercept for slit 2
6	7.600413E-02	slope for slit 2
7	-7.387072E-07	quadratic for slit 2
8	2933.527	intercept for slit 3
9	.0751006	slope for slit 3
10	-7.337653E-07	quadratic for slit 3
11	2968.578	intercept for slit 4
12	7.440717E-02	slope for slit 4
13	-7.512483E-07	quadratic for slit 4
14	3003.31	intercept for slit 5
15	7.325987E-02	slope for slit 5
16	-7.065609E-07	quadratic for slit 5
17	2823.907	intercept for mercury exit slit
18	.0774763	slope for mercury exit slit
19	-7.259538E-07	quadratic for mercury exit slit
20-36	-	Not used

UMKSETUP.nnn - Umkehr setup file

#	Example
1	SXUNI4M.DAT
2	STDTABS.DAT
3	O3TABLE.DAT
4	CQMS.DAT
5	4.1099 2.3155 1.5600 0.8637
6	0.6760 0.3187 0.1490 0.0776 .. ozone coefficients for #039 STN TMO
7	3 6 11 12 1 1.0 812.0
8	999 1 34.838 0
9	0 ... debug file

1 - 4. Tables used in the calculation of Umkehrs.
5 - 6. Ozone coefficients
7. This line has 7 parameters:
    1 Minimum starting zenith angle
    2 Maximum starting zenith angle
    3 Minimum ending zenith angle
    4 Maximum ending zenith angle
    5 Output control flag
    6 Ozone scaling factor (used with Dobson data)
    7 Surface pressure of the station (in mmHg)
8. This line has 4 parameters:
    1 Station identifying number (3 digits)
    2 Parameter no longer used (set to 1)
    3 Latitude of station - used for first guess
    4 Output control flag (set to 0)
9. Flag for debugging purposes only.

UVRJJJYY.nnn

First column: wavelength in Angstrom.

Second column is responsivity in counts/mW/m^2/nm.

ZSFJJJYY.nnn (ZSFVAL)- Zenith Sky Constants

Zenith Sky constants are used in the ZS ozone calculations, and are Location/Brewer dependent. They are derived by making a comparison of near simultaneous DS and ZS measurements over a wide range of mu and ozone values (usually many months).

The values supplied in ZSFVAL.nnn are for a Brewer #035 operating in Toronto, Canada, and will produce results which are accurate to within 5% or so. These values can be used until a new set can be derived for the new site.

Example	Name
Zeni	Header
-.0064	Coefficient #1
-.01968	Coefficient #2
.01654	Coefficient #3
.194706	Coefficient #4
.280512	Coefficient #5
-.061317	Coefficient #6
-.490686	Coefficient #7
.456243	Coefficient #8
-.045191	Coefficient #9

APPENDIX C UV Processing

LAMP DATA ANALYSIS

Brewer Response Files

RESIII.EXE is used to determine the responsivity of a Brewer with the aid of data from a calibrated external tungsten-halogen lamp. Requirements for program execution are a LAMP_LLL.IRX file for each lamp used, and the XL or UL file, XLJJJYY.nnn. The output of this program is a new response file. It is recommended that the new response files be named with the format UVRJJJYY.nnn. This file should be compared to previous response files to determine if there has been a possible change in the performance of either Brewer electronics or optics. The response file is similar to the SL test results for keeping track of instrument stability. The response file is also accessed by the UV and UVSUM routines and AB_UVDAT to calculate a damaging ultra-violet (DUV) amount for each scan and for the day. The most representative response file should be kept in the Brewer data directory C:\BDATA\NNN.

To use RESIII.EXE, it should reside in a directory containing the XL scans and the Lamp irradiance files.

1. The program is launched by typing “RESIII”

2. At the prompt, the instrument number is entered.

3. All lamp files and XL scans matching that instrument are read into a list. The list shows all scans - any scans that do not have a lamp file available are marked with a (!)

4. The scans to be processed are selected by ranges and lists of numbers (ie. "2,5-7,12", results in scans 2,5,6,7, and 12 to be processed. Scans that have no lamp files are skipped.

5. If a new response file is desired, the filename of the new file is entered in the form form UVRJJJYY.NNN

6. The new response file is placed in the C:\BDATA\NNN directory, and replaces the old RES file in OP_ST.NNN.

The response file calculated each time will be affected by temperature (lower response with higher temperatures), lamp positioning, and power supply stability. Changes from accepted response values of more than 5% should prompt investigation into the discrepancy. Statistics from the response calculations should give percent standard deviations of <1.5% to be considered acceptable.

Lamp Irradiance Files

RD_UX.EXE is used to process external lamp scans from the XL or UL routine to produce lamp irradiance files. The input files are in units of raw counts per second, the output files have units of $W/m^2/nm$ or $mW/m^2/nm$.

Instructions:

1. Create a test directory and copy RD_UX from the uv-lamp directory to the test directory.
2. Copy the UL or XL file(s) that you wish to process to the test directory.
3. Create a /nnn directory in your test directory (nnn is your Brewer number).
4. Copy the appropriate UV response file into the /nnn directory.
5. Run the RD_UX program and follow the directions given.
6. A list of all scans is displayed and the user is asked to select the scans to be used.
7. A single processed file will be prefixed by the letter "P" such as, PXLJJJYY.nnn. If individual files for each scan were requested, then individual files of the form PXLJJJSS.nnn will be produced - where SS is the sequence of the scan.
8. The P file (or files) represent the irradiance of the lamp used.

UV DATA ANALYSIS PROGRAMS

AB_UVDAT.EXE processes multiple UVJJJYY.nnn files in a similar fashion to the UV.RTN and the UVSUM.RTN except that integrated results are tabulated along with data from the individual wavelengths.

AB_UVDAT, UVSUM.RTN and UV.RTN have a UVA correction built into the weighting curves.
Calculated results represent both the UVB and UVA regions (290-400nm).
AB_UVDAT creates two data files, UVBJJJYY, and DUVJJJYY, for each UV file processed, and appends to a third file, UVOAVG.
Two action spectra, Erythema and Diffey, are used separately to weight the UV scans.
AB_UVDAT requires access to the appropriate instrument response file.

The integration technique used in UV.RTN, UVSUM.RTN and AB_UVDAT is one of histogram summation with the following properties.
The raw counts in the UV file are converted throughout to counts per second and corrected for instrument dead time.
The average of the counts recorded at wavelengths <=292nm represent a dark count (noise) value and is subtracted from all other wavelengths.
The corrected raw counts are then divided by the instrument response values and multiplied by the appropriate weighting value at each wavelength.
Scan integration is then the sum of the histograms, each 0.5 nm wide and as high as the corrected weighted irradiance.

For the UVSUM.RTN, daily irradiance integration is the sum of histograms that are as wide as the time between consecutive scans and as high as the average of the irradiance of two consecutive scans.

For AB_UVDAT daily irradiance integration is the sum of histograms that are as wide as the average of the difference of the time for the following and the previous scan and as high as the irradiance for that particular scan.

For the most representative daily integral values it is recommended that UV scans be taken throughout the daylight hours at regular zenith angle intervals.
Histogram summation starts at the time of the first UV scan and stops at the time of the last UV scan.
On a clear day without variable clouds or other aerosols the energy curve assumes a normal distribution

Using AB_UVDAT.EXE

Input:
1. A range of consecutive UVJJJYY.nnn files
2. the appropriate UV response file.

Output:
1. One UVOAVG.nnn file which tabelates the average values from the other output files.
2. One UVBJJJYY.nnn file for each input file.
3. One DUVJJJYY.nnn file for each input file.

1. Create a test directory.
2. Copy AB_UVDAT.EXE to the test directory.
3. Copy the UV response file into the test directory.
4. Copy the UV files to be processed into the test directory
5. Run AB_UVDAT follow the drections given.

UV and UX Data Analysis Programs

RD_UX.EXE is used to reduce the UV data produced by the UA, UC, UF, UV, and UX routines.
The input file is in units of raw counts per second and outputs may be chosen units of in $W/m^2/nm$ or in $mW/m^2/nm$.

Instructions:

1. Create a test directory and copy RD_UX from the uv_lamps directory to the test directory.
2. Copy the UL or XL file(s) that you wish to process to the test directory.
3. Create a /nnn directory in your test directory (nnn is your Brewer number).
4. Copy the appropriate UV response file into the /nnn directory.
5. Run the RD_UX program and follow the directions given.
6. A list of all scans is displayed and the user is asked to select the scans to be used.
7. The user will then be asked whether or not to correct for stray light – the stray light correction subtracts the average of the counts below 292.2 nm from each measurement.
8. A single processed file will be prefixed by the letter "P" such as, PUVJJJYY.nnn. If individual files for each scan were requested, then individual files of the form PUVJJJSS.nnn will be produced - where SS is the sequence of the scan.
9. The PUV file (or files) represent the irradiance of the UV scans.

APPENDIX D NOBREWER

It is often useful to be able to operate the Brewer software without having a Brewer connected to the Computer.
A batch file, C:\NOBREW.BAT, has been developed which sets a number of operating parameters to make the software think that Brewer communicatins are taking place.

In this mode of operation a number of operations can be done:

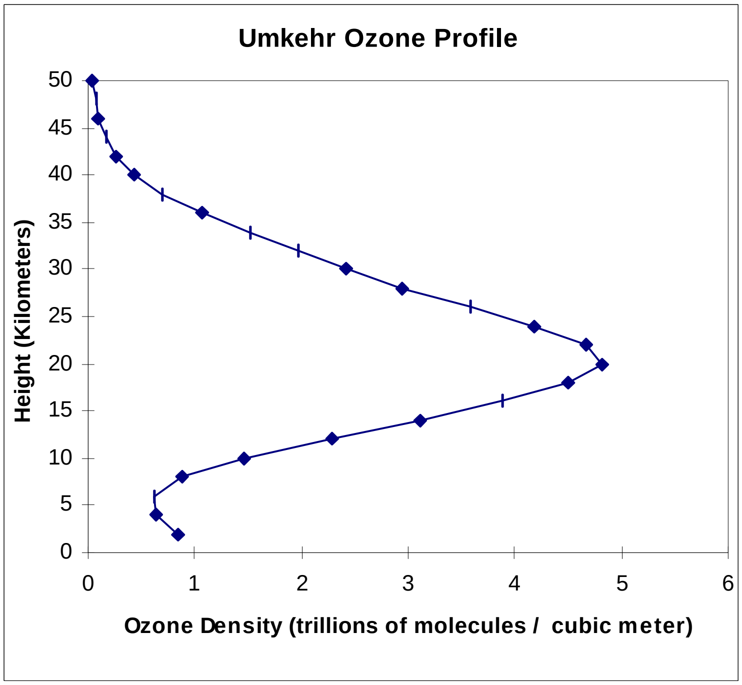
--Schedules can be written using SE and the solar angle information can be printed using SA.
--Dates and time can be changed as can Site Information and Brewer number.
--Configuration , Instrument Constant, and Operating State Files can be updated and saved.

