



BREWER MKIV
SPECTROPHOTOMETER
Operator's Manual



Examples:

V, 120 <Return>

Set the baud rate to 1200 bps, echo enabled.

V, 120, 1 <Return>

Set the baud rate to 1200 bps, echo disabled. (Refer to section 3: Communicating via an ASCII Terminal for further examples.)

5.15 Z: Transmit Contents of Specified A/D Channel

Syntax: Z

Description:

Digitize the analog channels specified in a previously defined A/D (analog-to-digital) Table, then transmit to the Terminal the digitized values as a comma-separated record. The A/D Converter is a single-ended, 8-bit device whose output is a byte-value in the range 0...255, corresponding to an analog range of 0 to 5.0 volts. The list of A/D channels is shown in Table cwb.5-4.

A/D Channel	Channel Name	Conversion Factor	Offset	Typical Reading Byte Value	Engineering Value
0	Brewer Temperature 1	0.3620°C/bit	-33.27	173	29.4°C
1	Brewer Temperature 2	0.3620°C/bit	-33.27	-	24.7°C
2	Brewer Temperature 3	0.3620°C/bit	-33.27	-	23.1°C
3	H.T. Voltage	10.94 V/bit	-840.0	200	1348 V
4	+15 V Power Supply	98.5 mV/bit	0	148	+14.6 V
5	+5 V Power Supply	24.4 mV/bit	0	205	+5.0 V
6	-15 V Power Supply	97.7 mV/bit	0	150	-14.7 V
7	+24 V Power Supply	117 mV/bit	0	212	+24.8 V
8	Rate Meter	1950 pulses/bit	0	200	390000
9	Not Used	-	-	-	-
10	Not Used	-	-	-	-
11	Not Used	-	-	-	-
12	+5 V Secondary Supply	24.4 mV/bit	0	210	+5.1 V
13	-8 V Secondary Supply	38.8 mV/bit	0	213	-8.2 V
14	Standard Lamp Current	10.68 mA/bit	0	150	1.6 A
15	Standard Lamp voltage	48.5 mV/bit	0	220	+10.7 V

Table cwb.5-4: To convert the returned decimal value to engineering units multiply by the appropriate conversion factor then add the listed offset. For example, a reading of 148 for the +15 V Power Supply corresponds to $98.5 \times 148 = 14578$ mV 14.6 V.

**BREWER MKIV Spectrophotometer
Operator's Manual**

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0. INTRODUCTION

This manual describes how to operate the Brewer Spectrophotometer via an IBM PC compatible type microcomputer. Although this manual is intended to be useful for both the novice user and the experienced Brewer operator, it assumes that you are familiar with the Brewer's purpose and specifications.

Chapter 1 explains how to get started with the Brewer Software.

Chapter 2 is an overview describing how the user interacts with the Brewer Program. The Brewer Command Summary is a complete list including a brief description of the host of Brewer commands.

Chapter 3 is a collection of operating hints and guidelines.

Chapter 4 explains how to recover from various errors.

Chapter 5 explains how to re-configure files for a different computer.

The attachments contain the description of the brewer system and the description of communications between the PC and the Brewer.

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1. UNPACKING AND SETUP INSTRUCTIONS

1.1 Brewer Setup

NOTE: Before accepting shipment from the carrier, inspect shipping container(s) carefully for damage. If any dents or major scratches, cuts, etc. are evident, then file a damage claim with the carrier. Only after incoming inspection and operation tests of the Brewer are successfully completed, should the shipment be accepted.

Remove the lid and foam cover from the crate containing the Brewer and carefully remove the cables, manuals and Brewer. Review sections 2 and 3 of the Operator's Manual, and set up initially as follows without the Azimuth Tracker.

Remove the Brewer case cover by unlatching the four latches. Inspect for any damaged parts. Connect the two circular connectors to the Brewer. AC power cable #BA-W12 connects to "AC POWER" and the data cable #BA-W14 connects to "COMPUTER" (Refer to Brewer cover for connector markings).

Setup the computer equipment (see figure om.1-1). Refer to the manuals for each individual piece of equipment. Note that the printer shipping screws are removed prior to use.

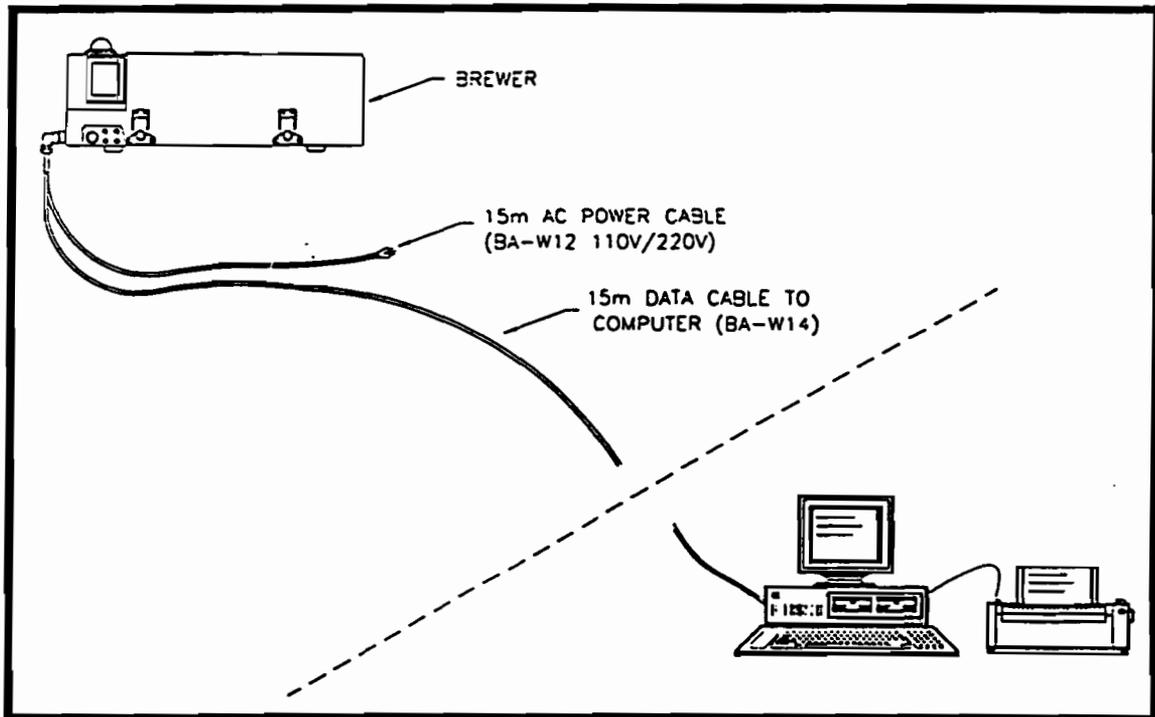


Figure om.1-1: Brewer/Computer Equipment Setup

Connect the data cable to the RS232 (Comm Port) connector on the back of the control computer. Note some computers may have a 9 pin RS232 connector in which case an adapter is required.

Plug the power cable into an electrical outlet and press the ON/OFF switch. A "click" should be heard from the slit mask inside the Brewer, the green LED should light.

The Brewer internal clock (located on the Clock Monitor board, refer to page 7.5.4-1 of the Maintenance Manual) has battery back-up. Switch SW1 is set to the middle position (OFF) for shipping. Move the switch to the left position (when facing back end of board, installed in card rack) to turn battery power to ON.

If the Brewer software is not yet configured, proceed to section 6, "Configuring the Control Computer".

After configuring the Control Computer, then proceed to section 2.1, "Loading the Brewer Operating Program", and load the operating program as per the instructions.

After reviewing section 3, "Brewer Commands Overview", perform the following operation tests:

HG: mercury lamp calibration (see table 5.1 in Acceptance Manual)

SL: Standard Lamp Test (see table 5.2 in Acceptance Manual)

RS: Run Stop Test (see table 5.4 in Acceptance Manual)

DT: Dead Time Test (see table 5.3 in Acceptance Manual)

AP: A/D Voltage Printouts (see page 10 in Acceptance Manual)

FR HG: Micrometers/FW#3 reset and mercury lamp calibration
(see table 5.1 in Acceptance Manual. The HG test first step set position should be within 5 steps of the final position. If greater than 5 steps, the micrometer #1 offset constant may need to be adjusted)

SL: Standard Lamp (repeat 4 times) (see table 5.3 in Acceptance Manual)

Compare the results with those in the Acceptance Manual and consult SCI-TEC if any are out of tolerance.

The Brewer and Control Computer are normally left ON at all times (24 hours a day).

1.2 Azimuth Tracker (Option B) Setup

The azimuth tracker is delivered in two parts; those being the tripod stand and the tracker enclosure (see figure om.1-2). The tripod stand can be assembled by spreading the three legs such that the pads on the ends of the legs rest on the ground, after which the supporting members from each leg are bolted to the top of the stand.

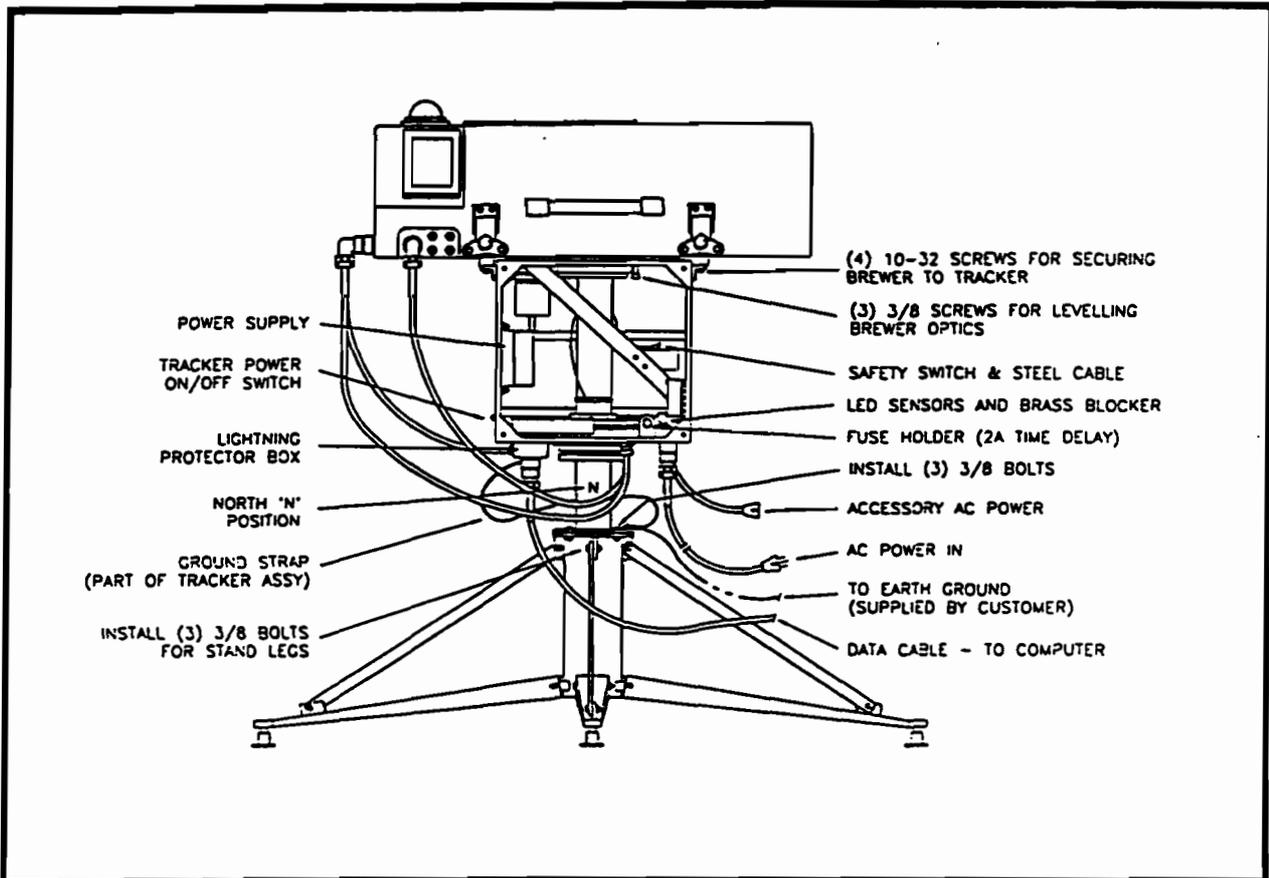


Figure om.1-2: Azimuth Tracker & Tripod Stand (front view with cover removed)

The azimuth tracker enclosure can then be bolted to the top of the stand. Ensure the north position marking "N" on the base of the pedestal points approximately north for sites in the northern hemisphere. For southern hemisphere sites, the marking "N" can be pointed approximately south (optional).