A Brewer must not be connected to the COM: port that is defined in the Configuration file and is being accessed by NOBREW.

Quite often the Brewer sotware is installed on a second computer and NOBREW is operated away from the Brewer.

APPENDIX E UMKEHR PROCESSING

Umkehr profiles show the vertical distribution of Ozone in the Atmosphere from ground level to 50 km.



Using the UM.RTN, the Brewer Spectrophotometer takes Umkehr measurements through a series of Zenith Sky samples of multiple wavelengths between solar zenith angles of 60 and 91^{O} in the morning and in the evening.

Data is stored in the daily ‘B’ file and at the End of Day is written to a daily ‘U’ file.

Umkehr processing software, the purpose of which is to process the Brewer raw Umkehr data into graphable profiles, has been developed by Scientists at the Atmospheric Environment Service of Canada. This software is not a SCI-TEC poduct, nor does SCI-TEC claim to have expertise in the area of Umkehr processing. We will, however, endevour to provide whatever information we can to assist users in the generation of ozone profiles for their stations, and the following discussion is a first attempt.

This Appendix briefly describes the steps necessary to process Umkehr Data. For further expert assistance, especially as concerns the quality of data, and station dependent parameters, it is suggested that WMO or AES scientists be consulted.

For a more in-depth discussion of the theory and practicalities of Umkehr measurements and presentation, experts at Environment Canada or the WOUDC should be consulted.

1. Conventions: JJJYY Julian day and year
nnn Brewer number

2. All Umkehr Data and data processing programs should reside in a common directory..

3. The main programs for processing and analysis are:

PREPRO.EXE	-- a preprocessing program
TOMKEHR.EXE	-- the Umkehr analysis program
RUNPRE.BAT	-- a batch file used to launch PREPRO.EXE
RUNUMK.BAT	-- a batch file used to launch TOMKEHR.EXE

The proper execution of PREPRO.EXE and TOMKEHR.EXE requires that the following files also be present:

UJJJYY.nnn	-- Brewer Umkehr data file to be analyzed
OZOAVGYY.nnn	-- daily average ozone value file

SXUNI4M.DAT
STDTABS.DAT
O3TABLE.DAT
CQMS.DAT

PRESETUP.nnn -- a file containing station data which is created by using a text editor to modify a sample file such that it contains:
-- the ozoavg file to be used
-- the station number, station code, latitude, longitude

UMKSETUP.nnn -- a file created during the Brewer calibration containing pointers to the above .DAT files, ozone coefficients, and sun angle information.
-- must be edited to include as line 7 the following:
3,6,11,12,1,1.0,pressure, where pressure is mean station pressure in milibars

4. The batch file RUNPRE.BAT will invoke PREPRO.EXE and set the necessary parameters when the command line RUNPRE JJJYY.nnn is issued.

5. Three files are created following the successful execution of PREPRO:

UPJJJYY.nnn	-the preprocessor output listing
UDJJJYY.nnn	-output data to be used by the analysis program
UGJJJYY.nnn	-reduced data

6. The batch file RUNUMK.BAT sets up and runs TOMKEHR.EXE when the command line RUNUMK JJYY.nnn is issued.

7. Successful execution of TOMKER results in the creation of three files:

USJJJYY.nnn
UOJJJYY.nnn
UNJJJYY.nnn suitable for graphing the ozone profile.

Some useful information on the Umkehr processing software and its use may be found in the following three documents written by Dr. T.C. McElroy:

-- Umkehr Inversion Algorirhm for the Brewer Ozone Spectrophotometer
-- Readme.Doc
-- Readme.V3

Copies of these documents are available from SCI-TEC Instruments Inc.

APPENDIX F FACTORY TESTS

Setup and Calibration Tests

The tests and calibration techniques described here are essentially those performed by the factory before the Brewer Spectrophotometer is shipped. [Refer to the Final Test Record for the set of test results, graphs, and derived constants for a specific instrument.] Some of these tests (HV, SH) would only be performed by the user after repair or replacement of one or more of the instrument's optical or mechanical components. In contrast, the HG (mercury-line calibration) and SL (standard lamp) tests should be performed at least once per day. The remaining tests should be carried out at approximately monthly intervals to verify correct instrument performance. The order in which these tests are described is significant. Tests which follow later in the sequence assume that the earlier tests and calibrations have been successful. A complete instrument recalibration (a task not to be undertaken lightly) would therefore follow the ordering implied in this section.

Table F-1 summarizes the settings of the Brewer's controllable elements for each of the setup tests. The software will automatically set the elements to where they should be for a specific test.

All of the following tests assume that the spectrometer is in focus and properly aligned in accordance with the Optical Frame Alignment document.

Table: F-1 Settings for each of the Brewer Tests

Test	Wave-Length	Slitmask Motor Position	Std Lamp	Hg Lamp	Filter Wheel 1	Filter Wheel 2	Iris	Prism	Azimuth Tracker
DT	Ref	3,5,7	On	Off	1	0,1	Open	1800	N/A
HG	Estab Ref	0	Off	On	1	0	Open	1800	N/A
HV	Ref	1,2	On	Off	1	0	Open	1800	N/A
RS	Ref	0-7	On	Off	1	0	Open	1800	N/A
SC	Ref	0-6	Off	Off	1	0,1,2	Close	Point at sun	Point at sun
SH	Ref	0-2	On	Off	1	0	Open	1800	N/A
SL	Ref	1-6	On	Off	1	0	Open	1800	N/A
SR	N/A	N/A	Off	Off	N/A	N/A	N/A	N/A	0-3600

SH Shutter-Motor (Slitmask Motor) Timing Test

The SH test determines the optimum value for the timing constant used in the control of the slitmask motor.

If the instrument is being calibrated for the first time it should be ensured that the high-voltage setting for the photomultiplier is somewhere within the range -1300 to -1400 volts before attempting to run the SH test. [The high-voltage setting will be optimized later] Also, the micrometer should be set to the reference-wavelength position (Hg line at 302.2 nm).

Measurements of the Dark Count, and light intensity of the tungsten-halogen (standard) lamp are taken through the HG and Wavelength 1 slits for a range of motor-delay constants. Observations are typically made over a range of 20 different values for the delay constant.

Method:

The SH command is entered to start the slitmask-motor timing test. The program prompts for the minimum, maximum, and increment for trial values of the delay constant. Typical values are a minimum value of 10, a maximum of 100, and an increment of 2. After a five-minute lamp warm-up period, the program performs a series of intensity measurements for each trial value of the timing constant, then prints the measurements in tabular format. The following information is contained in the printout:

DELAY	CAL	DARK	WAVELENGTH 1
10	1737768	7557	92828
12	1738031	480	93450
14	1737408	39	93100
16	1738864	37	93422
18	1738388	44	93318
20	1737191	28	93579
22	1738692	36	93580
24	1742088	40	93713
26	1737650	34	93666
28	1737937	32	93596
30	1739330	35	93605
32	1738615	41	93749
34	1738849	33	94036
36	1737947	35	93859
38	1738791	34	94128
40	1738398	39	93948
42	1710601	43	94193
44	1738853	41	94077
46	1737273	42	94555
48	1737608	44	94805
50	1735986	41	95543

Dark Count versus Slitmask Delay should be plotted and compared to the plot shown in the Final Test Record. The optimum slitmask delay time is that which minimizes the dark count - typically this delay constant would lie within the range 10 to 50. For the table above the optimum delay constant is 14.

The new delay constant should agree with the final test record value within an acceptance tolerance of ±5. If the new constant is significantly different from the final test value then the factory should be contacted before changing the configuration in the firmware since a complete instrument re-calibration may be necessary.

HV: High Voltage Test

The HV test determines the optimum high-voltage setting for the PMT.
This test requires access to the High voltage module and the front of the Main Electronics Circuit Board.
Measurements of the apparent light intensity of the quartz-halogen (standard) lamp are taken through slits 1 and 2 (dark count, and wavelength 1) for a range of high voltages.
Prior to starting the test, locate shorting plug J2 on the High Voltage Module, and E16 on the Main Electronics Circuit Board.

Method:

1. Turn off Brewer power and move the shorting bar from Pins 2-3 to Pins 1-2, and restore Brewer power.
2. Enter the HV command, and at the prompts, enter the PMT number, the preamp discriminator level (30mv), the minimum (900), maximum (1800) and incremental (50) voltages for the test.
3. The Standard Lamp is turned ON, FW#1 is put to Position 1, FW#2 to Position 0, the Iris is opened, and the Prism turned to the Lamps.
4. Following a 5 minute lamp warmup, the test runs, and data is written to a HVJJJYY.nnn file, and to the screen.

Table F-2 : Typical photomultiplier response output

HIGH VOLTAGE	DARK	WAVELENGTH 1
900	0	2
950	0	117
1000	0	8374
1050	0	62970
1100	1	136027
1150	2	186339
1200	0	216645
1250	1	233441
1300	5	242576
1350	4	248336
1400	5	254274
1450	3	260972
1500	9	268805
1550	9	278936
1600	5	293655
1650	12	315073
1700	15	347252
1750	10	394088
1800	16	458521

A plot of the dark count and wavelength 1 intensity values vs the high voltage should be compared to the plot in the Final Test Record.

The wavelength 1 data should exhibit a region of minimum slope (plateau).

The optimum setting for the high voltage is near the middle of the plateau. A useful improvement in the signal-to-noise ratio may be achieved by choosing a voltage slightly lower than the exact centre of this plateau if the dark count is increasing rapidly in that vicinity.

When the optimum value for the High Voltage has been determined, if it is desired to change the current setting, then the HVSET should be used.

HVSET: Set PMT High Voltage

HVSET is used to set the PMT High Voltage as determined from the HV test.

This test requires access to the High voltage module and the front of the Main Electronics Circuit Board.

Prior to starting the test, locate shorting plug J2 and potentiometer R4 on the High Voltage Module, and test point E16 on the Main Electronics Board.

Method:

1. Turn off Brewer power and move the shorting bar from Pins 2-3 to Pins 1-2, and restore Brewer power.
2. Enter the HVSET command and enter the desired HV value at the prompt.
3. Measure the voltage at E16 on the Main Electronics PCB.
4. Turn off Brewer power and move the shorting plug on J2 back to 2-3, and restore power.
5. Monitor E16 and adjust R4 on the High Voltage Module until E16 is set to the voltage as recorded in step 3.
6. Confirm the setting with an AP command.

RS: Slitmask Motor Run/Stop Test

The RS test verifies that the slitmask motor (slitmask motor) is operating correctly.

In the normal, or "dynamic" mode of operation the slitmask is cycled rapidly, permitting individual measurements to be made at intervals of 131 milliseconds. To ensure that the light intensities are being properly measured in this dynamic mode, the RS test also measures intensities in a "static" mode. Light passing through each slit is measured for a longer period of time during which the slitmask motor is stationary.

Type RS. This test runs for approximately 10 minutes, including a five-minute warmup time for the standard lamp. No further operator interaction is required. Results will be printed in a format similar to the following:

Table F-3 Typical Slitmask Test Results

POSITION	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
RUN	234503	54	1760383	1681139	1704288	1529450	1313677	3062937
STOP	234100	55	1760880	1682069	1704610	1531027	1313654	3063356
RUN/STOP	1.0017	0.9818	0.9997	0.9994	0.9998	0.9990	1.0000	0.9999
RATIOS (RUN)			-0.036	-0.0319	-0.0586	-0.99	0.2808	0.1657
RATIOS (STOP)			-0.0346	-0.0306	-0.0564	-0.1005	0.2872	0.1682

The test is deemed successful if the ratio RUN/STOP for the five operational wavelengths (slitmask positions 2..6) are in the range 0.997 to 1.003, and if the ratio for dark count (position 1) lies within the range 0.20 to 5.0. If the ratios fall outside the acceptance range, there may be problems with either the slitmask alignment, the slitmask-motor power supply or drive circuitry, or an improper motor timing constant may have been stored in the instrument Constants File (refer back to the slitmask-motor timing test, SH).

Normal operational ratios (R1 - R6) are printed out in the last two lines so that ratios in the dynamic (RUN) and static (STOP) modes can be compared.

DT: Photomultiplier Deadtime Test

The DT test measures the deadtime of the photomultiplier and photon-counting circuitry. This test takes readings at four slitmask positions:

Slitmask Position	Description	BASIC Variable
1	Darkcount	F(1)
3	Wavelength 2	F(3)
5	Wavelength 4	F(5)
7	Wavelength 2&4	F(7)

Position 7 allows simultaneous observation through slits 3 and 5. Dark count-corrected counts are stored in the BASIC F() array (refer to the Preliminary Data Reduction document for details). The following algorithm is used to derive a value for instrument deadtime:

Assume Poisson statistics:

$$N = N_0 \cdot e^{-N_0 \cdot t}$$

$$t = \frac{1}{N_0} \cdot \log_e \left(\frac{N_0}{N} \right)$$

where:

N_0 is the true count-rate (counts/sec),
N is the observed count-rate,
τ is the deadtime (sec). (The BASIC variable T1 is used for τ .)

1. As a first approximation set the true (unknown) count-rates equal to the observed count-rates:

$$F_3' \leftarrow F_3$$

$$F_5' \leftarrow F_5$$

1. Compute an estimate for deadtime:

$$t \leftarrow \frac{1}{F_3' + F_5'} \cdot \log_e \frac{F_3' + F'}{F_7}$$

3. Revise the estimates for the true count-rates:

$$F_3' \leftarrow F_3 \cdot e^{F_3' \cdot t}$$
$$F_5' \leftarrow F_5 \cdot e^{F_5' \cdot t}$$

4. Iterate steps 2 and 3 until the value for T1 converges.

Deadtime measurements are made at both high and moderate light intensity levels by using two different neutral-density filter settings (positions 0, 1 for Filterwheel #2); five measurements are taken at the higher intensity, ten at the lower intensity.

Method:

The command DT is issued.

Following the usual five minute lamp warm-up, and a further 10 minutes for test to run, results will be printed in a format similar to the following:

FILTER #1/1 AND FILTER #2/0

GMT	DEADTIME
191054	4.94288936E-08
191119	4.81299056E-08
191143	4.93662915E-08
191208	4.91343971E-08
191233	4.84666031E-08

48.705 ± .6

FILTER #1/1 AND FILTER #2/1

GMT	DEADTIME
191424	4.48950597E-08
191449	4.58755779E-08
191513	4.49521729E-08
191538	4.67340357E-08
191603	4.49957964E-08
191627	4.81735377E-08
191652	4.55349271E-08
191716	4.51368558E-08
191741	4.53192958E-08
191805	4.58533414E-08

45.747 ± 1

Following each block of measurements the deadtime mean and deadtime standard deviation (in nanoseconds) are calculated and printed. The high- and low-intensity deadtime means should agree (within an acceptance tolerance of two standard deviations), and should lie in the range 35 to 50 nanoseconds. Failure to meet this criterion indicates possible difficulties with either the slitmask motor operation, the high-voltage circuitry, or photon counting circuitry.

This newly determined deadtime constant should not be entered into the instrument Constants File unless it is significantly different (by more than about 5 ns) from the old value (if you are confident that the instrument is currently running properly). You should contact the factory before altering the stored constant since a complete recalibration may be required.

HG: Mercury-Line Wavelength Calibration

The HG test precisely locates the mercury line-spectrum, then repositions the micrometer so that the diffraction grating disperses the five operating wavelengths onto the appropriate exit slits. The test uses the mercury discharge lamp and the Hg calibration slit (slitmask position 0).

The software establishes the position of the mercury line-spectrum by scanning the micrometer forwards from step position 50 to step 280 in 10-step increments, then reversing direction and scanning from step 280 back to step 50 (note: 1 micrometer step 0.007 nm). At each position the light intensity dispersed through the calibration slit is recorded, building a 24-point profile of the mercury spectrum. This measured spectrum is compared with an internally-stored reference spectrum to determine that step position which maximizes the correlation between the measured and stored spectra. If this interpolated step number falls within the acceptance limits [147.00..149.99] the mercury spectrum is deemed to have been located, and the micrometer is moved to its operational setting (step number 286 ± 3, or 13 ± 3 micrometer steps below the mercury calibration point; this small displacement is an instrument-dependent constant known as the 'offset' stored in the instrument Constants File, and is determined by the SC test). If, however, the mercury calibration point falls outside the acceptance range, the micrometer is reset to the newly calibrated step number and the test repeated. Iterations continue until the calibration point converges correctly.

Method:

The command HG is issued.

The program will read and display the current Brewer temperature, and a checklist of required foreoptic settings will then be displayed:

*** measurement procedure ***

check:

1 - filter #1 to position #1
2 - filter #2 to position #0
3 - open iris
4 - rotate director prism to lamps
* press return when ready *

These controllable elements will be set automatically.

After a five-minute lamp warm-up period the program will perform a series of intensity measurements over a micrometer step-number range of 50 to 280 as described earlier. The photon count for each observation point is displayed on the screen. You should observe a peaking trend as the micrometer passes through step position 150 (sample number 15). When the micrometer has completed its there-and-back journey the program computes and displays the five correlation coefficients corresponding to attempted curve matchings (between the measured spectrum and the internally-stored reference spectrum) at step positions 110, 130, 150, 170, 190. From these measurements the mercury calibration point is determined and printed in the following format:

Brewer Temp = 29 C (3.66 V)
190112 (.987) HG CALD AT STEP# 298.47 SET TO STEP# 286
9540

This report indicates that at 19:01:12 (C.U.T.: Co-ordinated Universal Time, also known as GMT), a maximum spectral-matching correlation coefficient of 0‘987 was obtained for an (interpolated) mercury calibration point of 298.47. The operational setting of the micrometer is arrived at by subtracting the 'offset' retrieved from the instrument Constants File (the offset is 12 in this case) from 298.47, then truncating the result. 9540 is the peak count across all 24 observation points.

The micrometer is automatically repositioned to the operational point (step #286 in this case), and the test ends.

Should the interpolated calibration point fall outside the [147.00..149.99] acceptance range, the micrometer is automatically repositioned at the truncated calibration minus the offset and the test is repeated until the interpolated calibration point lies between 147 and 150. A sample printout for an HG test which converged in two iterations is shown below (the offset for this instrument is 10 steps):

```
BREWER TEMP = 26 C ( 3.52 V)
103409 ( .9919 ) HG CALD AT STEP # 296.1 SET TO STEP # 286  60871
103651 ( .9927 ) HG CALD AT STEP # 287.0 SET TO STEP # 286  61019
```

SL: Standard Lamp Test

The SL test is a general quality-assurance examination of Brewer performance across the full range of operational wavelengths. An internal, well-regulated, quartz-halogen 'standard' lamp is used as the light source. This source produces a continuous light spectrum (unlike the mercury lamp which emits discrete wavelengths.) which is stable and consistently reproducible. This test should be run on a regular basis (e.g. twice daily) to establish a set of instrument performance records.

Method:

Type SL. The test runs through the same temperature and foreoptic positioning procedures described in HG, then waits the obligatory five minutes for the quartz-halogen lamp to warm up. The program then conducts seven measurement runs over the dark-count channel and the five operational wavelength channels. Each run cycles the slitmask through 20 oscillations, accumulating the photon counts in the BASIC one-dimensional F() array (described under Preliminary Data Reduction). These raw counts are printed in the following format:

Brewer Temp = 27 C (3.56 V)

	C.U.T.	CY	ZEN	MU	DRK	1	2	3	4	5
SL0	20:54:25	20	65.63	2.384	32	1102112	1052861	1066768	956627	820941
SL0	20:55:02	20	65.67	2.388	35	1101966	1054190	1067478	957870	821186
SL0	20:55:40	20	65.72	2.392	43	1102630	1053024	1067318	958662	821366
SL0	20:56:18	20	65.76	2.395	36	1101330	1054009	1068002	957890	821567
SL0	20:57:02	20	65.81	2.4	31	1101960	1053736	1068197	957257	820730
SL0	20:57:46	20	65.86	2.404	37	1102690	1052931	1067378	959002	821232
SL0	20:58:24	20	65.9	2.408	43	1102507	1053022	1067047	958135	822097

The SL0 indicates that the Standard Lamp test was performed with Filter Wheel #2 in position 0 (ie no neutral-density attenuation). CY is the number of slit-mask oscillations over which the counts were accumulated. ZEN and MU are the current solar-zenith angle and airmass respectively (these are irrelevant to the SL test and are presented for operator information only). The next six columns are the photon count totals for the dark channel and the five operational channels. When all seven measurement runs are complete the program corrects the raw photon counts for dark count, deadtime, and temperature-dependence, then prints a series of summary statistics:

20:56:22   Feb 21/85   65.763   2.395   27 C DEG   SL 0

Mean1	mean5	MS(4)	MS(5)	MS(6)	MS(7)	MS(8)	MS(9)
1102170	821302	-623	-426	-488	-694	596	418
+ 483	+ 445	+ 3	+ 5	+ 5	+ 4	+ 15	+ 9

The first line shows the time, date, solar-zenith angle, airmass, instrument temperature and test identification. The second line of data displays the mean corrected count for channels 1 and 5, the single-ratios MS(4) through MS(7), and the double-ratios MS(8) (the SO_2 ratio), and MS(9) (the O_3 ratio). The derivation and interpretation of these values is detailed under Preliminary Data Reduction.