The ON/OFF switch and power indicator are located on the left side near the front of the enclosure. The switch controls the input power to the power supply for the azimuth stepping motor and drivers.

Remove the front cover of the azimuth tracker (the cover closest to the ON/OFF switch). Rotate the tracker until the blocker (brass angle 3.8 cm wide on the large circular plate on the bottom of the pedestal) is situated such that it is blocking the LED sensors. This position is defined as "zero", the front of the tracker should be pointing north. In this position, ensure that the tracker can rotate a full 360° clockwise without activating the safety switch.

The safety switch is an assembly attached to the pedestal by a steel cable. The cable is attached to the switch by nylon string with a breaking strength of 3 kilograms. The switch is set such that if a failure occurs and the tracker goes past the position sensors without detection, in either direction (CW or CCW), the switch will be activated and effectively shut power off to the tracker electronics. This usually prevents damage to data and power cables.

The allowed distance of travel from starting position is approximately +450° CW and -100° CCW before the safety switch is activated. The nylon string provides an additional safety device by protecting the switch should the operator attempt to rotate the tracker in the wrong direction after a failure has occurred. The tracker should not be operated without this safety device in place. The nylon string can be obtained at a hardware store as "8lb test fishing line".

Proper electrical grounding is necessary to ensure the lightning protector circuit will operate correctly in the event of a voltage surge. The Brewer data circuit is protected by a lightning protector box which is located on the bottom of the tracker and is connected to the stand with a braided ground strap. After the final operating location of the Brewer and tracker has been determined, a grounding wire/cable must be continued from the tracker stand to earth ground.

1.3 Leveling the Tracker

The tracker can now be leveled. Since the manufacturing process cannot ensure that the top of the enclosure is exactly perpendicular to the axis of rotation, the procedures listed below should be followed. Ensure that the tracker power is turned OFF during this procedure.

Place an accurate bubble level or clinometer on the top of the tracker enclosure with the front facing north. Slowly rotate the tracker a minimum of 270° and observe the bubble level. The bubble should remain in the same position throughout the rotation. Adjustments for the appropriate leg pads may be required to obtain this condition. Note that the bubble may or may not be in the center of the level.

After this procedure the tracker should be rotating about the local vertical to the accuracy to which the bubble can be read.

It is recommended that the supplied stand tie-down kit (chain & turnbuckle) be attached to a suitable eyebolt (~.25" dia) embedded in a concrete pad or roof beam to ensure the Brewer and stand do not move during operation. Alternately, a minimum of (3) 10 kilogram bags of sand can be used. Place one on each stand leg.

1.4 Attachment of Brewer to Azimuth Tracker

The three 3/8-24 SST bolts (rounded ends) protruding from the top of the tracker enclosure are to level the Brewer optics assembly to the tracker. The screws are preset at the factory if all the units are purchased together. These bolts fit into (3) v-grooves (under each shock mount holding the optics assembly) to form a kinematic mount.

Carefully mate the Brewer to the tracker and attach with (4) #10-32UNF x 5/8" long screws provided. NOTE: Ensure the hex tool is held straight when starting these screws to prevent cross-threading.

The AC power cable #BA-W12 supplied with the Brewer is used to power both the Brewer and the Azimuth tracker. Connect the power cable to the connector beside the short accessory power cable on the bottom of the tracker. Then connect the tracker power cable #BA-W30 (part of the tracker) to the connector marked "AC POWER" on the side of the Brewer cover. The remaining cable from the tracker

(#BA-W19) connects to the connector marked "AZIMUTH" on the front of the Brewer cover.

NOTE: For installations with 220VAC incoming power, the male plug on the power cable (BA-W12) will have to be replaced with an appropriate plug (not included) to match that of the AC power receptacle.

Connect the data cable #BA-W14 to the lightning protector box located on the bottom of the tracker. Then connect the cable which comes from the lightning protector box (#BA-W60) to the connector marked "COMPUTER" on the side of the Brewer cover.

Once all the cables have been installed and power supplied to the tracker and Brewer, the incoming AC power voltages should be measured on the accessory AC power cable (see figures om.1-2 & om.1-3) to ensure they match the specifications listed in the table below.

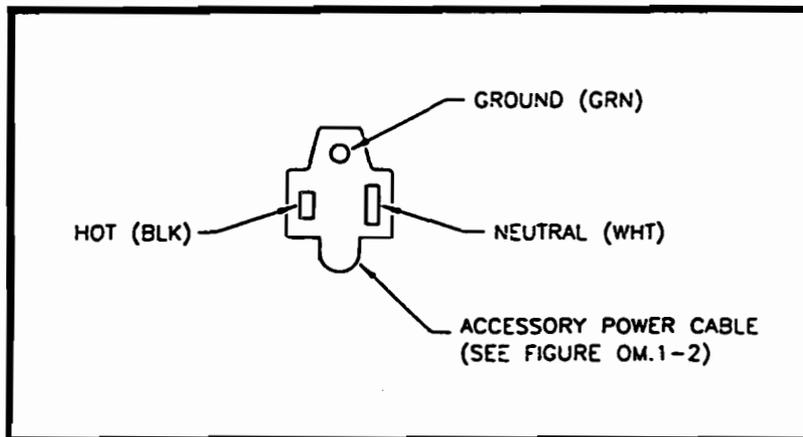


Figure om.1-3: Measuring Voltages for Incoming AC Power.

measured voltages between....	220VAC installations	110VAC installations
ground & neutral	0 VAC	0 VAC
ground & hot	220 VAC	120 VAC
neutral & hot	220 VAC	120 VAC

1.5 Azimuth Tracker Maintenance

The Azimuth Tracker requires very little maintenance. The friction drive, the 25 cm aluminum drive wheel and the 1.2 cm stainless steel rod should be inspected and cleaned with a dry tissue at least every 3 months. It should be done sooner if the steps/revolution test indicates a change. This test should be done on a weekly basis as a method of confirming azimuth tracker operation. If the variance is greater than 10 steps, the cleaning procedure should be done as soon as possible.

The friction drive arm is set with 20lbs of tension on the lower spring and 8lbs on the upper spring to provide drive friction and gear mesh pressures respectively.

The system is protected with a standard 2 amp fuse in the holder at the front of the tracker, with access by removing the front cover. The power supply voltage should be checked periodically and should measure 5.30 volts.

Please do not hesitate to contact the manufacturer should you require additional information.

1.6 Brewer Lubrication

The brass gear on the zenith drive has a hole to allow a small drop of low temperature rated light oil to be applied approximately once a year.

2. GETTING STARTED

The Brewer Spectrophotometer operates with an IBM PC compatible computer with dual disk drives or a hard disk and asynchronous serial card. The Brewer System consists of four major components: The Brewer Spectrophotometer (which may be mounted on an Azimuth Tracker), the microcomputer, and compatible printer.

If you are setting up the Brewer System for the first time you should read the Brewer Acceptance Manual for instructions on unpacking, configuring, and testing the Brewer System.

Also read chapter 6 for information about configuring the control computer to work with your Brewer.

* The Spectrophotometer is connected to the RS232 Port of the PC via the 15-meter weatherproof Data Cable.

* The printer is connected to the PC printer port.

If you have not already done so you should make a back-up copy of the Brewer Operating Program disk.

Store the original in a safe place; use the copy for the day-to-day running of the Brewer System.

2.1 Loading the Brewer Operating Program

This section details the procedures which should be carried out if your Brewer System is being readied (initialized) for the first time. It also assumes the program disk has been configured for the computer being used, i.e. proper DOS / GWBASIC operating systems, disk drives and directories allocated and bootup requirements have been observed. See Chapter 6 for details on configuring a new control computer for the Brewer.

Check that all component parts of the Brewer System are present and properly interconnected (serial communications cable from PC to Brewer; and from PC to printer), that each unit is powered by AC line voltage, and that the printer is online.

If you are running the Brewer software from diskette, insert the Brewer Operating Program diskette into drive a:, close the drive door and create a data directory (C:\BDATA) on the hard drive. To load the Brewer program, turn the PC power switch off then on or press the 3 keys, CONTROL/ALT/DEL simultaneously. The screen will display the following sequence:

DOS version, etc.

and files copied, etc.

The screen will clear, then a series of 'merging' messages will appear:

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Merging init.rtn

op.st.rtn

inst.rtn

da_lo.rtn

po.rtn

The top of the screen will then display a date, instrument number, location, time, etc.;

nov 14/89 day=311 * O3 #050 * AES HQ C.U.T. I 22:50:31

menu 652208 bytes free RS232 IN: OUT:

Your date, location, and instrument number display may not be the same as shown above since this depends upon when and where the program disk was last used and with which instrument. The (bytes free) is an indication of how many bytes are available on the data drive. The bytes free is calculated at the end of the initialization and reset sequence. Note: (NO2) changes to (O3) for Ozone operation.

At this time the printer will advance the paper drive and the screen will then indicate:

POSITION PAPER TO TOP OF PAGE

* PRESS RETURN WHEN READY *

Check that the paper is positioned correctly in the printer at the top of form position with the fold about 0.5 inch (12 mm) above the print-head. This ensures that the printouts will be neatly arranged with proper margins at the top and bottom of each page. Now press Return or wait about 15 seconds.

The instrument constants will now be printed:

Note: Following is for O3 and is slightly different for NO2.

```
BREWER INSTRUMENT #050
.....
*SLIT          * 1 * 2 * 3 * 4 * 5 *
.....
*WAVELENGTH(nm) * 306.321* 310.057* 313.495* 316.814* 320.010*
*TEMPERATURE COEFFS* 5.260* 4.355* 3.554* 2.700* 1.500*
.....
ETC values : 03 = 3422 : S02 = 3853
03 absn coeffs : 03 = .332 : S02 = 1.079
S02 absn coeffs : 03 = 0S02 = 2.35
Micrometer steps/deg = 0
Calibration step# = 136 * Umkehr offset = 1610 * O3 Diode offset = 3050
Zenith steps/rev = 2816 * Dead time = 4.3E-08 * slit mask motor delay= 74
M-10 Mode change = 2650 * M-6 O3/S02 set = 242
Ozone observations for Nov 14/89
Observations made at AES HQ
```

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Lat. = 43.782; Long= 79.47; Pressure = 1000

Your values may differ, for these constants are instrument specific and no two instruments are identical. Do not concern yourself with these constants at this time for they have been set by the manufacturer and need only be changed after an instrument repair. If the wrong instrument # file appears then after the reset, etc. the NO command will have to be used to select the correct instrument.

The PC will then issue a reset command to the Brewer, and will wait 7 seconds for the Brewer to respond:

```
RESET IN 7 SECONDS...6...5...4...3...2...1
```

After the 7-second count down the PC should briefly indicate

```
RECEIVING BREWER RESET MESSAGE:
```

Before displaying and printing the power-up message transmitted by the Brewer:

```
BREWER SPECTROPHOTOMETER
#050
AES SCI-TEC
CANADA
VERSION 39.10 FEB 1, 1994
```

The top two lines of the screen should show the time, communications activity, date, location, and instrument number:

```
nov 14/89 day=311 * O3 #050 * AES HQ C.U.T. I 22:50:31
menu 652208 bytes free RS232 IN: OUT:
```

The C.U.T. (Coordinated Universal Time) is a display of the Brewer's internal clock in hh:mm:ss format;. 'RS232 IN: OUT:' is an indicator of input and output communications between the computer and the Brewer. These two status lines are always updated except when the PC is recording data.