The third line of data shows the standard deviation for each of the quantities in the line above (there is no ASCII symbol for '±', hence the leading '+' sign).

The single-ratios MS(4) through MS(7) should remain reasonably constant from test to test; the allowable drifts in the SO_2 (MS(8)) and O_3 (MS(9)) double-ratios are about ±1.5%.

Thermal Tests

The Thermal Tests consist of a battery of diagnostics which determine the extent to which the spectrophotometer's performance is affected by temperature.

Measurements are made with the quartz-halogen (standard) lamp powered alternately by an external voltage-regulated power supply, and by the instrument's own internal power supply. (The external supply is set to provide a constant power level of 16 watts - this requires that both current and voltage be monitored.) Light intensity measurements are taken at a number of points which span the temperature range -20 to +40°C. The wavelength setting must be recalibrated (via the HG command) at each new temperature before the standard-lamp intensities are measured. These intensity data are analyzed to yield the absolute temperature coefficients for each of the five operational wavelengths; the negative of each coefficient is stored in the instrument Constants File for subsequent use during data reduction.

During the course of the Thermal Tests all of the Brewer electromechanical subsystems should be thoroughly exercised, and any malfunction corrected.

Method:

The instrument's standard lamp should be powered by an adjustable supply which is set to about 16 watts and controlled to within ±1 milliwatt during the test. It is therefore necessary to monitor both the voltage and current supplying the lamp to within ±1 mV and ±1 mA respectively.

The instrument is placed in a chamber where the ambient temperature can be set to values between -30 and +40°C. (These temperature settings cause the internal Brewer temperature monitor to register between approximately -20 and +50°C.) The temperature should be set at about six temperature settings over the range. When the temperature has stabilized at each temperature setting, perform an HG wavelength calibration test.

Turn the standard lamp on using the external power supply; after the lamp has warmed up and the power to the lamp has stabilized, use the SL command to request a standard lamp measurement with cycles set to 50. The raw counts printed out at the five wavelengths as part of the standard lamp record are converted to base-ten logarithms of the count-rates (corrected for dark count and deadtime) and multiplied by 104 to yield F(1) to F(6) as described under Compensating for Deadtime in Preliminary Data Reduction.

Use the five F() values at all the Brewer temperature settings to determine the five temperature response coefficients in the following five equations:

$$F(i) \leftarrow F_0(i) + TC(i) * T, \quad i = 2 \text{ to } 6$$

where

F(i)	are the scaled, corrected count rates
$F_0(i)$	= F(i) at 0 °C
TC(i)	is the temperature response coef. for the i'th operational wavelength
T	is the Brewer temperature in °C.

The values of F0(i) and TC(i) are determined by linearly regressing F(i) against T. By using the negative of the TC(i) coefficients (as described in Compensating for Temperature under Preliminary Data Reduction document) the wavelength-dependent temperature response of the instrument is compensated.

Compare the TC(i) coefficients with those listed in the Final Test Manual. If the freshly determined values do not agree with those obtained at the factory you should consult SCI-TEC or AES regarding the advisability of updating the instrument Constants File (CF command). Although the zero-Celsius values, F0(i), are not used by the Brewer software they should be recorded for future reference.

SC: Scan Test on Direct Sun

The SC test determines the correct operational setting of the wavelength-adjusting micrometer. The program takes measurements of O_3 and $S0_2$ column amounts over an operator-specified range of micrometer positions (wavelengths) then prints reduced data for each of the positions.

Method:

Before running the SC test you should first ensure that the wavelength calibration is current: perform an HG (mercury-line calibration). Next, run a DS (direct sun) test to check that the appropriate neutral-density filter (Filterwheel #2) is in place. Type SC to begin the scan test. In response to the program prompts enter the minimum, maximum and increment for the stepper-motor step number - suggested values are 124, 148 and 2 respectively.

Plot the O_3 and SO_2 values as a function of step number.

Table F-4: O_3 and SO_2 column amounts vs. wavelength for a typical Scan Test on direct sun.

Step#	$[O_3]$	$[SO_2]$
124	328.4	6.4
126	333.4	5.0
128	336.3	3.6
130	338.4	3.2
132	341.3	2.7
134	345.3	1.7
136	346.4	2.0
138	348.0	2.3
140	344.8	3.5
142	347.1	3.9
144	344.4	5.7
146	342.6	6.9
148	338.9	9.2

The proper operational setting is that step number for which the O_3 value is a maximum; the SO_2 value should have a minimum within 1 or 2 micrometer steps of the O_3 maximum. This operational setting should be compared with the value currently stored in the instrument Constants File - if the new value is significantly different and you are confident the instrument is performing correctly then the instrument Constants File should be updated via the CF command. [Contact the factory before altering this constant since a complete recalibration may be required.]

The exact position of the peak of the O_3 value does change by 1 or 2 steps depending on the airmass and the amount of O_3 present. For best results this test should be performed at low airmass values (mu < 1.5).

Instrument Inter-Comparison Calibration

The Instrument Inter-Comparison Calibration determines the absorption coefficients and extraterrestrial constants for the measurement of O_3 and SO_2. These constants are instrument dependent and must be determined for all instruments prior to O_3 or SO_2 measurements.

The uncalibrated instrument is compared to a certified Brewer reference by the analysis of a large number of time-coincident direct-sun O_3 observations made by the two instruments.

Method:

The method by which direct-sun O_3 and SO_2 values are derived from the raw photon counts at the five operational wavelengths is outlined in sections 2 and 3 of Preliminary Data Reduction. After corrections for dark count, deadtime, Rayleigh scattering, and instrument temperature have been applied, the O_3 and SO_2 (MS(11) and MS(10)), values are calculated using the following formulae:

$$MS(11) \leftarrow \frac{MS(9) - B1}{A1 \cdot M2}$$

$$MS(10) \leftarrow \frac{1}{A2} \cdot \left[\frac{MS(8) - B2}{A3 \cdot M2} - MS(11) \right]$$

where

MS(8)	is the weighted double-ratio for SO_2
MS(9)	is the weighted double-ratio for O_3
A1	is the differential O_3 absorption coefficient for the O_3 ratio

B1 is the extraterrestrial constant for the O_3 ratio
A2 is the relative SO_2 to O_3 absorption for the SO_2 ratio = (2.44)
A3 is the differential O_3 absorption coefficient for the SO_2 ratio
B2 is the extraterrestrial constant for the SO_2 ratio
M2 is the airmass, also referred to as MU.

The method to determine the four instrument-dependent values (A1, B1, A3, B2) for a particular instrument via the Inter-Comparison Calibration procedure is outlined below.

Many simultaneous direct-sun measurements (at least 40) are made with both the instrument to be calibrated and a reference instrument. Measurements should be taken over a wide range of airmass values (1.0 < mu < 3.0) for at least one full day of good observing conditions. The O_3 and SO_2 values (MS(11) and MS(10)) are determined from the measurements made with the reference instrument. These values, together with the values of MS(8), MS(9), and M2 valid for the instrument being calibrated are substituted into the above two equations which are rewritten as follows:

$$\mathrm{MS(9)} \leftarrow \mathrm{B1} + \mathrm{A1} \cdot \mathrm{M2} \cdot \mathrm{MS(11)}$$

$$\mathrm{MS(8)} \leftarrow \mathrm{B2} + \mathrm{A3} \cdot [\mathrm{M2} \cdot \mathrm{A2} \cdot \mathrm{MS(10)} + \mathrm{M2} \cdot \mathrm{MS(11)}]$$

Two least-squares linear regression fits are applied to these equations and the resulting two pairs of regression coefficients (B1, A1; B2, A3) are the four instrument-dependent coefficients.

As for all previous tests, consult AES or SCI-TEC prior to altering any of the constants in the instrument Constants File.

AZ: Zero the Azimuth Tracker

The AZ command re-orients the Azimuth Tracker to its zero-step position. This routine is activated automatically following a system reset (RE command). The operator should use this command if there is concern that the azimuth drive has lost track of where it is for such reasons as temporary power loss to the Tracker or other physical disturbance.

Note that the AZ routine can only be accessed if the instrument configuration (IC) is setup to include an Azimuth Tracker System.

Method:
Type AZ . The following screen display appears while the program steps the azimuth drive towards its internal optically-sensed reference flange:

```
*** zeroing azimuth
                    press Del to abort
```

The operator can abort the operation by pressing the DEL (delete) key; the program will return to the previously displayed menu. When the program has located the reference flange it compares the predicted and actual flange positions, then displays the step discrepancy on the screen for about 5 seconds:

```
*** discrepancy = n
AZIMUTH  ZEROED  AT  HH:MM:SS   DISCREPANCY  =  N
```

N will usually be a small integer lying in the range -10 < n < 10. (The Tracker stepper-motor gearing is approximately 15000 steps per revolution, so a discrepancy of 10 steps corresponds to a positional error of 0.2°). N will be much larger if the Brewer has recently been reset or if the Tracker has been physically perturbed (eg power interruption).

The Azimuth Tracker then returns to the solar azimuth and the previously active menu is displayed.

SR: Azimuth Tracker Steps-per-Revolution Calibration

The SR test determines the number of steps required for the azimuth drive motor to turn the Brewer through 360° in azimuth. This test establishes the steps-per-revolution constant which is used by the Brewer program to orient the Brewer in azimuth to within ±1 minute of arc.

An opto-sensor located inside the Azimuth Tracker detects a reference flange on the stationary drive-wheel. The azimuth drive motor is 'zeroed' on this reference, then stepped forward until the flange is again detected on the next revolution. At this point the tracker has rotated exactly 360°, and the steps-per-revolution constant has been determined.

The SR routine can only be accessed if the instrument configuration (I C) has been setup to include an Azimuth Tracker.

Method:

Type SR to initiate the steps-per-revolution test. The first portion of the calibration proceeds exactly as for AZ . Once the internal optically-sensed reference flange has been detected, the azimuth step-count is set to zero and the drive motor is stepped forward until the flange is again detected after 360° of rotation. During the forward search the following screen message is displayed:

```
*** finding az steps/rev
press del to abort
```

It takes approximately 30 seconds to rotate through 360°. (The operator may abort the steps-per-revolution calibration at any time by pressing the DEL key.) Calibration results are displayed as follows:

```
steps/rev measured at 14675
old value = 14678
do you want new value saved? - y/n
```

Enter 'y' if you want to update the calibration value; type 'n' if you feel the test was unsatisfactory for any reason or if the value hasn't changed. A timestamped calibration record will be printed:

```
AZ STEPS/REV = 14675 AT HH:MM:SS
```

The Azimuth Tracker then returns to the solar azimuth and the previously displayed menu will appear.