Below the status lines should appear one or more 'INITIALIZING' messages:

```
*** INITIALIZING BREWER MOTORS ***
*** ZEROING ZENITH
*** ZEROING AZIMUTH
```

During each step the PC and Brewer are in communication with each other. Confirm this by watching the "RS232 IN: OUT" display at the top of the screen: character (*) should appear to rapidly alternate back and forth in the spaces following the "RS232 IN: OUT". If your Brewer System is fully automated then allow all the above steps to run to completion (if the azimuth tracker is not being used then press DEL key to abort the zeroing azimuth operation). DO NOT ABORT if the azimuth tracker

is operable since this will cause a false zero to be assumed by the Brewer internal micro-computer. If the ZEROING ZENITH and AZIMUTH message do not appear then check the instrument constants file (IC command) for proper settings, after the main menu appears.

The zeroing of the Azimuth Tracker will take approximately two minutes. When finished, the printer will display:

Azimuth zeroed at 09:10:20 Discrepancy = N

where the discrepancy value, N, is usually a small positive or negative number (following power on start up N will be large). The discrepancy is the difference between the actual and the microprocessor-stored step position for the Azimuth Tracker.

The initialization is now complete. The date and location were read in from the program disk and represent when and where the program disk was last used. The time was read in from the Brewer clock providing the clock is 'ON' in IC file. These parameters (which are displayed at the top of the screen) are now used to calculate where the sun is and an automated Brewer/Tracker System should align the Brewer toward the sun. If any of the time, date, or location fields are not correct, they will have to be updated with the TI (time reset), DA (date reset) or LL (location update) routines.

After the program has positioned the Brewer to face approximately toward the sun (this takes between 30 and 60 seconds) the screen will display the Main Menu: Note: the operating mode is shown next to the command descriptor (main menu NO2). It can be toggled between NO₂ and O₃ / SO₂ by the command O3 an N2. Eg.: If in NO₂ operation, issue a O3 command to switch to O₃/SO₂ operation.

```
nov 14/89 day=311 * O3 #050 * AES HQ      C.U.T.  I 22:50:31
menu                652208 bytes free      RS232 IN:  OUT:
mu= 1.886 Tracking Sun                      * za= 58.30
cm->
```

Enter a desired command or select a submenu from the following list:

command	main menu NO2
dm	data management menu
om	operating menu
tm	test menu
hk	housekeeping menu
up	update menu
sm	summaries printout menu
sp	special operating menu
os	operational setup menu
em	extended menu

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Note the screen clock indicator to the left of the time of day display. The "I" indicates the internal clock of the Brewer is in use and an "E" indicates the computer clock is in use. If the clock error message is received 4 times, then the internal clock is turned off and the time is controlled by the computer. When the time is set later, the operator is asked if he wants the Brewer clock turned back on before setting the time.

When the Brewer is taking its common operational measurements in O₃ operation, the above display is replaced with an information box which contains daily mean of DS ozone, ZS ozone, DS SO₂, last DUV result, last SL R6 result and HG temperature information. An example of this display is shown below.

```
nov 14/89 day=311 * O3 #100 * AES HQ C.U.T. I 22:50:31
menu                652208 bytes free    RS232 IN:  OUT:
```

*** taking ds measurement ***

Press HOME to stop

Mean ds O3	274.2
Mean zs O3	270.2
Mean ds SO2	+0.5
DUV at 12:47:51	57.0
SL R6 at 07:45:19	1904
Last HG at 12:49:15	26°C
Current temperature	27°C

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3. BREWER COMMANDS OVERVIEW

3.1 Menu Organization

The Main Menu gives information on how to enter the Brewer commands as well as how to access one of the nine secondary menus.

- | | |
|-----------------------------|------|
| (1) Data Management Menu | (DM) |
| (2) Observations Menu | (OM) |
| (3) Test Menu | (TM) |
| (4) Housekeeping Menu | (HK) |
| (5) Update Menu | (UP) |
| (6) Summaries Printout Menu | (SM) |
| (7) Special Operations Menu | (SP) |
| (8) Operational Setup Menu | (OS) |
| (9) Extended Menu | (EM) |

A notable feature of this menu system is that it has an 'open' structure: any command which appears on one of the six menus can be directly accessed from any of the six menus, as well as from the Main Menu. Thus the 'menus' serve as 'help' screens rather than strict menu-selection instructions.

Note that there is also a menu of "non-menu" items (NM) that can be viewed. These commands should NOT be run by the user; the program automatically accesses them when required.

The nine secondary menus, and the non-menu items, are listed below:

DM: DATA MANAGEMENT MENU

command	data management menu
dd	print data directory
dds	display data directory
ld	long data format
sd	short data format
nd	initialize new data disk
nr	no data recording
di	turn on data recording
pn	turn printer on

command	data management menu
pf	turn printer off
pd	print to disk
pb	play back data (Bxxxx)

OM: OBSERVATIONS MENU

command	observations menu
ds	direct sun
fm	focused moon
fz	focused sun
sc	direct sun scan
ss	direct sun UV scan
ua	time extended UV scan
uf	fast UVB scan
um	umkehr measurement
uv	UV scan
ux	extended UV scan
zb	zenith blue
zc	zenith cloud
zp	zenith perpendicular
zs	zenith sky

TM: TEST MENU

command	test menu
ci	slit 1 scan
dsp	dispersion test
dt	dead time
hg	mercury lamp calibration
hv	high voltage adjust
rs	slit mask run & stop
sh	slit mask timing
sl	standard lamp calibration
sr	azimuth steps-per-rev
tt	setup teletype control
tu	test UVB alignment

HK: HOUSEKEEPING MENU

command	housekeeping menu
po	prints out instrument info
ap	print a/d monitor

command	housekeeping menu
az	zero azimuth tracker
ze	zero zenith drive
cf	edit instrument constants
ic	edit system configuration
lf	edit station locations
si	manually site the sun
sim	manually site the moon
re	resets instrument
fr	reset FW#3 and micrometer
st	read instrument status

UP: UPDATE MENU

command	update menu
da	change date
ll	change location
no	change instrument number
te	change temp (39°C/4.25v)
ti	change time
co	add comment

SM: SUMMARIES PRINTOUT MENU

command	summaries printout menu
sum	make daily summary file
ed	initiate end-of-day sequence
ed-pd	end-of-day (print to disk)
ub	DUV summary
dssum	direct sun summary
fmsum	focused moon summary
fzsum	fz ozone summary
hgsum	mercury lamp summary
nosum	NO2 data summary
ozsum	O3 data summary
slsum	standard lamp summary
tcsun	update summary with new TC
uvsum	O3 uvb summary
zssum	zenith sky summary

SP: SPECIAL OPERATIONS MENU

command	special operations menu
cz	custom scan
ex	exit to DOS
qs	quick lamp scan
shell	shell to DOS
ul	UV lamp scan
x1	extended UV lamp scan

OS: OPERATIONS SETUP MENU

command	operations setup menu
cy	set slit mask cycles
au	setup auto command sequence
auc	repeat au
cs	setup command sequence
sa	make printout of solar angles
se	edit a schedule
sk	run a schedule today
skc	run a schedule continuously
o3	switch to ozone mode
n2	switch to NO2 mode
w0-w4	waits (1/5/10/20/30 min.)

EM: EXTENDED MENU

command	extended menu
b0	lamps off
b1	mercury lamp on
b2	standard lamp on
ddp	print program directory
ff	printer form feed
tr	turn tracker on
tf	turn tracker off
sleep	end operations
end_day	sum & print (month/day/year)
as	point tracker to the sun
pz	point to zenith

All menus display the MU (air-mass) and ZA (solar zenith-angle) settings which will be continuously updated during the course of the day, as well as the C.U.T., date, instrument number, location and data bytes available. Pressing the Return key without a command entry causes the Main Menu to reappear.

To select a command, type the appropriate character code displayed in the menu, then press the Return key.

3.2 Reserved Keys: HOME, DEL, CONTROL/BREAK

HOME Key

Press this key to terminate an observation or operation prematurely. This key should not be used unless the message "press HOME key to abort" is displayed on the screen.

DEL Key

This key is not normally used for routine work. It can be used in an emergency to bypass the five-minute warm-up period of the mercury or standard lamps (do not make a habit of using the key for this purpose since it is important that the lamps be fully warmed). This key is also used to terminate some operations, e.g. zeroing azimuth if no tracker present and in Teletype mode (TT).

CONTROL/BREAK Keys

These keys allows you to temporarily halt the Brewer Program so that you can access the GW-BASIC operating system.

Once the CONTROL/BREAK keys have been pressed you should see:

```
BREAK IN XXXX                (PROGRAM LINE #)
```

```
OK
```

You now have full access not only to all GW-BASIC commands, but also to the Brewer Program itself.

There are two ways to reactivate the Brewer program:

* Instruct the program to 'continue' by typing:

```
CONT (RETURN)
```

* The two-line status display should return to the screen. If the program cannot continue, or if the message 'syntax error' or RESUME error is displayed then type

```
RUN (RETURN)
```

This should restart the program from the beginning provided that the in-memory copy of the Brewer Program is intact. If this fails, then the program will have to be reloaded from disk - use the (CONTROL/ALT/DEL) method.

3.3 Brewer Command Summary

This section is an alphabetical listing of each Brewer command, complete with a brief description and an indication of the menu in which the command appears. The commands are printed here in capital letters but when using only small letters are allowed by the software. Furthermore the important tests and measurements are identified with the designators: DAILY, WEEKLY, or TEST. This is to give the operator some guidelines. The commands marked DAILY can and should be used in schedules. The commands marked WEEKLY or TEST are special and should not be used in schedules since they need operator interface. Note that only 2 letter commands can be used in schedules.

AP	<p>Print Out A/D monitor prints instrument values captured by the 16 A/D channels. It is important to monitor +5V PS as a minimum. The command sequence APDTRS (AP followed by dead time test and then run/stop test) should be programmed once in each schedule. Ensure printer is on for this series of tests.</p>	(HK menu) DAILY
AS	<p>Azimuth to Sun if brewer has not been doing measurements then the azimuth tracker stops. This command moves the tracker to the sun.</p>	(EM menu) TEST
AU	<p>AUtomatic operation sets the Brewer System in fully automated mode whereby it follows a predetermined sequence of commands (HG, DS, ZS, DS, ZS, DS, ZS, DS, ZS, UX) until the evening (MU = 8.5), at which time the system produces a daily summary. An operator is required to restart the AU routine the following day. This command is often used in schedules during the mid-part of the day.</p>	(OS menu)
AUC	<p>AUtomatic operation (Continuous) is similar to the AU command, except that the predetermined sequence of commands will control the Brewer System for several days of unattended operation.</p>	(OS menu) TEST
AZ	<p>Zeroing Azimuth Tracker re-orientes the Brewer/Tracker System to its zero-step position. This is a useful test for checking Azimuth Tracker operation and can be used in schedules if desired.</p>	(HK menu) TEST
BO	<p>turn off lamps</p>	(EM menu) TEST
B1	<p>turn on Mercury Lamp is useful in schedules or command sequencing, e.g. b1dshg. This sequence allows a DS to be taken while the lamp is warming up for a HG test. The lamp will be turned off at the end the HG test; however ensure in schedules that there is enough time between zenith angle entries for the tests to be completed or the lamp can be left on.</p>	(EM menu) DAILY
B2	<p>turn on Standard Lamp can be used in schedules like B1 above, however be careful that it is not left on for long periods waiting for the next operation or moon to rise for example.</p>	(EM menu) TEST
CF	<p>update instrument Constants File permits the operator to revise the instrument constants. Necessary when the instrument has been re-calibrated following a repair. DO NOT CHANGE any constants without the agreement of SCI-TEC.</p>	(HK menu) TEST