The Humidity Sensor Test

The Honeywell HIH-3605-A-CP sensor is a monolithic IC humidity sensor that provides a proportional voltage output to relative humidity. The sensor is buffered by an Op Amp and the output is connected to one of the analog input channels of the A/D converter. A temperature sensor is located near the humidity sensor to provide temperature compensation for the device. The two measured values, relative humidity and temperature allow the absolute humidity to be calculated.

The humidity sensor is supplied with a sensor specific data printout. The values of the data printout are entered into a formula which calculates the moisture content inside the instrument.

The Calibration confirmation test consists of placing the sensor in a sealed container with a variety of water saturated salts that result in known, and accurate, RH values.

NaCl solution is 75.3%; the measured RH using the above formulas is <u>75.7%</u>
$MgCl_2$ solution is 32.8%; the measured RH using the above formulas is <u>32.6%</u>
LiCl solution is 11.3%; the measured RH using the above formulas is <u>12.3%</u>
Dry N2 is 0%; the measured RH using the above formulas is <u>0.07%</u>

These results show that the sensor is well within the range of its specifications

Method:
Attach the data printout from the humidity sensor container to this document.

Enter the values of origin and slope into the configuration file of the instrument.

Confirm normal operation of the instrument through the use of the routines TE and AP. Refer to the operators manual for specific use of these routines.

Model: IH-3605B   Channel: 189   File 98080318
Wafer: thunder   MRP: thunder

Pin 3: +5 VOLTS PRECISION SUPPLY
Pin 2: E+ SIGNAL OUTPUT
Pin 1: NEGATIVE or POWER COMMON

HYCAL Sensing Products	Linear output for 2% RH accy @25C:
Honeywell Inc.	Zero offset = 0.868 V
9C Founders Blvd	Slope = 28.981 mV / %RH
El Paso TX 79906	RH = (Vout – 0.868) / 0.290
Calculated Values at 5V:	Radiometric response for 0 to 100%RH:
Vout @0%=0.868 @75.3%=3.050	Vout = Vsupply * (0.1736 to 0.7533)

NaCl solution is 75.3%, the measured relative humidity is ______%
$MgCl_2$ solution is 32.8%, the measured relative humidity is ______%
LiCl solution is 11.3%, the measured relative humidity using is ______%
Dry nitrogen solution is 0%, the measured relative humidity is _____%

Appendix G Preliminary Data Reduction

This section describes how the Brewer software processes the raw photon-count data to determine ozone (O_3) and sulphur dioxide (SO_2) column amounts. Seven of the two-character menu commands (SL, SC, DS, ZB, ZC, ZP, M) access a common suite of data reduction algorithms, as shown in figure G-1.

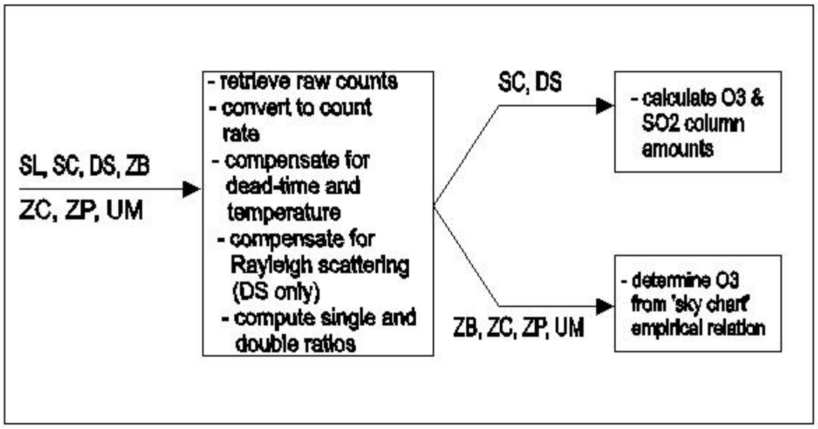


Figure G-1: Data Reduction Flowchart

Converting Raw Counts to Light Intensity

Raw photon counts are automatically retrieved from six wavelength channels (one dark-count channel, five operational channels.

The computer requests raw photon-count data from the spectrophotometer by transmitting appropriate command strings, for example:

R, 1, 6, 20 (run the slitmask motor through positions 1 to 6, then back to position 1, accumulating the counts to six separate channels; repeat this sequence 20 times)

O (output to the computer the six photon counts measured in the previous R command)

The returned photon-count values are stored in the F() array. These raw values are written to the printer.

Converting Raw Data to Count Rates

The core program subtracts the dark count (stored in F(1)) from the operational-wavelength counts, then scales the result to produce count rates, in counts per second:

$$F_i \leftarrow \frac{2 \times (F_i - F_1)}{CY \times IT} , \qquad i = 2..6$$

where

CY is the number of slitmask cycles (20 in the above example)

IT = 0.1147 is the interval-scaling factor which incorporates slit sampling time and duty cycle

Compensating for Deadtime

Poisson statistics are assumed so that for any observation at a true count rate F0 (counts/second) the observed rate F will be

$$F \leftarrow F_0 \cdot e^{-F_0 \cdot T_1}$$

where T1 is the deadtime of the photon-counting system (as determined by the deadtime test, DT, run as part of the Brewer setup procedures).

This equation is solved this equation for F0 by iterating 9 times on the (rearranged) expression:

$$F_0 \leftarrow F \cdot e^{F_0 \cdot T_1}$$

This compensation is performed for each of the five operational wavelengths. The deadtime-compensated count rates are normalized by computing the base-ten logarithm, then scaled by 104, thus allowing integer arithmetic.

Compensating for Temperature

The count rates are corrected for the temperature-dependent bandpass characteristics of various filters inside the spectrometer assembly:

$$F_i \leftarrow F_i + \left(PC + TC_i\right) \cdot TE + AF_p, \quad i = 2..6$$

where

PC	is the constant part of the temperature coefficient
TCi	are the wavelength-dependent temperature coefficients read from the spectrophotometer's Constants File (stored on disk)
TE	is the instrument temperature in degrees Celsius
AFp	is the attenuation value of the neutral-density filters at position p (the array AF of attenuation values is also read from the instrument Constants File).

Compensating for Rayleigh Scattering (DS only)

If the reading is of the direct sun, the count rates are adjusted by compensating the effect of Rayleigh-scattering attenuation for the airmass calculated for the time of the observation:

$$F_i \leftarrow F_i + \frac{BE_i \times M3 \times PZ}{1013}, \qquad i = 2..6$$

where

BEI	are the Rayleigh coefficients.
PZ	is the atmospheric pressure at the site of the instrument (in millibars)
1013	is standard atmospheric pressure (millibars)
M3	is the airmass (also referred to as the path-lengthening factor) for a layer of height 5 km above the earth.

M3 is recalculated prior to each solar observation:

$$M3 \leftarrow \sec(\arcsin\,[k \cdot \sin(A)])$$

where

A	is solar zenith angle
k =	R / (R + Z)
R	is radius of earth (6370 km)
Z	is layer height (5 km)

These airmass calculations are imbedded within the "equation of time" computations.

A second path-lengthening factor, M2, is also calculated. This airmass corresponds to a layer height of 22 km.

Computing Single and Double Ratios

At this point the count rates Fi have been corrected and compensated for deadtime, temperature, and (if applicable) Rayleigh scattering. Four sets of single ratios are formed (recall that these count rates are in logarithm units, hence a "ratio" is formed by computing the difference):

$MS_4 \leftarrow F_5 - F_2$ (includes effects of O_3 and SO_2)

$MS_5 \leftarrow F_5 - F_3$

$MS_6 \leftarrow F_5 - F_4$ (affected predominantly by O_3)

$MS_7 \leftarrow F_6 - F_5$

Only the shortest of the five observation wavelengths (306.3 nm, count rate F(2)) is significantly affected by SO_2 column amounts, so ratios MS(5) , MS(6), MS(7) will be largely independent of SO_2 effects.

Two higher-order ratios are formed:

$$MS_8 \leftarrow MS_4 - 3.2 \cdot MS_7$$

$$MS_9 \leftarrow MS_5 - 0.5 \cdot MS_6 - 1.7 \cdot MS_7$$

Both of these functions have weightings which remove the effects of absorption which are linear with wavelength. In addition, they are stabilized with respect to small wavelength calibration errors. The second function is weighted to remove SO_2 absorption effects

These ratios are written to disk and printer.

Determining O_3 and SO_2 from Direct-Sun Data

The O_3 amount, MS11, is determined from the logarithms of the count rates for the four longer wavelengths :

$$MS_{11} \leftarrow \frac{MS_9 - B1}{A1 \cdot M2}$$

where

MS9 is the double ratio described in the previous section

B1 is the extra-terrestrial coefficient for the O3 wavelength combination (instrument-dependent)

A1 is the differential O3 absorption coefficient for the O3 wavelength combination (instrument-dependent)

M2 is the path-lengthening factor for an ozone layer of height 22 km.

The SO2 determination is slightly more complicated because of the correction needed due to O3 :

$$MS_{11} \leftarrow \frac{MS_8 - B2}{A2 \cdot A3 \cdot M2} - \frac{MS_{11}}{A2}$$

where

A2 is the ratio of the SO_2 absorption coefficient to the O_3 absorption coefficient of the SO_2 wavelength combination; A2 is nominally set equal to 2.44

A3 is the differential O_3 absorption coefficient for the SO_2 wavelength combination (instrument-dependent)

B2 is the extra-terrestrial coefficient for the SO_2 wavelength combination (instrument-dependent).

Determining O_3 and SO_2 from Zenith-Sky Data

The determination of O_3 and SO_2 amounts from zenith-sky data is accomplished through the application of an empirical polynomial relation (a numerical "sky chart"). It is assumed that the O_3 function determined from zenith-sky observations can be analytically related to the value of the total ozone and the solar zenith angle. The relation assumed has the following form:

$$A \cdot X^2 + B \cdot X + C - F_{sky}$$

where

$$A \leftarrow a + b \cdot M2 + c \cdot M2^2$$
$$B \leftarrow d + e \cdot M2 + f \cdot M2^2$$
$$C \leftarrow g + h \cdot M2 + k \cdot M2^2$$

M2 is the path-lengthening factor for the O_3 layer
F_{sky} is the observed zenith-sky value
a, b, c, . . k are site- and instrument-dependent constants
X is the deduced direct-sun O_3 value.

It must be emphasized that the constants a . . k are NOT factory-set: they can only be determined after a large number (say 500 or more) of (Fsky, M2, XDS) data triples have been constructed from pairs of observations made on the direct sun (XDS, M2) and on the zenith sky (Fsky, M2). These data triples should span the full range of M2 and O_3 values.

The constants for instrument #15 are quoted here for reference:

a	+0.0164	d	+0.0396	g	-0.2778
b	-0.0836	e	+0.6326	h	-0.1262
c	+0.0185	f	-0.0705	k	-0.0122

Cloudy-sky (ZC) data are treated in the same way as the zenith blue-sky (ZB) observations: this is only a good approximation for thin cloud; satisfactory treatment of thick-cloud observations awaits development of an improved cloud-sky relation.

APPENDIX H Computer / Brewer Interface (TeleType)

The TT command gives an operator direct control of various Brewer functions by allowing low level commands to be sent directly from the Computer keyboard. With this feature, most useful as a troubleshooting tool, all motors can be moved, lamps turned on, and data sampled.

This command is useful only when the Brewer and Computer are communicating, and is sent from the Main Menu with the command, TT.

A printed copy of all transactions can be preserved if the printer has previously been turned on with the PN command, and a printout is requested after launching TelyType command.

Command Level

A command string consists of zero or more commands separated by semicolons, optionally followed by the A "command", and sent with 'Enter'.

Examples of TT commands:

B,2	- turn on the Quartz Halogen Lamp
M,1,0	- move the Zenith Prism to the 0 (Lamps) position
R,0,7,10;O;A	- run the shutter from position 0 to 7 a total of 10 times,
	- output the resulting counts, and
	- repeat until interrupted by "HOME"

When executing a command string, the Brewer executes each command set in turn. Commands within a command set are executed concurrently. The command set is assumed to have ended when the first command in the set has ended, even if other commands in the set are still executing. Any commands which generate output transmit that output in accordance to the rules of the low level protocol in effect.

Command strings terminating in the A "command" get repeated indefinitely. In the case of the computer interface low level protocol, an ESC command is required to terminate execution; in the case of the TTY low level protocol a break must be sent.

The following sections identify the various commands. Commands with single character opcodes constitute the commands supported by the COSMAC based Brewers. They are augmented by a number of commands supported only by later versions of the Brewer. These newer commands have multicharacter opcodes and provide functions specific to newer electronics or provide more natural commands for functions supported by the COSMAC based Brewers.

A number of the commands listed below are used only for diagnostics and are not nornally used in day to day operations, but are included for completeness. The commnds in more common use are marked by **.

Turn the the mercury lamp and/or the standard lamp on or off. This command requires configuration variables.

1. ** B

Syntax

B, <mask>

Parameters

The parameter <mask> takes one of four values or an error is logged:

<mask>	standard lamp state	Mercury lamp state
0	off	Off
1	off	On
2	on	Off
3	on	On

*Note: if the configuration variable USE.B3.FOR.LAMPS is set to YES then the lamps are both turned on with B,3. If the configuration variable is set to NO then the state of the lamps are not altered and the command is essentially ignored.

Example

B,2

Turn the standard lamp on and the mercury lamp off, update lamp state variables in the background.

2. F

Define the fill characters to be used at the start of every transmission from the Brewer to the controller when using the TTY interface low level protocol.

Syntax

F,<count>,<ASCII code>

Parameters

parameter	range	Meaning
<ASCII code>	0 to 255	the character to be used as a fill character
<count>	0 to 255	the number of fill characters to use for each output message

Example

F, 1, 7

Transmit a single BEL character at start of each output message.

2. HVADJUST

Adjusts the High Voltage power supply. This command requires configuration variables.

Syntax

HVADJUST <delta>

Parameters

Parameter / response	format	Meaning
<delta>	-128 to 127	steps to adjust the supply

Use of this command resets the NVRAM variable which keeps track of the latest measurement of the HV supply voltage. The watermarks are also centered around the new HV supply setting; note that this is different in operation from other watermarks.

4. ** I

Initializes the specified motor to its 'zero' position and set the corresponding step-count accumulator to 0; moves the motor to its default position. This command requires configuration variables. If the slow and maximum velocities specified for a motor are equal, then the motor reset routine is abbreviated, i.e., the movement does not include moving off the sensor and searching for it at a different speed than the maximum. I commands do not work concurrently (although on reset all motors initialize at once).

Syntax

I,<m>

Parameters

The following table gives the permissible values for <m>.

<m>	Motor	symbolic form of <m>
1	Zenith prism	ZENITH
2	Azimuth Tracker	AZIMUTH
3	Iris	IRIS
4	Filterwheel 1	FILTER.WHEEL.1
5	Filterwheel 2	FILTER.WHEEL.2
6	Filterwheel 3	FILTER.WHEEL 3
9	Micrometer 2	MICROMETER.2
10	Micrometer 1	MICROMETER.1
11	Slitmask 1	SLITMASK.1
12	Slitmask 2	SLITMASK.2
13	Zenith Tracker	TRACKER.ZENITH

Example

I,4

The motor used by Filterwheel 1 is initialized.

5. LOGENTRY

Report the next entry in the log

Syntax

LOGENTRY

Response

A character string identifying a problem. This string has the form

YYYY DDD HH:MM:SS <text>

where the text may be (for example)

1995 033 14:22:03 All log entries reported

Entry

LOGENTRY
1996 302 13:10:02 Warm reset requested. Tepid reset generated (RAM was corrupt).
Reading the oldest unreported log entry;
LOGSTART
LOGENTRY
1996 302 13:10:07 Motor #8: IIC communications error
LOGENTRY
1996 302 13:10:14 MUGWUMP: symbol not found
reading the oldest log entry;
LOGFINISH
LOGENTRY
1996 302 13:10:22 All log items reported
skipping past all the entries

6. LOGFINISH

Resets the log to act as though the newest entry in the log has already been reported.

Syntax

LOGFINISH

Example

see LOGENTRY

7. LOGSTART

Resets the log iterator to the oldest entry in the log.

Syntax

LOGSTART

Example

see LOGENTRY

8. ** M

Move the specified motor to the specified position. If the motor hits a limit sensor during its movement, then the motor is reset to its initial position and the requested motor position is again moved to. This command requires configuration variables. See section 10.31.7 for examples.

Syntax

M,<m>,<s>

Parameters

The <m> identifies the motor to move. See the section on the I command for possible values.

The <s> defines the motion required. If <s> is positive the motor moves to the given position. If <s> is negative, the motor moves |<s>| steps backward and resets the 'zero' position of the motor to be this new position.

Example

M, 4, 256

Moves the translucent ground quartz diffuser on filterwheel 1 into the optical path.

9. ** O

Transmit to the controller all photon count data accumulated by the most recent R command, then zero the photon count accumulators. This command requires configuration variables.

Syntax

O

Response

<c0>,<c1>,<c2>,...,<cn>

Each count number returned is in the form of a decimal value using ASCII characters. Each number occupies exactly nine characters and the value is right-justified and padded with spaces. The last value in the list does not have a comma or space but a carriage return as expected.

Parameters

The <ci> are photon counts in the range 0 to 16777215, one for each slitmask position measured in the most recent R command.

Example

See section on the R command.

10. PMT

Reads a count using the PMT. This command requires configuration variables.

Syntax

PMT

Response

<count>

The count value (decimal number using ASCII characters) is right justified and padded with spaces in a nine-character string.

Parameters

Parameter / response	format	meaning
<count>	0 to 2^{24}-1	the PMT count taken

11. ** R

Measure the light intensity. This command requires configuration variables. The configuration variable sets up the slit positions to correspond to a motor step position.

Syntax

R,<p1>,<p2>,<p3>

Parameters

<p1> may take values from 0 to 7, <p2> takes on values from <p1> to 7, and <p3> takes on values from 1 to 255. In response the Brewer measures the light intensity for each of the wavelength positions <p1> thru <p2> by running the slitmask from <p1> to <p2> and back accumulating the counts for each separate position. This counts are accumulated for <p3> repetitions of this back-and-forth scan. Every R command zeroes the count accumulators for all slitmask positions. See the notes on the configuration variable SLIT.PACE in section 5.19 Configuration Parameters.

If there are no parameters specified, the parameters from the previous R command are used. If no previous R command parameters had been specified (as would be the case after a warm start, for example) all of the parameters are assumed to be zero and no scan is performed. In essence, all that happens is the count accumulators are zeroed. The correspondence between <p1> or <p2> and slitmask position is given in the following table:

Slitmask position	meaning
0	Hg calibration: 302.1 nm
1	Dark Count
2	$\lambda 1$ 306.2 nm
3	$\lambda 2$ 310.0 nm
4	$\lambda 3$ 313.5 nm
5	$\lambda 4$ 316.8 nm
6	$\lambda 5$ 320.0 nm
7	$\lambda 2$ & $\lambda 4$ for Deadtime test

Example

R; O

0

If the above had been called before any other R command then a single zero is returned indicating that there were no scans taken.

R,2,4,4;O[sent to Brewer]

5638, 4996, 54886[returned by Brewer]

Sample and accumulate the light intensities for slitmask positions 2, 3,4,4,3 and 2. Repeat this sequence 4 times. In this example the O command is used to display example results. The returned counts correspond to slitmask positions 2, 3 and 4 respectively.

R; O[sent to Brewer]

5549, 4989, 54880[returned by Brewer]

In the above, the R parameters had already been specified as 2, 4, 4.

The new values returned correspond to a new run of the R command as specified.

12. S

Report the status of the most recent run command. This command requires configuration variables.

Syntax

S

Response

<p1>,<p2>,<count>,<p3>,0,<interrupted>,

Each number returned in the above string is in the form of a decimal value using ASCII characters. Each number occupies exactly four characters and the value is right-justified and padded with spaces. The last value in the list always has a comma. The number of parameters returned is limited only by the string length.

Parameters

The <pi> are the corresponding parameter from the most recent R command. The remaining parameters are given in the following table.

Response field	format	Meaning
<count>	0..<p3>	Number of cycles completed
<interrupted>	boolean	on if the Run command was interrupted (by a break)

Example

S

2, 4, 2, 4, 0, 1,

Reports that the R command was R,2,4,4 and was interrupted during the third scan.

13. SAVE

Stores the current set of RAM configuration parameters in Flash memory.

Syntax

SAVE

Response

<retCode>

Parameters.

Response	**format**	**Meaning**
<retCode>	0 - 127	number of sets of configuration parameters for which there was room when the operation started. 0 means that no room was left and parameters are not stored

14. STEPS

Determines the number of steps in a complete revolution of the azimuth tracker. This command should always be immediately preceded by an I,2 command and followed by a ?STEPS query. This command requires configuration variables.

Syntax

STEPS

Example

I.2

Ensures that the motor position is accurately known.

STEPS

Moves the motor exactly one revolution and records the number of steps required.

?STEPS

17979

Reports that the most recent STEPS command discovered 17979 steps in a revolution.