CI	Lamp scan on slit 1 for scanning either the internal mercury or standard lamps. Note that you must turn the proper lamp on first with the B1W1CI command, (e.g. HG lamp on) wait 5 minutes then scan. The data is stored in the Clddy.### file in a format ready for graphing which includes a log of counts/sec in the last column.	(TM menu) TEST
CO	COmment line permits the operator to enter comments (describing sky clarity, blueness, cloud cover, etc.) Comments are printed and are recorded in the data file.	(UP menu) TEST
CS	Command Sequencing sets the Brewer System on temporary automatic mode of operation whereby it follows a user-specified sequence of commands a given number of times.	(OS menu) TEST
CY	slit mask CYcle setting permits the operator to change the number of slit mask cycles per observation run (usually set at 20).	(OS menu) TEST
CZ	Custom scan special scan capability permits the operator to make a custom scan of internal lamp, external lamp or sky from the quartz window or UV dome. Records setup in CZ.CFG file for automatic repeating of test if desired. The data is stored in the CZddy.### file.	(SP Menu) TEST
DA	DAte update allows the Brewer's calendar date setting to be changed. Under continuous operation with the computer connected to the Brewer the date will switch at 24:00 C.U.T. However operators should check the screen daily for proper date and time. To enter a new date type DA, then enter numeric day (2 digits), 01 for 1st, etc. and similarly with the month and year. Press return after entering the year.	(UP menu) TEST
DD	Disk Directory prints the directory of the data-storage disk.	(DM menu) DAILY
DDP	Program Directory printout prints the program directory.	(EM menu) TEST
DDS	Data Directory display to the screen	(DM menu) TEST
DI	Disk recording instructs the system to begin recording data to the disk drive specified in the constants file. If the DISK TURNED OFF! message appears at top of the screen then the DI command must be issued to correct the fault. The NR command disables data-recording. The DISK TURNED OFF! message appears if the data disk is full or not installed.	(DM menu) DAILY
DM	Data Management menu displays the Data Management Menu. This menu provides commands which control disk operations, data-output formatting, and production of daily data summary printouts.	(Main Menu) TEST
DS	Direct-Sun observation executes an O ₃ , and SO ₂ observation with the instrument oriented towards the sun. Data is printed, and normally stored on disk. The ground-quartz plate is in (Filter #1 position #1), iris is closed and Filter #2 automatically selects the correct filter	(OM menu) DAILY

before this measurement starts. The Brewer performs a series of five (20 cycle) observation runs. The raw photon counts of the dark count and five wavelengths and a calculation of ozone and sulphur dioxide is printed after each observation. After the fifth scan a set of summary statistics are printed and the data stored on disk. At the end of each run, the slit #5 counts are checked and if counts are greater than 4 million, measurement is terminated. This is provided for cloud conditions. In NO₂ mode a DS measurement of NO₂ is performed as described above.

DSP	DiSPersion test	(TM menu)
	collects data for a dispersion test analysis. This test is used to determine the absorption coefficients, wavelength versus step number constants and resolution versus step number equations for each slit.	
DSSUM	Direct-Sun data SUMmary	(SM menu) TEST
	instructs the PC to print the daily data-summary of all DS observations made during the local day.	
DT	photomultiplier Deadtime Test	(TM menu) DAILY
	is an instrument test which measures the deadtime of the photomultiplier and photon-counting circuitry at high and low intensity levels from the standard lamp. The results should agree within 5% of the constant for the instrument. This test should be done at least once a day and results printed, e.g. the sequence APDTRS is included in ED sequence.	
ED	End of Day	(SM menu) TEST
	initiates the following sequence of end-of-day commands: SUM, OZSUM, NOSUM, FMSUM, FZSUM, HGSUM, SLSUM, UVSUM, ZSSUM, PO, AP, DT, RS, RE and FR. This operation is performed automatically when in schedule operation at local midnight. It is not necessary to program ED in the schedules.	
ED-PD	End of Day - Print to Disk	(SM menu)
	performs an end of day (ED) identical to ED, except that all data is printed to a disk file instead of on a printer. This is useful if you wish to save paper.	
EM	Extended menu	(Main Menu)
	displays the extended menu. This menu contains options for controlling the lamps (such as B0), the tracker (such as TF and AS), and so on.	
END_DAY	END of DAY	(EM menu) TEST
	performs an end of day (ED) on previous dates, e.g. type END DAY Apr 28/89 and if there is a day file (B11989.011) on the data disk then a SUM file is created and the summaries are printed.	
FF	Form Feed	(EM menu)
	forces a form feed on the printer connected to the computer.	
FM	Focused Moon Observation	(OM menu) DAILY
	executes an O ₃ and SO ₂ observation with the Brewer oriented towards the moon. The normal-filterwheel setup is Filter #1 to position #3 (open) and Filter #2 to position #0. The Brewer performs a series of five (80-cycle) observation runs. The rest of the measurement is like a DS observation and the same constants are used to calculate the ozone and sulphur dioxide. In NO ₂ mode a DS measurement of NO ₂ is performed as described above.	
FMSUM	Focused Moon SUMmary	(SM menu) TEST
	instructs the PC to print the daily data-summary of all FM observation made since the previous local midnight. Note the command will only work if the summary file	

for that day exists. This command is performed automatically under SKC operation or with the ED command.

- FR** **Filter wheel #3 Reset and micrometer diode search** (HK menu) TEST
is a test which measures the micrometer and FW #3 motor (if present) steps between the normal setting and the diode reference. These measured constants are stored in the instrument constants file.
- FZ** **Focused sun observation** (O₃ only)(OM menu) DAILY
a low sun angle (high zenith angle) direct sun type of measurement that corrects for scattered radiation. The scattered radiation signal is measured by off-setting the sun's image from the entrance slit by 1°. The scattered signal is then subtracted from the focused (direct) sun signal to give better representation of the incoming direct radiation. This routine will give reasonably accurate values down to solar elevations of 5° (airmass = 8.2) compared to 10°-20° (airmass = 5-3.2) without corrections.
- FZSUM** **Focused sun observation SUMmary** (SM menu) TEST
instructs the host computer to print the daily data summary of all FZ observations performed that day.
- HG** **Mercury wavelength calibration test** (TM menu) DAILY
is a frequently conducted test which precisely locates the mercury-line spectrum, then re-positions the micrometer so that the diffraction grating disperses the five operational wavelengths onto the appropriate exit slits. If the micrometer is in the wrong position and the test fails then the diode offset is measured and the micrometer is re-positioned to the diode offset constant value and the test is re-started.
- HGSUM** **Mercury lamp data SUMmary** (SM menu) TEST
instructs the PC to print the daily data summary of all HG tests conducted that day.
- HK** **HouseKeeping Menu** (Main Menu)
displays the housekeeping menu. This menu contains routines needed for general maintenance such as IC, RE, FR and so on.
- HV** **High Voltage test** (O₃ only)(TM menu) TEST
is an instrument test that determines the optimal high-voltage setting for the photomultiplier. This test is normally performed at the factory before the Brewer is shipped to the customer. It would only be performed by the user after repair or replacement of one or more of the instrument's optical or mechanical components, or when correct instrument performance needs to be verified.
- IC** **Instrument Configuration** (HK menu) TEST
displays the current status of the Instrument's Configuration (a list of upgrade options either present or not present) on the screen, and allows changes to be made.
- LD** **Long Data output format to printer** (DM menu) TEST
sets the printer data-output to expanded format (the default setting is SD: short data-output format). If LD appears in the DM menu then the current mode is SD (short) format.
- LF** **Location File update** (HK menu) TEST
displays the list of the location names and geographical coordinates of known Brewer instruments sites throughout the world and allows changes to be made.

LL	Location update permits updating the location coordinates (latitude, longitude) and the location identifier at the top of the screen. Normally used when the instrument is on a moving observation platform (e.g.. airplane or ship) and when an instrument is first used at a different site.	(UP menu) TEST
N2	switch to NO₂ operation from O₃/SO₂	(OS Menu) TEST
ND	New data Disk formats a new data disk for the user.	(DM menu) TEST
NO	instrument Number permits the disk-stored instrument identifier to be changed in the event the program disk is used with another instrument.	(UP menu) TEST
NOSUM	NO₂ Summaries produces DS and ZS summaries together with daily statistics.	(NO ₂ only)(SM menu)
NR	No data Recording instructs the PC to shut off data recording. However, the data will still be printed. Use the DI command to re-enable recording. Note when the NR command appears on the Data Management menu it means that the system is currently recording data. The message ! DISK TURNED OFF! appears on the second line of the screen in place "Bytes Free" when this command is in use.	(DM menu) TEST
O3	switch to O₃/SO₂ operation from NO₂ this command will cause a MKIV Brewer to change order filter in FW#3 to blue type (BG-13) and adjust the grating to the NO ₂ operating wavelengths.	(OS Menu) TEST
OM	Operating Menu displays the Operating Menu which is a listing of command codes for frequently used observations and instrument tests.	(Main Menu) TEST
OS	Operational Setup Menu displays the operational setup menu. This menu contains routines that are needed when the program is configured to work with a new or different Brewer instrument.	(Main Menu)
OZSUM	OZone data SUMmary instructs the PC to print in chronological order the daily data summaries of the DS and ZS ozone observations made during the local day. Stores daily statistics in a OZOAVG.### file.	(O ₃ only)(SM menu) TEST
PB	data PlayBack allows the operator to select any day's stored data file and have it printed. Enter filename only (i.e. B11889 without the extension). This operation was designed mainly for correcting data e.g. with new temperature co-efficients, and so a new data file entitled OP11889.011 is created on the data disk.	(DM menu) TEST
PD	Print to Disk directs printer to a file. Data will be written to a "D" file on disk. Note: you must use the PF command to close the file after writing to it.	(EM menu) DAILY
PF	Printer off - saves paper	(DM menu) DAILY
PN	Printer on.	(DM menu) DAILY

PO	PrintOut instrument constants allows the user to print the contents of the instrument constants file. (Frequently used as a convenient means for checking the top-of-form position for the printer.)	(HK menu) DAILY
PZ	Point to Zenith sets the zenith motor-drive to zero degrees zenith angle, i.e., the zenith prism is pointing vertically upwards.	(EM menu) TEST
QS	Quick Scan is an instrument test which is used in conjunction with UL tests for quick look results of lamp scan result changes. Test produces a printout of wavelength, intensity, and % change from the first measurement on file.	(SP Menu) TEST
RE	REset and initialize Brewer motors sets all installed Brewer motors (except for micrometer motor) to their zero position: the azimuth and zenith motors move to optically-sensed end stops; the other motors move into mechanical end stops.	(HK menu) DAILY
REP	REPort displays the following instrument average files, or their NO2 equivalents if a MKIV Brewer is in NO2 mode: SLOAVG, HGOAVG, APOAVG, DTOAVG, MIOAVG and RSOAVG. The range of days to print or view is selectable.	(-)
RS	slit mask-motor Run/Stop test is an instrument performance test that verifies whether the slit mask motor is operating correctly or not. In schedule (SKC) operation it is recommended that this test be done at the end of the day with the analog voltage and dead time test as follows: APDTRS. The RUN/STOP ratios for slit mask positions 2 through 6 should be in the range of 0.997 to 1.003.	(HK menu) DAILY
SA	Solar Angle printout is a separate routine which will calculate and print the solar and lunar angles versus time for the day and location in use.	(OS menu) TEST
SC	SCan test on direct sun is an instrument test which determines the correct operations setting of the wavelength-adjusting micrometer. This test is normally performed at the factory before the Brewer is shipped to the customer. It would only be performed by the user after repair or replacement of one or more of the instrument's optical or mechanical components, or when correct instrument performance needs to be verified. Performs a scan and outputs the results at each micrometer position selected to disk and printer. A graph is produced on the printer which allows the operator to determine if the setting is correct. This command may be used in schedules and even if the printer is off with the PF command the graph will be printed.	(O ₃ only)(OM menu) TEST
SD	Short Data output format to printer sets the hard-copy output to condensed format which is the standard default setting. See also LD command (long format) for further information.	(DM menu) TEST
SE	Schedule file Edit allows the user to create or revise a daily observation schedule for the Brewer. Command sequences are carried out at user-specified solar zenith angles. The schedule files are named by the operator and stored on the program disk with *.skd extensions.	(OS menu) TEST