15. T

Retransmit the output from the most recent non-null response.

Syntax

T

Response

Depends on which of the commands was most recent.

Parameters

The <pi> identify parameters being set, the <vi> give the values to which they are being set. The following table gives the permissible values for <pi> and the corresponding meaning for the <vi>.

Example

T[sent to Brewer]

1996 302 13:10:22 All log items reported[returned by Brewer]
The previous command string (which in this case was a call to determine the lamp state) was returned.

16. USECONFIG

Restarts software using the configuration in RAM.

Syntax

USECONFIG

17. V

Set the baud rate and the flag which controls echoing.

Syntax

V,<cps>[,<echo>]

Parameters

Parameter	format	Meaning
<cps>	byte	one of 30, 60, 120, 240, 480 or 960. The approximate number of characters per second. Baud rate set to 10*<cps>
<echo>	boolean	on to suppress character echoing

Examples

V,120

The prompt ("->") after this command will be sent at 1200 baud

V,960,1

The prompt ("->") after this command will be sent at 9600 baud and character echoing will be suppressed.

18. CONFIGURATION PARAMETERS

A variety of configuration parameters define the operation of the Brewer. Commands exist to set and read each of these. They share a common syntax so the complete set are listed in the table below:

Syntax

?<name> or

?<name>[<index>]to read the configuration variable

!<name> <value> or

!<name>[<index>] <value>to write the configuration variable

Response

The <names**>**

Parameters

parameter / response	Format	meaning
<name>	Identifier	starting address within the space
<index>	Identifier or number	which element of a vector of such values
<value>	Depends on <name>	depends on <name>

The <name>s

<name>	format of <value>	Effective	meaning of <value>
BREWER.ID	integer value (0-65536)	next warm start or USECONFIG	This is the Brewer ID used to manage multidrop protocol. Copied to NVRAM on initialization.
CLOSE.TIME	Float seconds	Immediate	number of seconds before the PMT window closes when we start to move the slitmask
IMMINENT	float seconds	Immediate	number of seconds before the PMT window closes that we should start to watch PMT window closely so we move the motor at the proper time
LAMP.RESET.TIME	float seconds	Next time lamp is turned on	The amount of time before the lamp will be automatically turned off.
LAMP.CONV.CURRENT [<lamp>]	float amps	Immediate	conversion constant for lamp current as measured at A/D
LAMP.CONV.VOLTAGE [<lamp>]	float volts	Immediate	conversion constant for lamp voltage as measured at A/D
MODEL	unsigned integer	immediate	the 'mark' number of the brewer
MOISTURE.LIMIT	float grams/cubic m	on reset	Permitted maximum in watermark recording of moisture content inside the Brewer.
MOTOR.ADDRESS [<motorId>]	unsigned integer (0-11)	Immediate	Identifies the 751 used to talk to this motor
MOTOR.CLASS [<motorId>]	one of: NOMOTOR MICROMOTOR TRACKERMOTOR STANDARDMOTOR SENSORLESSMOTOR	Immediate	The type of motor at this motorId and hence the algorithm used to initialize it.
MOTOR.INITIAL[<motorId>]	signed integer steps	Immediate	position of motor from step 0 after initialization
MOTOR.MAX.ACC [<motorId>]	unsigned integer paces/(256*tick)^2	on reset	maximum absolute value of motor acceleration to be permitted
MOTOR.MAX.JERK [<motorId>]	unsigned integer paces/(256*tick)^3	on reset	maximum absolute value of rate of change of motor acceleration to be permitted inside a time slice
MOTOR.MAX.SEARCH [<motorId>]	signed integer paces	on reset	max number of paces before search stopped
MOTOR.MAX.VEL[<motorId>]	unsigned integer paces/(256*tick)	on reset	maximum absolute value of motor velocity to be permitted
MOTOR.MAX.POS [<motorId>]	signed integer paces	on reset	maximum value of motor position to be permitted
MOTOR.MIN.POS [<motorId>]	signed integer paces	on reset	minimum value of motor position to be permitted
MOTOR.ORIGIN [<motorId>]	signed integer paces	on reset	position of step 0 after initialization
MOTOR.REF.PLAY [<motorId>]	signed integer paces	on reset	uncertainty of position of motor with respect to reference sensor when sensor is detected at high speed and arbitrary direction.
MOTOR.RESET.POS[<motorId>]	signed integer paces	during motor init	position of motor to be paced at before commencing motor init to ref sensor
MOTOR.SLOPE [<motorId>]	signed integer paces/step	Immediate	number of paces to a step (see M command)
MOTOR.SLOW.VEL [<motorId>]	unsigned integer paces/(256*tick)	during motor init	value of motor velocity to be permitted during final approach of search. If equal to max vel init routine is shortened.
MOTOR.STOP.METHOD [<motorId>]	int one of 1, 3 none 0 reduced 2 full	on reset	power applied for stopped motor

MOTOR.TIME.OUT [<motorId>]	float seconds	Immediate	amount of time that a motor is given to complete movement before timing out.
OPEN.TIME	float seconds	Immediate	number of seconds after PMT window closes before we open the PMT window
PMT.WINDOW.RESOLUTION	float seconds	Immediate	seconds in a window timing tick
PMT.WINDOW.TIME	float seconds	Immediate	seconds in a window. Should be an integral multiple of PMT resolution time.
RESET.TIME.OUT	unsigned integer seconds	on reset	the length of time allowed for initialization of all motors. This should be larger than the largest value of MOTOR.TIME.OUT.
RH.ORIGIN	float volt at 0 RH	immediate	Humidity sensor calibration provided by manufacturer
RH.SLOPE	Float volt/%	immediate	Humidity sensor calibration provided by manufacturer
SUPPLY.CONVERSION [<powerSupply>]	float	Immediate	Number of volts at the output of the supply to read one volt via the A/D
SUPPLY.DELTA[<powerSupply>]	float volts	on reset	Permitted (max-nominal and nominal-min) voltage in watermark recording
SUPPLY.NOMINAL [<powerSupply>]	float volts	on reset	Center voltage in watermark recording
TEMP.DELTA [<thermalPoint>]	float degrees	on reset	Permitted (max-nominal and nominal-min) temperature excursion in watermark recording
TEMP.NOMINAL [<thermalPoint>]	float degrees	on reset	Center temperature in watermark recording
TEMP.ORIGIN [<thermalPoint>]	float degrees	Immediate	number of degrees Celcius offset for 0 volts at the A/D
TEMP.SLOPE [<thermalPoint>]	Float degrees/volt	immediate	number of degrees Celcius per volt at the A/D (linear thermistors are used here)
TRACKER.DEBOUNCE.TIME	Float seconds	immediate	debounce time for the tracker control switches
USE.B3.FOR.LAMPS	Boolean	immediate	Sets response to command: B,3. If set to YES, lamps are turned on else the command is ignored.
VERSION.ELEC	unsigned byte	immediate	Records the electronics version
VOLTS.PER.BIT	Float volts	immediate	Resolution of A/D converter in volts per A/D unit (bit)

Possible <index>es

<index>	**Meaning**	**possibilities/format**
<address>	location within the space	ANSI C integer format[1]
<analogPt>	which A/D mux input	integer 0 to 23
<digitalPt>	which digital input	integer 0 to 15
<lamp>	which Brewer internal lamp	0 to 1 or identifier - One of: HG, STD
<motorId>	identifies a motor	see section on I command
<powerSupply>	identifies a power supply	0 to 6 or identifier One of: HV, +12V, +5V, -12V, +24V, +5VSEC (secondary supply), -5VSEC
<thermalPoint>	identifies a thermal sensor	0 to 5 or identifier One of: PMT (photomultiplier), FAN (internal temperature), BASE, BELOW.SPECTRO, WINDOW.AREA, EXTERNAL (external temperature)
<trackerSwitch>	identifies a tracker switch digital input	0 to 4 or identifier One of: CW, CCW, UP, DOWN, COARSE

Examples

?MOTOR.MAX.ACC[IRIS]

reports the current maximum acceleration for the iris motor.

!PMT.HV.TOLERANCE 50

sets the value of the high voltage tolerance to 50 millivolts.

19. Operational Information

[1] The first character must be a digit. The number interpretted as decimal unless the first digit is a 0 in which case the second character is tested. If it is 'x' or 'X' the remaining digits are interpretted as a hexadecimal number. If the second character is a digit the number is interpretted as octal.

A variety of operational status values define the current state of the Brewer. Commands exist to set and read each of these. They share a common syntax so the complete set are listed in the table below:

Syntax

?<name>	or
?<name>[<index>]	to read the status variable
!<name> <value>	or
!<name>[<index>] <value>	to write the status variable

Response

<value>	? form only

Parameters

parameter / response	format	meaning
<name>	identifier	parameter in question
<index>	identifier or number	which of many
<value>	depends on <name>	depends on <name>

Possible Names

<name>	Format of <value>	writeable?	meaning of <value>
ANALOG.NOW [<analogPt>]	10-bit integer	no	A/D output value in A/D units
BREAK.ABORT.TIME	float seconds	Yes, reset to 0.25 on tepid resets	The elapsed time in seconds for a continuous TTY line-break to abort command processing.
BREAK.RESET.TIME	float seconds	Yes, reset to 5.0 on tepid resets	The elapsed time in seconds for a continuous TTY line-break to force a warm restart of the Brewer.
BYTE.X [<address>]	ANSI C integer format (Hex on output)	yes	value of the relevant byte in external RAM
BYTE.F [<address>]	ANSI C integer format (Hex on output)	no	reads value from Flash memory
BYTE.C [<address>]	ANSI C integer format (Hex on output)	no	value of the relevant byte in CODE space
BYTE.D [<address>]	ANSI C integer format (Hex on output)	yes	value of the relevant byte in DATA space
DIGITAL.INPUT [<digitalPt>]	OFF or ON	no	reads whether input is ON or OFF; logic levels are transparent to the user.
DIGITAL.OUTPUT [<digitalPt >]	OFF or ON	yes	digital output point ON or OFF with logic levels transparent to the user.
ECHO.SUPPRESSION	ON/OFF		Suppresses TTY mode echoing when ON, allows echoing when OFF.
HG.SWITCH	OFF or ON	yes	mercury lamp set OFF or ON
STD.SWITCH	OFF or ON	yes	standard lamp set OFF or ON
LAMP.POWER [<lamp>]	watts	no	lamp power consumption
LAMP.STATE [<lamp>]	lamp state type	yes	state of lamp (OFF or ON)
MOISTURE	Grams/cu. m	no	Moisture content of air inside the Brewer
MOISTURE.HIGH	Grams/cu m	yes	Moisture content high (watermark)
MOTOR.ALLSTILL	TRUE or FALSE	no	True only if all the motors have stopped moving