SLEEP	SLEEP mode for computer screen not normally used and if it is then the operator must press the key C to wake up computer software.	(EM menu) TEST
SLSUM	Standard Lamp data SUMmary instructs the PC to print the daily data summary of all SL tests conducted that day.	(SM menu) TEST
SM	Summaries printout Menu displays the summaries printout menu. This menu contains all summary routines used by ED, as well as other summary reporting methods.	(Main Menu)
SP	SPecial operating menu displays the Special operating Menu which contains a miscellany of less frequently used operations and setup tests.	(Main menu) TEST
SR	azimuth tracker Steps-per-Revolution is a calibration test which determines the number of steps required for the Azimuth Tracker to turn the Brewer through 360 degrees in azimuth. The tracker first zeros itself and outputs a discrepancy value; then it turns 360 degrees clockwise. The Steps/rev are output to the printer and should be close to 14680 steps. The test should be done weekly and if the value changes over time then servicing is required.	(TM menu) WEEKLY
SS	direct Sun UVB Scan is a new routine which allows raw data to be collected and stored from a scan from 290 to 325nm for original MKIV and 290 to 363nm for extended range MKIV systems.	(OP menu) DAILY
ST	brewer STatus and control permits the operator to switch the mercury and standard lamps on and off, and to control all installed stepper motors except the slit mask motor.	(HK menu) TEST
SUM	SUMmary data file instructs the PC to scan the current day file (e.g. B11889.011) and store on disk the data-summaries information of each measurement into a new file entitled e.g. S11889.011. The Umkehr data is processed and put into a separate file entitled e.g. U11889.011. Note this SUM operation and summary printouts are performed automatically at local midnight when the Brewer is in schedule (SKC) operation or with the ED (end of day) command.	(SM menu) TEST
SW	SWitch command used to switch modes from/to NO ₂ or O ₃ . A new operating program and a complementary set of routines are used for each mode.	(OP menu) DAILY
TCSUM	Temperature Coefficient SUMmary change changes a daily summary file using updated temperature coefficients.	(SM menu) TEST
TE	TEmperature printout prints out the current Brewer temperature in degrees Celsius and its equivalent voltmeter reading (decimal fraction between 0 and 5.00 volts.	(UP menu) TEST
TF	Turn ofF zenith tracking shuts off the zenith stepper motor; the TR command line appears in place of the TF line on the Update menu. The default setting is motor on and TF appears in the menu.	(EM menu) TEST

TI	<p>Time reset</p> <p>permits the operator to reset the Brewer's internal clock, providing the clock option is turned on in the instrument configuration IC file. Brewer time must be GMT or C.U.T., Co-ordinated Universal Time. Enter a six-digit time setting (hhmmss) in six key strokes and press RETURN to set the PC and Brewer clocks. If the Brewer loses power and when it comes back on the CLOCK board in the Brewer should return the correct time to the PC since it has battery backup.</p>	(UP menu) TEST
TM	<p>Testing Menu</p> <p>displays the Testing Menu: a directory of commands pertaining to instruments tests which are normally conducted at the factory.</p>	(Main menu) TEST
TR	<p>TuRn on zenith tracking</p> <p>turns on the zenith tracking motor: the TF command line appears in place of the TR line on the Update Menu.</p>	(EM menu) TEST
TT	<p>TeleType communications to brewer</p> <p>sets the PC program to its 'teletype' mode, allowing the operator to directly control the Brewer with a set of low-level commands.</p>	(TM menu) TEST
TU	<p>Test Uvb alignment</p> <p>Using an external quartz-halogen lamp over the UVB-dome, the TU test finds the step position of the zenith prism for which the light intensity is a maximum through slit 1 of the spectrometer. This test should be performed if alignment problems are suspected. The results should then be compared with those given in the Brewer Acceptance Manual (typically 2112 ±4 steps).</p>	(TM menu) TEST
UA	<p>time extended UV scan</p> <p>is similar in purpose to the UX routine. The primary difference is that an extended UV scan will be started on the next half hour. The name of the output data file is formatted as UVdddy.###.</p>	(SP menu) TEST
UB	<p>(O₃ mode only)</p> <p>is the same as the UVSUM routine. The two character name is given to allow programming into schedules if a UV summary printout is required before the end of day sequence is executed.</p>	(O ₃ only)(SM menu) DAILY
UF	<p>Fast uvb scan</p> <p>is similar in purpose to the UV routine. The difference is that the UF scan is performed in the ascending wavelength direction only. Four cycles are observed if the wavelength is below 3000 Angstroms otherwise two cycles are observed. All data is recorded as a 1 cycle observation. The scan writes to the UFdddy.### data file. When scanning is complete, a calculation of the UVB/UVA McKinley-Diffey weighted irradiance is outputted to the printer and appended to the DUVdddy.### file.</p>	(SP menu) TEST
UL	<p>UV-B Lamp scan test</p> <p>performs a scan of a external lamp through the UVB port and stores the data in a day file beginning with a UL. The operator is asked to input the lamp name and distance (normally 5 cm. for small lamp) at the start of measurement or command sequence.</p>	(SP menu) TEST
UM	<p>UMkehr observation</p> <p>performs standard Umkehr (O₃-layer) observations. Clear sky conditions are necessary for good results. It is normal that this observation is controlled under</p>	(OM menu) DAILY

ZB,ZC,ZS	Zenith-sky observations all commands instruct the Brewer to execute seven measurement runs in which the zenith prism is oriented vertically and the Azimuth Tracker is set towards the sun. The three command codes refer to three distinct sky conditions: ZB for zenith-blue ('clear'), ZC for zenith-cloud ('obscured'), and ZS for zenith-sky ('variable'), - used primarily in schedules. The filterwheel setup is both Filters to positions #0, which puts the polarizer element in for the zenith measurements. Note on recent instruments that a film polarizer is used in Filter #1 position #0 and the original instruments had permanent polarizing prisms installed in the rear fore-optics. In NO2 mode a DS measurement of NO2 is performed as described above.	(OM menu) DAILY
ZE	ZEroring zenith drive repositions the zenith prism to its zero-step position (at the lamps). The zenith diode is found and the prism is moved a constant (zenith offset) number of steps to the lamps (hard stop) position or zero-step.	(HK menu) TEST
ZP	Perpendicular Zenith observation is an (infrequently conducted) variation of the ZS observation in which the Azimuth Tracker orients the instrument perpendicular to the sun. Instrument set-up is similar to that for Umkehr observations.	(OM menu) TEST
ZSSUM	Zenith Sky data SUMmary (NO₂ only) prints out a calculation of the stratospheric and tropospheric amount of NO ₂ in m-atm-cm or Dobson units for each morning and evening twilight periods if a series of ZS measurements are available between zenith angles of 84.5 and 96.5 degrees.	(SP menu) TEST

4. DAILY HOUSEKEEPING DETAILS

This chapter contains guidelines on routine care and maintenance of the Brewer system.

4.1 Daily Checks (assuming schedule operation is in progress):

Clean the window and dome each morning and check pointing accuracy if convenient. Confirm the correct date, time, adequate bytes free on the data disk for the next day. Of course the location and instrument number must be correct as well.

Inspect the summary printouts from the previous day by manually recording the important lamp test results from the previous day's records and look for any problems. The SL test results are most important, especially ratios R5 and R6 which should stay consistent within +/- .5%. The HGSUM data should be scanned as well for any micrometer problems. The DT results should be within nominal readings (+/-5 ns). The RS ratios for operating wavelengths 2-7 should be better than +/- 0.3%. The main power supply +5v should be +4.95 to +5.1 volts. Lamp intensities should be noted to detect any deterioration. Note the HG lamp intensity changes a great deal with temperature.

The pointing accuracy may be checked while in a schedule, during a DS measurement by viewing that the sun's image is not on the IRIS. If it is then a SI (sighting) should be performed. Corrections should be noted to ensure good installation (i.e. level) and tracking operation. Before performing SI it may be necessary to do a RE or AZ to confirm a new sighting is actually required, please note the azimuth discrepancy after this test. Perform the steps per revolution SR test weekly. This may show that the tracker drive wheel needs to be cleaned.

4.2 Other Notes on some possible problems:

There may be occasions when the micrometer will have to be reset by hand so become familiar with its normal setting. This problem may occur if the constants for DIODE OFFSET and MIC STEPS/DEG are not correct or if the mechanism becomes sticky.

In the main menu a quick test to check if Brewer is communicating to the computer is TE, temperature check, or TI for checking time. If nothing happens then do a RE (reset) or if you cannot return to the menu then press Control-Break and type RUN, or do a complete boot-up. Note after returning from DOS if you used the SHELL command then type a TI (timer set) command to help ensure proper operation.

The printer can get turned off by the program if the paper runs out or jams. If this happens the PN command will have to be issued. This is why it important to program this command into schedules for the most important times of the day, especially at the end of the day. When the printer is off the measurements default to the screen. The PF command turns the printer off.

Approximate run times for the following measurements are shown below:

HG (without B1)	7-9 min.
SL(without B2)	9 min
DS	3 min
ZS	4 min
UV	8 min
UM	Indeterminate must be aborted with HOME key or new schedule entry.
FM	11 min

4.4 Field Definitions of Data Files

This section describes the data field structures of the various files generated by the Brewer Ozone Spectrophotometer. Most of the Brewer data is stored in the daily B-file (Bdddy.###) opened at the start of each day. The UVB scan data is stored in it's own UV-file (UVdddy.###) each day. The end of day (ED) process creates two extra files from the B-file, namely the S-file (Sdddy.###) and the U-file (Udddy.###) which contains re-processed Umkehr data for the day. Summary statistics of atmospheric observations and instrument performance tests are written to various average files (???AVG.###).

4.4.1 B file structure: Bdddy.###

Bdddy.### files always begin with the characters *version*. The beginning of a B file always contains three sections: the version string, the instrument constants, and a data header. All items are separated by a carriage return (ASCII 13 decimal), and all sections are separated by a carriage return-linefeed pair (ASCII 13, 10 decimal). The following pages describe the format of each B file section.

Note that older B file formats did not contain a version string section or an instrument constants section. If no version string section exists, assume the file to be version 0.

Also, note that most processing programs search for the *summary* and *n2summary* headers first.