MOTOR.POS [<motorId>]	stepss	no	current motor position
MOTOR.LOST [<motorId>]	Boolean	no	current motor position unknown exactly
MOTOR.LIMIT.LOW [<motorId>]	Boolean	no	low travel limit sensor activated
MOTOR.LIMIT.HIGH [<motorId>]	Boolean	no	high travel limit sensor activated
MOTOR.REF.LOW [<motorId>]	Boolean	no	lower reference sensor (#1) activated
MOTOR.REF.HIGH [<motorId>]	Boolean	no	upper reference sensor (#2) activated
MOTOR.DISCREPANCY [<motorId>]	paces	no	position of the reference position on the most recent motor initialization. This is a measure of accumulated motor position error between the most recent and the immediately prior initialization.
MOTOR.ZERO.POS[<motorId>]	signed integer paces	no	the same as MOTOR.ORIGIN on a reset, but is updated by negative M commands.
PMT.SELECT	integer (1 to 3)	yes	selects the PMT in use; 3 means both
RH	%	no	Relative Humidity inside the Brewer
STEPS	integer steps	no	the number of steps in a complete revolution of the azimuth tracker
SUPPLY.VOLTAGE.HIGH [<powerSupply>]	volts	yes	supply voltage high (watermark)
SUPPLY.VOLTAGE.LOW [<powerSupply>]	volts	yes	supply voltage low (watermark)
SUPPLY.VALUE [<powerSupply>]	volts	no	supply voltage
SUPPLY.SETTING.HV	volts	no	HV supply setting recorded at last adjustment.
TEMP.HIGH [<thermalPoint>]	degrees	yes	lamp power consumption high (watermark)
TEMP.LOW [<thermalPoint>]	degrees	yes	lamp power consumption low (watermark)
TEMP [<thermalPoint>]	degrees	no	lamp power consumption
TIME	<year> <day> <hour> <min> <sec>	yes	-4 digits -3 digits -2 digits -2 digits -2 digits
TRACKER.SWITCH.SETTING [<trackerSwitch >]	ON/OFF	no	reports the debounced tracker switch status that is indexed
TRACKER.SWITCHES	integer bit map	no	bit is on if the switch (see <trackerSwitch) is currently pressed. These are debounced values.
TTY.FILL.CHARACTER	integer ASCII code (0-255)	yes	TTY mode echo character ASCII code
TTY.FILL.COUNT	integer count (0-255)	yes	TTY echo character padding count
VERSION.FW[<info>]	integer	no	Version information and design date for the firmware. <info> is one of: YEAR, MONTH, DAY, VERS, REL

Examples

?MOTOR.POS[IRIS]

reports the current position in half-step units of the iris motor.

!SUPPLY.VOLTAGE.HIGH[+5V] 5.00

resets the upper voltage watermark to the nominal value for the +5 volt supply.

Motor positions for instrument control

Motor # & Name	Step #	Position	Command String
1: Zenith Prism	0	pointing at standard lamp (internal)	M,1,0
	1408	pointing at zenith sky (external)	M,1,1408
	2112	pointing at UVB port (external)	M,1,2112
2: AzimuthTracker	0	reference direction (North)	M,2,0
	14670	reference direction, 1 full turn CW from step #0	M,2,14670
3: Iris	0	iris fully closed	M,3,0
	75 or 250	iris fully open	M,3,75 or M,3,250
4: Filterwheel #1	320	0: film polarizer	M,4,320
	256	1: quartz diffuser (translucent)	M,4,256
	192	2: blocked aperture (opaque)	M,4,192
	128	3: clear aperture (transparent)	M,4,128
	64	4: quartz diffuser; ND of f=2.0 (translucent)	M,4,64
	0	5: clear aperture (transparent)	M,4,0
5: Filterwheel #2	0	0: f = 0	M,5,0
	64	1: f = 0.5	M,5,64
	128	2: f = 1.0 f = neutral density factor	M,5,128
	192	3: f = 1.5[Attenuation = 10^f]	M,5,192
	256	4: f = 2.0	M,5,256
	320	5: f = 2.5	M,5,320
10: Micrometer #1	Approx 290	calibrated micrometer setting	M,10,xxxx
9: Micrometer #2		(nominal setting is 6±1.5mm; there are 576 steps/mm) (wavelength change of 0.006nm/step) (positive steps increase wavelength and decrease micrometer setting)	M,9,xxxx
11: Slit Mask	0	0: slit 0 (HG) 303.2 - 426.4 nm	M,11,xxxx
	2	1: dark count ----------------------	NOTE: R,0,6,2;O;A
	4	2: slit 1 306.3 - 431.4 nm	gives a real time
	6	3: slit 2 310.1 - 437.3 nm	listing of the registers
	8	4: slit 3 313.5 - 442.8 nm	from 0 to 6 press
	10	5: slit 4 316.8 - 448.1 nm	<<delete>> to stop.
	12	6: slit 5 320.1 - 453.2 nm	
	14	7: dead time ----------------------	

APPENDIX I FIRMWARE LOG

Messages appearing in the Instrument Log (accessed using the RL command) have the following format:

yyyy ddd hh mm ss <message part 1>

yyyy ddd hh mm ss <message part 2>

...

yyyy ddd hh mm ss <message part n>

The 'yyyy ddd hh mm ss' identifies the time on the instrument clock at the time when the message was recorded. The possible values of <message part 1> are given below. Usually there is only the <message part 1>.

<name>: Bad arraySpacing, AddVectors().

Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

<name>: Can't add preexisting symbol.

Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

<name>: Enum type mismatch.

Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

<name>: Hash table too full.

Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

<name>: Symbol not found.

Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

A command used only by one mode was entered in another mode.

Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Analog: initialization timed out.

During initialization the circuitry used to read analog input channels failed to initialize properly.

Attempt to exceed max boundary

An M command was issued to a position beyond the highest in the range of the motor. Instead it was moved to the highest legal position.

Attempt to exceed min boundary

An M command was issued to a position beyond the lowest in the range of the motor. Instead it was moved to the lowest legal position.

Bad command, no config variables:

A command was issued which required configuration when no configuration was loaded. The subsequent message indicates the command. If the instrument is in Cosmac mode at the time, it also responds immediately with "Sorry, need configuration variables."

Bad command string. Command string buffer cleared.

An illegal command was (not) processed. The subsequent message indicates the command.

Bad digital output setting. Only ON/OFF allowed.

(Self-explanitory)

Checksum bad in low level command.

During initialization, loadmode or opmode a message with a bad checksum was received. This is normal if an initialization starts while a packet is being sent and is of no consequence at that time. At other times it indicates a noisy communication line.

Command not accepted while another in progress.

Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Config signature did not write properly.
The configuration was not correctly written to Flash memory. Possibly the Flash memory chip has failed.

Flash config checksum error.
The data in the configuration is corrupted. Possibly the Flash memory chip has failed.

Flash config memory full.
Configuration can be saved to Flash memory(see SAVE command) only four times. Reload the firmware.

Lamp <number>: told neither ON, OFF.. what??
Only ON and OFF are valid settings for a lamp.

MAIN.C : motor initialization timed out.
Motor initialization failed to complete in the allotted time (RESET.TIME.OUT). Operation proceeds with the motors which did initialize.

Motor <number>: appears stuck with a reference sensor activated.
An attempt was made to initialize a motor but the motion which should have removed the blocker from a reference sensor did not do so.

Motor <number> became lost during M command.
Motor has been reset to its reference position.

Warning that a motor encountered an end of travel limit. This indicates that for some time prior to this message the motor was not in position.

Motor <number>: configured as nonexisting, cannot be moved/reset.
An attempt was made to move a motor which has been configured to a MOTOR.CLASS of NOMOTOR.

Motor <number>: IIC communications error
Error communicating with the controller for the given motor. If this error persists it indicates a failure in the instrument electronics.

Motor <number>: Motor busy.
Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Motor <number>: Motor lost.
The motor controller and the instrument controller are out of step. This error will be corrected next time the moter is moved. If this error persists for the given motor, please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Motor <number>: Move attempted outside of logical bounds
An attempt was made to move the given motor out of bounds. If this error persists, please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Motor <number>: Movement attempted with too large a jerk
Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Motor <number>: Movement attempted with too large an acceleration
Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Motor <number>: Movement attempted with too large a velocity
If this error persists for the given motor, please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.

Motor <number>: time allotted (<ss> seconds) for motor movement has expired. Motor stopped.

The value <ss> comes from the MOTOR.TIME.OUT configuration parameter.

New value set for watermark <nameOfWatermark>: <latestMark> <unitsOfWatermark>.
The indicated watermark value has been changed to <latestMark>. The possible watermarks are identified in Appendix H.

No Flash config segment in Flash to copy into RAM upon initialization
Attempt to initialize when no configuration information had been loaded yet. This message is normal as part of the process of loading new firmware.

Parallel command operation not supported:
A command was issued which requested that two operations run in parallel when that is not legal. The subsequent two messages indicate that the command is bad and present the command. The following commands cannot start while another command is still in operation: I, PMT, R, SAVE, STEPS, USECONFIG

PMT counter failure
The two independent counters on the PMT did not match count rates (differed by more than 2).Counter 2 has been disabled until explicitly re-enabled or until the instrument reinitializes.

Reset <requestedReset> -> <actualResetType> from <resetTime> until <restartTime>. Counts: <tepidResetCount>,<warmResetCount>

This is an information message. A message of this form is added each time the instrument initializes. The fields:

<requestedReset>

The type of initialization that was requested. Possibilities:

Warm simply reset all the hardware to default settings

Tepid rebuild the content of volatile RAM

Cold rebuild the non-volatile RAM and volatile RAM, then reset all the hardware to default settings

No not requested at all; either the power was cycled or the watchdog circuit restarted the firmware

<actualResetType>

The type of initialization that was actually performed. This can be

Warm, Tepid or Cold. The log is cleared unless this is Warm

<resetTime>

The last time read from the clock before the initialization started (e.g. just before power down). This is only guaranteed to be valid on Warm resets although it is normally valid for Tepid resets as well.

<restartTime>

The first time read from the clock after the initialization started (e.g. just after power up). This time may be incorrect on a cold start.

<tepidResetCount>

The number of tepid resets attempted since the last successful initialization

<warmResetCount>
Please notify SCI-TEC <info@sci-tec.com> of the circumstances

The number of warm resets attempted since the last successful initialization

Resetting zero position illegal here:

When several motors are told to move simultaneously, none may move to a -ve step position, thereby resetting the actual position of 0. The subsequent message indicates the command which contains the error.

Second Flash operation attempted while one in progress in which this message was generated.

Unknown RCommand state called.
Please notify SCI-TEC <info@sci-tec.com> of the circumstances in which this message was generated.