4.4.1a Version String

version=1 version string, number after the equals sign is the version number

4.4.1b Instrument Constants

Note that this section of the file format is identical to the ICFVAL.nnn file in the instrument data directory.

inst	basic instrument constants
0	ozone temperature coefficient for slit 1
-2.949	ozone temperature coefficient for slit 5

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0	micrometer steps per degree
.3461	ozone on ozone ratio
2.35	SO2 on SO2 ratio
1.1565	ozone on SO2 ratio
3448	ETC on ozone ratio
3558	ETC on SO2 ratio
.000000044	dead time (seconds)
292	wavelength calibration step number
78	slit mask motor delay
1777	Umkehr offset
0	neutral density of filter 0
5000	neutral density of filter 1
25000	neutral density of filter 5
2816	zenith motor steps per revolution
mkii	Brewer model type (one of mkii, mkiii, or mkiv)
1	COM port number
0	ozone temperature coefficient for mercury exit slit
0	NO2 temperature coefficient for mercury exit slit (MKIV only)
0	NO2 temperature coefficient for slit 1
0	NO2 temperature coefficient for slit 5
1885	ozone micrometer offset
2310	ozone micrometer #2 offset (MKIII only)
242	ozone filterwheel #3 position
-.3	NO2 absorption coefficient (MKIV only)
745	NO2 direct sun ETC (MKIV only)
742	NO2 zenith sky ETC (MKIV only)
5089	NO2 micrometer offset (MKIV only)
178	NO2 filterwheel #3 position (MKIV only)
3204	ozone/NO2 mode change distance for micrometer (MKIV only)
.996	grating slope (MKIII only)

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1.901	grating intercept (MKIII only)
3469	micrometer zero position
75	number of motor steps to open iris
0.2	computer buffer delay (larger numbers for faster computers)
64	NO2 filterwheel #1 position (MKIV only)
256	ozone filterwheel #1 position
0	filterwheel #2 position
64	UV filterwheel #2 position
40	number of steps from zenith sensor to the hard stop

Note that this section of the file format is identical to the DCFVAL.nnn file in the instrument data directory.

disp	dispersion constants
2797.237	intercept for slit 1
.07283272	slope for slit 1
-.00000057826	quadratic for slit 1
2837.617	intercept for slit 2
.07210223	slope for slit 2
-.00000058722	quadratic for slit 2
2945.481	intercept for slit 5
.06988658	slope for slit 5
-.00000060847	quadratic for slit 5
2755.701	intercept for mercury exit slit
.07597	slope for mercury exit slit
-.00000064887	quadratic for mercury exit slit
2797.237	NO2 intercept for slit 1
.07283272	NO2 slope for slit 1
-.00000057826	NO2 quadratic for slit 1
2837.617	NO2 intercept for slit 2
.07210223	NO2 slope for slit 2
-.00000058722	NO2 quadratic for slit 2
2945.481	NO2 intercept for slit 5

.06988658 NO2 slope for slit 5
 -.00000060847 NO2 quadratic for slit 5
 2755.701 NO2 intercept for mercury exit slit
 .07597 NO2 slope for mercury exit slit
 -.00000064887 NO2 quadratic for mercury exit slit

Note that this section of the file format is identical to the ZSFVAL.nnn file in the instrument data directory.

zeni zenith sky coefficients
 -.0064 coefficient #1
 -.01968 coefficient #2
 -.04506 coefficient #9

4.4.1c Data Header

dh header
 13 day
 08 month
 92 year
 Lindenberg location name
 52.21 latitude
 -14.12 longitude
 3.45 temperature in volts
 pr pressure
 1000 pressure value

4.4.1d Comment Block

co section type (comment block)
 13:20:00 time comment was logged
 user: text source of comment (user, hg, ze, az, etc.)
 always followed by a colon and space
 always followed by the comment text

4.4.1e Mercury Lamp B file data

hg type of measurement
 12:10:22 time of measurement

.9988 correlation value
 140.7029 HG calculated at step #
 141 micrometer set to this #
 2306 intensity counts at peak
 -6 temperature (deg. C)

4.4.1f Standard Lamp B file data

sl type of measurement
 a filter
 0 ND filter pos'n of filterwheel #2 (in steps)
 737.41 time - minutes since 00:00 hrs
 1 lower slit mask pos'n (1=dark)
 6 upper slit mask pos'n (6=slit 5)
 20 # of cycles
 625382 raw counts wavelength #0
 18 dark count
 824502 raw counts wavelength #1
 997920 raw counts wavelength #2
 1189457 raw counts wavelength #3
 1157092 raw counts wavelength #4
 970701 raw counts wavelength #5
 rat ratio
 1526 single ratio #1 MS(4)
 668 single ratio #2 MS(5)
 -125 single ratio #3 MS(6)
 -786 single ratio #4 MS(7)

Repeat the above 6 more times

sl	sl	sl	sl	sl	sl
a	a	a	a	a	a
0	0	0	0	0	0
737.99	738.57	739.15	739.72	740.3	740.88

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1	1	1	1	1	1
6	6	6	6	6	6
20	20	20	20	20	20
625382	625382	625382	625382	625382	625382
23	22	26	25	27	22
825466	824976	825114	824566	825258	825100
999513	999049	999304	1000116	999945	9999188
1190104	1189807	1190117	1190470	1187989	1190572
1157236	1156718	1156800	1157347	1157486	1157390
970886	972097	972494	971723	971187	971521
rat	rat	rat	rat	rat	rat
1521	1521	1521	1526	1523	1523
662	662	661	659	661	664
-127	-128	-128	-128	-118	-128
-786	-778	-777	-782	-786	-784

Summary

12:19:09	time
mar	month
08/	day
92	year
104.612	mean zenith angle during measurement
3.777	mean airmass
-6	temperature (deg. C)
sl	type of measurement
0	ND filter pos/n (in steps)
1523	mean single ratio #1 R1 MS(4)
662	mean single ratio #2 R2 MS(5)
-126	mean single ratio #3 R3 MS(6)
-783	mean single ratio #4 R4 MS(7)
4028	mean double ratio #1 R5 MS(8)

2056	mean double ratio #2 R6 MS(9)
824997.5	mean of counts from wavelength #1
971515.6	mean of counts from wavelength #5
2	st'd dev. single ratio #1
3	st'd dev. single ratio #2
4	st'd dev. single ratio #3
4	st'd dev. single ratio #4
13	st'd dev. double ratio #1
8	st'd dev. double ratio #2
387	st'd dev. counts wavelength #1
632	st'd dev. counts wavelength #5

4.4.1g Direct Sun B file data

ds	type of measurement
a	filter
64	ND filter position of #2 Filterwheel (in steps)
978.87	time - minutes since 00:00 hrs
1	lower slit mask position (1=dark)
6	upper slit mask position (6=slit 5)
20	# of cycles
625382	raw counts wavelength #0
11	dark count
13879	raw counts wavelength #1
345676	raw counts wavelength #2
437926	raw counts wavelength #3
728264	raw counts wavelength #4
805262	raw counts wavelength #5
rat	ratio
15671	single ratio #1 MS(4)
8345	single ratio #2 MS(5)
2820	single ratio #3 MS(6)

1 single ratio #4 MS(7)

Repeat the above 4 more times

ds ds ds ds

Summary

16:20:02	time
mar	month
08/	day
92	year
68.024	zenith angle
2.617	airmass
-5	temperature (deg. C)
ds	type of measurement
1	ND filter pos'n
15578	single ratio #1 MS(4)
8312	single ratio #2 MS(5)
2801	single ratio #3 MS(6)
-5	single ratio #4 MS(7)
15594	double ratio #1 MS(8)
6920	double ratio #2 MS(9)
.3	SO ₂ value MS(10)
404.4	O ₃ value MS(11)
71	st'd dev. single ratio #1
28	st'd dev. single ratio #2
16	st'd dev. single ratio #3
5	st'd dev. single ratio #4
56	st'd dev. double ratio #1
11	st'd dev. double ratio #2
.4	SO ₂ st'd dev.
.6	O ₃ st'd dev.

4.4.1h Zenith Sky B file data

zs	type of measurement
a	filter
0	ND filter pos'n in filter wheel step # co-ord's
974.43	time - minutes since 00:00 hrs
1	lower slit mask position
6	upper slit mask position
20	# of cycles
625382	raw counts wavelength #0
4	dark count
10125	raw counts wavelength #1
48805	raw counts wavelength #2
164527	raw counts wavelength #3
306533	raw counts wavelength #4
311495	raw counts wavelength #5
rat	ratio
14857	Single ratio #1 MS(4)
8021	single ratio #2 MS(5)
2727	single ratio #3 MS(6)
79	single ratio #4 MS(7)

Repeat the above 6 times

zs	zs	zs	zs	zs	zs
a	a	a	a	a	a
0	0	0	0	0	0
975.01	975.58	976.15	976.73	977.3	977.87
1	1	1	1	1	1
6	6	6	6	6	6
20	20	20	20	20	20
625382	625382	625382	625382	625382	625382
5	5	5	4	7	3

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10363	10463	10599	10600	10705	10937
48902	49435	49504	50401	50766	51123
166161	166921	168078	169687	170584	171559
308330	309775	311554	313718	315586	316859
312878	314465	316279	318418	319538	321391
rat	rat	rat	rat	rat	rat
14782	14761	14730	14760	14744	14667
8038	8011	8030	7982	7977	7964
2709	2710	2705	2694	2697	2689
72	74	74	73	63	70

Summary

16:16:09	time
mar	month
08/	day
92	year
68.477	zenith angle
2.667	air mass
-5	temperature (deg. C)
zs	type of measurement
0	ND filter position
14757	single ratio #1 MS(4)
8003	single ratio #2 MS(5)
2704	single ratio #3 MS(6)
72	single ratio #4 MS(7)
14526	double ratio #1 MS(8)
6528	double ratio #2 MS(9)
-48.6	SO ₂ value MS(10)
404.8	O ₃ value MS(11)
57	st'd dev. single ratio #1
29	st'd dev. single ratio #2

13	st'd dev. single ratio #3
5	st'd dev. single ratio #4
51	st'd dev. double ratio #1
21	st'd dev. double ratio #2
3.2	SO ₂ st'd dev.
2.1	O ₃ st'd dev.

4.4.2 UMKEHR raw data file structure: in B file

UMKEHR raw data is also stored in the B file with a similar structure as the ZS data, excluding the summary data. The UM data is re-processed as part of the SUM command. The following is one measurement at one set of wavelengths (short first):

um	type of measurement
240592	date
Santa Maria	location name
-29.69	latitude
53.728	longitude
3.49	last temperature
pr1000	pressure
0	ND filter position
1157.87	time - minutes since 00:00 hrs.
1	lower slit mask position
6	upper slit mask
40	# of cycles
625382	raw counts wavelength #0
120	dark count
97706	raw counts wavelength #1
294523	raw counts wavelength #2
759956	raw counts wavelength #3
1087648	raw counts wavelength #4
962462	raw counts wavelength #5
rat	ratio

105525 single ratio #1 MS(4)
 5722 single ratio #2 MS(5)
 1572 single ratio #3 MS(6)
 -574 single ratio #4 MS(7)

the long wavelengths are measured and stored in the same format. These long wavelengths correspond to approximately: 316.8, 320.1, 323.2, 326.4, 329.5nm. The short/long wavelength measurement sequence is repeated for as long as the UM command is engaged.

4.4.3 SUMMARY file structure: Sdddy.###

Sdddy.### files start with 'tc' and the 5 temperature coeff's 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. Listed below is the structure as described with an HG test followed by the end of file designator. Each item in a S-file is separated with a carriage return and line feed.

```
tc
.9283
1.178
.74
0
-1.413
hg
14:40:47
.988
147.43
133
1469
27
ef
```

Reference the B-file descriptions above for the DS, ZS, SL etc. measurements. Fields after and including the 'summary' statement are written into the S-files.

4.4.4 UV file Structure: UVdddy.###

UX integration time is 0.2294 seconds per cycle (header for each scan).

```
dt 4.3E-08      dead time
cy 1            # of cycles
```

dh	data header
26	day
04	month
92	year
Saskatoon	location
52.108	latitude
106.713	longitude
2.56	temperature (volts)
pr960	pressure in mb
dark 1	dark count
825.9	time (GMT) in minutes (1)
2865	wavelength (2)
1263	micrometer step # (3)
11	raw counts (4)
826.04	repeat 1
2870	repeat 2
1334	repeat 3
10	repeat 4

*1-4 repeat for wavelengths 2865-3630 Angstroms at 5A increments. A UV measurement is from 2900-3250-2900 Angstroms in 5A increments and # of cycles is 4 and counts for 4 cycles are recorded in the UV file. UF, UA scans have file structures that are the same or similar to UX file structure.

4.4.5 Average files structure: ???avg.###

These files contain daily statistical data or individual measurement results. The tabled structure of these files allows easy loading into any spreadsheet or statistical software for further analysis.

OZOAVG.###	SLOAVG.###
HGOAVG.###	APOAVG.###
RSOAVG.###	DTOAVG.###
FMOAVG.###	FZOAVG.###
OPAVG.###	MIOAVG.###
SCOAVG.###	

The above files (excluding AP, DT, RS, SC, MI) are created from the ??sum.rtn indicated by the first two letters of the average file. The exceptions are created from the ??rtn indicated by the first two letters of the average file. The opoavg.### file is created by the ED.RTN and also records the op-st.### file whenever IC command is used. Examples of the average files along with field descriptions are as follows:

OZOAVG.###

08391 452.1 +2.4 -0.6 0.6 16/29 185 20 445.2 +5.2 -12.3 26.4 19/22 199 19

08491 472.8 +2.1 -.08 1.2 22/35 185 19 465.5 +5.8 -7.3 25.1 16/20 190 19

08591 458.8 +9.3 -0.7 0.6 12/35 192 18 461.7 +7.2 -5.7 23.2 16/20 184 19

julian day & year (dddy), mean daily total column direct sun (ds) ozone, ds ozone standard deviation, mean daily total column ds sulphur dioxide, ds SO₂ standard deviation, number of good observations, number of total observations, harmonic mean of airmass for the measurements comprising the daily mean ozone, hour (GMT) that best represents the mean time for the mean daily ozone. The remaining fields are zenith sky data and have the same definitions as the ds data.

SLOAVG.###

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

dddy, low and high temperatures of the standard lamp test, number of sl tests, ratios 1 through 6, lamp intensity, standard deviation for ratios 1 through 6 and lamp intensity.

HGOAVG.###

08391 2592 33 18

08491 2330 25 20

08591 2483 34 22

dddy, maximum lamp intensity of the days scans, high Brewer temperature of the days scans and number of scans.

RSOAVG.###

08391 1.0006 1.1667 1.0003 .9995 1.0005 .9999 .9991 .9997

08491 1.0020 .9024 .9989 .9994 1.0001 .9992 .9998 .9996

dddy, run/stop ratio for slit mask positions 0 through 7.

DTOAVG.###

04991 41.66 43.375

05991 41.69 43.276

dddy, dead time for high and low intensities

APOAVG.###

08591 1566.80 5.17 1.61

08691 1555.86 5.17 1.61

dddyy, H.T. voltage, +5V, standard lamp circuit

FMOAVG.###, FZOAVG.###

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

dddyy, nightly mean ozone and its standard deviation, ETC, nightly mean SO₂ and its standard deviation, ETC, number of good observations, number of total observations.

MIOAVG.###

02791 28 133.69 6122 6124 5142 5144 -177 178

03791 22 136.02 6122 6124 5145 5144 -177 178

04991 25 135.01 6122 6123 5143 5144 -178 178

05991 16 134.45 6122 6121 5141 5144 -177 178

Temperature at time of test, pre-test mercury calibration step number, steps from operating position to zeroing diode, offset constant, Micrometer #2 steps from operating position, offset constant, FW#3 steps from operating position to offset constant.

OPAVG.###

ED, 017, ICFVAL, ZSFVAL, DCFVAL, 26, 03, 91, Saskatoon, 52, 108, 106.713, 960, 3.41,-1865, -8, 14671, 1, 1, 1, 1, 1, 1, 1, 1, (1, 0, 0, 1, 1, 0, 0, 0,) skc, fa, 07:21:42

ED, 011, 1.669, 2, 8, disk, 26, 03, 91, Saskatoon, 52, 108, 106.713, 960, 3.5, -1865, -8, 14671, 1, 1, 1, 1, 1, 1, 1, 1, (1, 0, 0, 1, 1, 0, 0, 0,) skc, fa, 07:21:46

This data comes from the ED.RTN, as well as the SW.RTN, and is the contents of the op_st.fil. At the end is the time of recording.

SCOAVG.###

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

dddyy, temperature, airmass, neutral density filter used, maximum step of scan, maximum ozone, minimum step of scan, minimum SO₂, HG cal pt.before scan.

Along with the average files is a routine (REP.RTN) to display the important instrument performance data. This routine will read the SLOAVG.###, HGOAVG.###, APOAVG.###, DTOAVG.###, MIOAVG.### and RSOAVG.### files and display results within a range of days specified by the operator. An asterisk will

appear beside the respective run/stop and dead time data if results are outside of a specific range defined as normal.

5. HELP - WHEN THINGS GO WRONG

5.1 Typing Errors

If you make a typing error e.g. with a chain of commands then use the Backspace key. In schedules the Insert and Delete keys can be used.

If you wish to stop the program, type EX and press RETURN. You can restart the program by typing BREWER at the DOS prompt. If the program refuses to start, you will need to reboot the computer by pressing the 3 keys, Control, Alt, Del, simultaneously or by turning the PC power off and then on.

5.2 Power Failures

If only the Brewer loses its input power then the Brewer software will automatically prompt for a response. If this fails after five consecutive attempts, and if the PC was under menu operation, then you must press the Return key to initiate a reset of the Brewer electronics and zero motors. If the Brewer was in schedule operation, then the program will automatically initiate a reset of the Brewer and then re-start the original schedule. Similarly the system recovers automatically if the PC, the Brewer, or both have a power interruption.

6. Configuring the Control Computer

6.1 Introduction

This section explains how to set up the Brewer software on the control computer for the first time. It is assumed that SCI-TEC has neither recommended nor supplied the control computer.

The Brewer software is supplied on 3.5 inch disks, and is set up for dual-drive use on IBM PC compatible computers with MS-DOS 3.1 or greater. IBM Basic or GW-BASIC is required to run this software.

If you wish to run this software from a hard drive, please read Sections 6.2, 6.3 and 6.4. If you intend to run from floppy disk only, please read Sections 6.2 and 6.4. For information on modifying the Brewer software, proceed to Section 6.5. Section 6.6 contains some other useful information about fixing setup problems.

6.2 File Organization

The floppy disk is organized into three subdirectories. The contents of these directories are as follows:

Directory	Files in Directory	Notes
\	autoexec.bat, brewer.bat, config.sys	These are files needed to run the Brewer s/w. Section 6.4 explains how to customize these files for your system.
\BDATA	none	This directory contains all the Brewer data files. The default location can be changed as explained in section 6.4.
\BREWER	*.asc, *.bas, *.fil, *.rtn	These files make up the Brewer operating software and must all be stored in one directory
\DOS	various	This directory contains useful DOS utility programs which may or may not already be available to you. They are not necessary to run the Brewer software

6.3 Brewer Software Hard Drive Installation

Since the Brewer software supplied is set up to run from disk by default, some setup changes must be made. The following procedure explains how to properly set up the software:

1. If the control computer already has MS-DOS installed, proceed to Step 4; otherwise, continue with Step 2.

2. If the computer is *not* configured to boot-up, then insert a boot disk supplied with the computer (*not* the Brewer software disk) and boot the computer. Wait until the computer is ready, and proceed to Step 4.
3. If MS-DOS is not yet installed on the computer, refer to the computer suppliers diskettes and manual to install MS-DOS and GWBASIC.EXE. These are normally installed in the C:\DOS directory
4. Remove any disk in the disk drive, and insert the Brewer software disk.
5. Type the following commands to copy the Brewer software to your hard drive:

```
a:
```

```
cd\
```

```
install nnn d:\brewer d:\bdata (where nnn = instrument #)
```

If you wish to install the Brewer software to the default directories C:\BREWER and C:\BDATA, you can simply type:

```
install
```

6. Edit the AUTOEXEC.BAT file and the BREWER.BAT file (found in directory c:\) as follows:

Edit the path= line (if present) to include the directory that you run the Brewer software from.

Ensure that the first cd line contains the directory name where the Brewer software is stored. This directory path should also appear on the set BREWDIR= line (note the capital letters!).

Here is an example AUTOEXEC.BAT file, with comments to help explain it:

```
@echo off

path=c:\;c:\dos;c:\brewer (Note the \brewer entry)

cd c:\brewer (Use the full path!)

set BREWDIR=c:\brewer (Use the full path!)

PROMPT Brewer $P$G

gwbasic main /f:10
```

Note that other lines may also appear here, but they should not be changed. The changes to BREWER.BAT should be identical, except that the path= line will not appear in the file.

7. Edit the CONFIG.SYS file if necessary. Changes may not be required; refer to your MS-DOS manual for more information.

The computer is now properly set up. Please proceed to Section 6.4 to configure the program to work with your specific Brewer model.

6.4 Configuring the Brewer Software for the First Time

Before you can run the Brewer software, two important files must be edited: the operating state file (found in \BREWER and \BDATA\###), and the instruments constants file (found in \BDATA\###). To edit these files, refer to the following table to determine what values you need to provide. The left column lists the actual value written in the OP_ST.### 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. The OP_ST.FIL in the program directory contains only the first two entries, instrument # and data directory.

Sample Value	SW Variable	Explanation
046	NOS	This is the ID number for your Brewer. This value is also used as a subdirectory name for all instrument data. This value MUST be correct before you run the Brewer software for the first time.
\BDATA	DDS	This is the directory to store all instrument data in. If you wish to store data on a different drive, that information can be entered here (i.e. D:\BDATA). Ensure that this value is correct in both operating states before you run the Brewer software for the first time!
ICFVAL	ICFS	This is the default filename for the instrument constants file. This value should never need changing, since the program allows you to change the filename whenever you edit the constants file with the CF routine.
ZSFVAL	ZSFS	This is the default filename for the zenith sky coefficients file, and should not normally be changed.
DCFVAL	DCF\$	This is the default filename for the dispersion constants file, and should not normally be changed.
UVRES	UVRS	This is the filename of the UV response file
04	DAS	Calendar day. This value, and the next two, can be changed by using the DA command from within the main program.
02	MOS	Month
94	YES	Year
Saskatoon	LOS	Location of Brewer instrument.
52.108	L1\$	Latitude of instrument.
106.713	L2\$	Longitude of instrument.

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Sample Value	SW Variable	Explanation
960	L3\$	Average climatic station pressure (millibars).
1.8	TE\$	Voltage representation of Brewer temperature.
215	NC%	Azimuth north correction.
0	HC%	Zenith horizon correction.
14689	SR%	Azimuth steps per revolution.
1	Q1%	Zenith drive present. Setting this value to 1 means that the drive is present, and a setting of 0 means it is not present.
1	Q2%	Azimuth drive present. Set to 1 or 0 as above.
1	Q3%	Iris present. Set as above.
1	Q4%	Filterwheel #1 present. Set as above.
1	Q5%	Filterwheel #2 present. Set as above.
1	Q6%	Clock board present. Set as above.
1	Q7%	A/D board present. Set as above.
1	Q8%	UVB port present. Set as above.
1	Q9%	Filterwheel #3 present. Set as above.
1	Q10%	New or old temperature circuit present. Set to 1 for a new temperature circuit, and 0 for an old circuit.
1	Q11%	Second film polarizer present. Set as described in Q1%
0	Q12%	Set to 1 to enable NOBREW operation, and 0 to disable it. This mode is intended for training or testing purposes, when no Brewer is connected to the computer. If a Brewer is connected, this value should always be set to 0.
1	Q13%	Wide HG slit present. Always set this to 1 on new Brewers.
0	Q14%	New Brewer electronics board. This should always be zero unless you have upgraded to the new electronics.
0	Q15%	Future use.
skc/menu	DIS	Schedule or menu indicator. Do not modify.
O3 or N2	MDDS	Mode.
UMKNO2	SK\$	Schedule name.

The ICFVAL.FIL is the instrument constants file. All of these values can be edited within the program by using the CF routine. However, two of the values MUST be correct before the software will run properly. These values are listed here:

Entry Position	Value	Description
Line 23 of file	mkiv	This is the Brewer type. Its value MUST be one of "mkii", "mkiii", or "mkiv" (without the quotation marks). Note that the entry must be in lower-case, and that it must not contain any spaces.
Line 24 of file	1	This entry is the COM port that the Brewer is connected to. This is normally either 1 or 2.

6.5 Editing the Brewer Software

If you intend to alter the Brewer software, then please note the following:

Always create a backup copy of your software before you change anything!

The Brewer main program is called MAIN.BAS. To change this routine, enter GWBASIC and type LOAD"MAIN.BAS". After changes are made, use SAVE"MAIN.BAS" to save the changes you made.

To change any modules, use the command LOAD"<file>.RTN", where <file> is the name you normally use to run the module. Modules must be saved in ASCII format, so save them with the command SAVE"<file>.RTN",A.

6.6 Printer Problems

If you are located in outside North America, you may need to change the printer page length. Line 13030 must be changed to read CHR\$(66) for North American length paper, and CHR\$(72) for European length paper.

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UVB STABILITY MONITORING AND DATA ANALYSIS PROCEDURES

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1. STABILITY CHECK METHOD

The following assumes SCI-TEC's portable UVB lamp assembly BA-126 is to be used. This assembly is intended for monitoring instrument stability and not to give an absolute responsivity calibration. It is recommended that NIST (or traceable to) 1000W lamps operated at 50cm distance from the teflon diffuser be used for absolute calibration.

1.1 Setup

There are four primary concerns when setting up for a UL or QS scan:

1. cleaning the UVB quartz dome
2. wavelength calibration
3. lamp positioning
4. warm-up time

The UVB quartz dome may be cleaned with distilled water and a soft, dry, lint free cloth.

Before a series of UL or XL scans are performed, an HG test should be conducted and no more than 2 to 3 consecutive scans should be done without performing an HG test. This will ensure proper wavelength calibration when numerous scans are desired. An appropriate command sequence would be "hgxb1ulhg".

When facing the front of the Brewer, the lamp housing is positioned on top of the UVB quartz dome with the nylon legs snug up against the left edge of the Brewer cover. Sliding the lamp housing left and the nylon legs right and tightening the legs will ensure lateral repeatability. Remove the rectangular lamp cover located on top of the lamp housing by unscrewing the nylon thumb screw and insert the lamp into the 6 pin socket. The aluminum shield around the lamp is keyed with the housing to keep the lamp right side up.

Vertical repeatability is achieved by positioning the lamp filament on exactly the same axis defined by the two sight holes on each side of the lamp shield. This axis represents 5cm from the teflon diffuser. If the lamp needs re-positioning be sure to use a clean, non-oily object to move the lamp. Do not let your skin touch the lamp. Replace the lamp cover on the lamp housing.

The external tungsten-halogen lamp should be allowed to warm up for at least 10 minutes and should be operated at a constant ambient temperature.

After ensuring the quartz dome is clean and allowing the appropriate warm up time for the lamp, the UL command(s) may be executed. It is important that the digital volt meter (DVM) be used to monitor the lamp voltage to 3 decimal places and be set to record the voltage during the UL scan. To set the DVM for three decimal places, hold the yellow button down, switch the DVM from the off position to the DC Volts position, hold the yellow button down for 2 or more seconds then release it. To start

recording, press the MIN/MAX button once. Retrieve and record the average voltage after each scan (or set of scans) by pressing the hold button and then the MIN/MAX button 3 times. The desirable operating voltage is 12.000V +/-0.002V. If necessary, voltage from the supply may be adjusted by a potentiometer accessible on the left side of the cavity where the lamp housing is stored in the power supply case.

Typically, 5 lamps accompany an external lamp power supply. It is recommended that bi-monthly lamp scans are taken with two of the 5 lamps, monthly lamp scans taken with a third lamp. The third lamp is used to judge the performance of the first two lamps. The remaining 2 lamps should be kept aside to replace any of the first 3 should discrepancies of more than 5% occur between the first 3.

1.2 UL Data Analysis Programs

BREWRESP.BAS is a BASIC program 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*.IRR file for each lamp used to create the UL file and the UL data for the appropriate Brewer. The output of this program is a new UVRES.### (response) file. It is recommended that the new response files be named with the format (UVRdddy.###). 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, UL and UVSUM routines and UVDATFIL 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 ozone program directory for use by the various routines.

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.

BREWIRR.BAS is also a BASIC program used to calculate irradiance files for an unknown external lamp. Requirements for this program are a LAMP*.IRR file for each calibrated lamp used and UL data recorded on the same Brewer by both types of lamps. Output from the program is a LAMP*.IRR (irradiance) file for the previously non-calibrated lamp. Statistics from the determination of an instrument response during the calculation of the uncalibrated lamp irradiance file should be examined closely. If % standard deviations of greater than 1.5 are observed, then generally other UL scans should be used to determine an appropriate irradiance file for the uncalibrated lamp.

1.3 UV Data Analysis Programs

AB_UVDAT.ASC processes the UVdddy.### 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 in to the weighting curves; calculated results represent both the UVB and UVA regions (290-400nm). Two data files are created by AB_UVDAT for each UV file processed; UVBdddy.### and DUVdddy.### (reference field definitions below). Two different action spectrums, Erythema and

Diffey, are used separately to weight the UV scans. This program requires access to the appropriate instrument response file. The UVB and DUV files are easily imported into and conveniently manipulated within spread sheet software.

AB_UVDAT.EXE is very similar to AB_UVDAT.ASC except that it's capable of processing many UV files during a single execution. A UVOAVG.### file is also produced or appended to by this program. Again the appropriate instrument response file is required.

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 $\leq 292\text{nm}$ 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 more 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

1.4 UX Data Analysis Programs

RD_UX.BAS and its executable program, RD_UX.EXE, are used to reduce the UV data produced by the UA, UC, UF, or UX routines. Output may be chosen in $\text{W/m}^2/\text{nm}$ or in $\text{mW/m}^2/\text{nm}$. RD_UX is also capable of processing external lamp scans from the XL routine to produce lamp irradiance files ($\text{mW/m}^2/\text{nm}$). It is most conveniently run in the directory where the UVB data is stored. The routine asks for the instrument number, the type of scan (UA, UC, UF, UX or XL), the date the UVB scans were taken (dddyy) and the location of the UVRES_X.### file. If the type of scan is not a lamp scan, then the user will be asked whether or not to correct for stray light. The stray light correction subtracts the average of the counts received below 292.2 nm for each measurement. The processed file will be prefixed by the letter "p" such as, PUXdddyy.###. If individual files for each scan are desired, the answering "y" to the last prompt will produce files such as PUXdddNN.###, where NN is the sequence of the scan.

1.5 XL Data Analysis Programs

X_RESP.BAS and its executable program, X_RESP.EXE are used to determine the extended responsivity (typically 2865-3630 Angstroms) of a Brewer with the aid of data from a calibrated tungsten-halogen lamp. The program requires a single

LAMP*.IRX file for the lamp used to create the corresponding XL file. For each scan of the external lamp in the XL file, an XRdddy?.### response file is created. It is recommended that a number of scans of the external lamp be performed thus generating several XRdddy?.### response files. The response files can then be averaged into a single response and compared to previous response files to determine if there has been a possible change in the performance of either the Brewer electronics or optics.

1.6 File Structure

The structure of the UL, LAMP, IRR, UVRES, UVB, DUV and UVOAVG files are as follows:

UL: (produced by UL.RTN)

Integration time, dead time, number of slit mask cycles, number of wavelengths observed in the 290-325 nm region, lamp number (i.d.), distance between filament and teflon diffuser, data header (date, location, latitude, longitude), voltage reading representative of Brewer temperature (PMT temperature), surface level atmospheric pressure (a constant), dark count; - the next four fields repeat 11 times - , decimal minutes since 00:00 hours, wavelength, micrometer step number, raw photon counts; - then - , dark count, - repeat 11 times again the fields - decimal minutes since 00:00 hours, wavelength, micrometer step number, raw photon counts.

LAMP: (from QS.RTN)

Julian day and year, distance of lamp filament to teflon diffuser, pmt temperature, dark count, next 11 fields are intensities at each of the 11 wavelengths, pseudo DUV calculation.

IRR: (from BREWIRR.BAS)

First row - lamp identification number Second row - distance between lamp filament and teflon diffuser Columns below - first wavelength then irradiance in milli watts per square metre

UVRES: (from BREWRESP.BAS)

There are two columns; first wavelength then responsivity in counts per milli watt per square metre per nanometre

UVB: (from AB_UVDAT.ASC/.EXE)

First row - decimal hours from 00:00 (GMT) First column - wavelength (angstroms) Other columns : one per scan taken as recorded in the UV data file - irradiance (watts per square metre per nanometre) Second last row - scan weighted (Erythema) UV (milli watts per square metre) Last row - scan weighted (Diffey) UV (milli-watts per square metre)

DUV: (from AB_UVDAT.ASC/EXE)

First column - decimal hours from 00:00 (GMT) Row 1 column 2 - daily weighted (Erythema) UV (joules per square metre) Row 1 column 3 - daily weighted (Diffey) UV (joules per square metre) Remainder of column 2 - scan weighted (Erythema) UV (milli watts per square metre) Remainder of column 3 - scan weighted (Diffey) UV (milli watts per square metre) Note: the last two fields can be cross referenced with the bottom two rows of the UVB file.

UVOAVG: (from AB_UVDAT.EXE)

Julian day and year, daily weighted Erythema UV, daily weighted Diffey UV, length of day; defined as the time difference between the first and last scan in the particular UV file, the number of scans in the UV file, representative hour; defined as the average hour during which the UV scans were taken over the day

PUX, PUF, PUV, PUA: (from RD_UX.EXE)

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: (from RD_UX.EXE)

First row - Lamp ###, Row 2 - distance in centimeters, Column 1 Row 3 - Wavelength (Angstroms), Row 4 - irradiance ($mw/m^2/nm$).

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BREWER SYSTEM DESCRIPTION & SPECIFICATIONS

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0. Introduction

The Brewer MKIV Spectrophotometer is a scientific instrument which measures atmospheric ozone and sulphur dioxide by examining the absorption of specific ultraviolet wavelengths from the solar spectrum. The instrument can also be switched to visible wavelengths and measure nitrogen dioxide

It is well recognized by the scientific community that marked fluctuations in atmospheric ozone and sulphur dioxide concentrations are linked to a variety of adverse environmental conditions. The ozone layer, which shields the Earth from the harmful effects of solar ultraviolet radiation, is believed to be vulnerable to attack by fluorocarbons and other effluents. Many scientists fear its depletion may irreversibly alter world climatic patterns. Atmospheric sulphur dioxide is closely associated with the 'acid rain' phenomenon which, like ozone depletion, has implications for the global environment.

Today's concern over the vulnerability of the ozone layer to destruction by atmospheric pollutants has increased the demand for high-quality, globally-distributed, total ozone measurements from a ground-based network of instrumentation. During the past one and a half decades the Atmospheric Environment Service of Environment Canada (AES) and the University of Toronto have conducted the development of the MKIII Brewer Spectrophotometer for the purpose of supplementing instrumentation in the World Ozone Network.

Though the Dobson instrument has served its purpose well since the 1930s, the Brewer Ozone Spectrophotometer is today becoming the instrument of choice for researchers measuring ozone and sulphur dioxide. At the request of the World Meteorological Organization, The instrument and its accompanying accessories are manufactured and marketed under license by SCI-TEC Instruments Inc. of Saskatoon, Saskatchewan, Canada. Seventy-seven Brewer instruments have already been incorporated in the World Ozone Network and measurements are currently being taken at research establishments in over thirty different countries.

The Brewer Spectrophotometer is the core component of a complete Brewer System which comprises the following items:

- * Brewer Spectrophotometer
- * IBM PC or compatible microcomputer
- * Printer - dot matrix printer - Centronics compatible parallel interface
- * Control software

The Brewer Spectrophotometer is normally supplied with automated iris & filter-wheel controls, azimuth & zenith trackers and a UVB monitor.

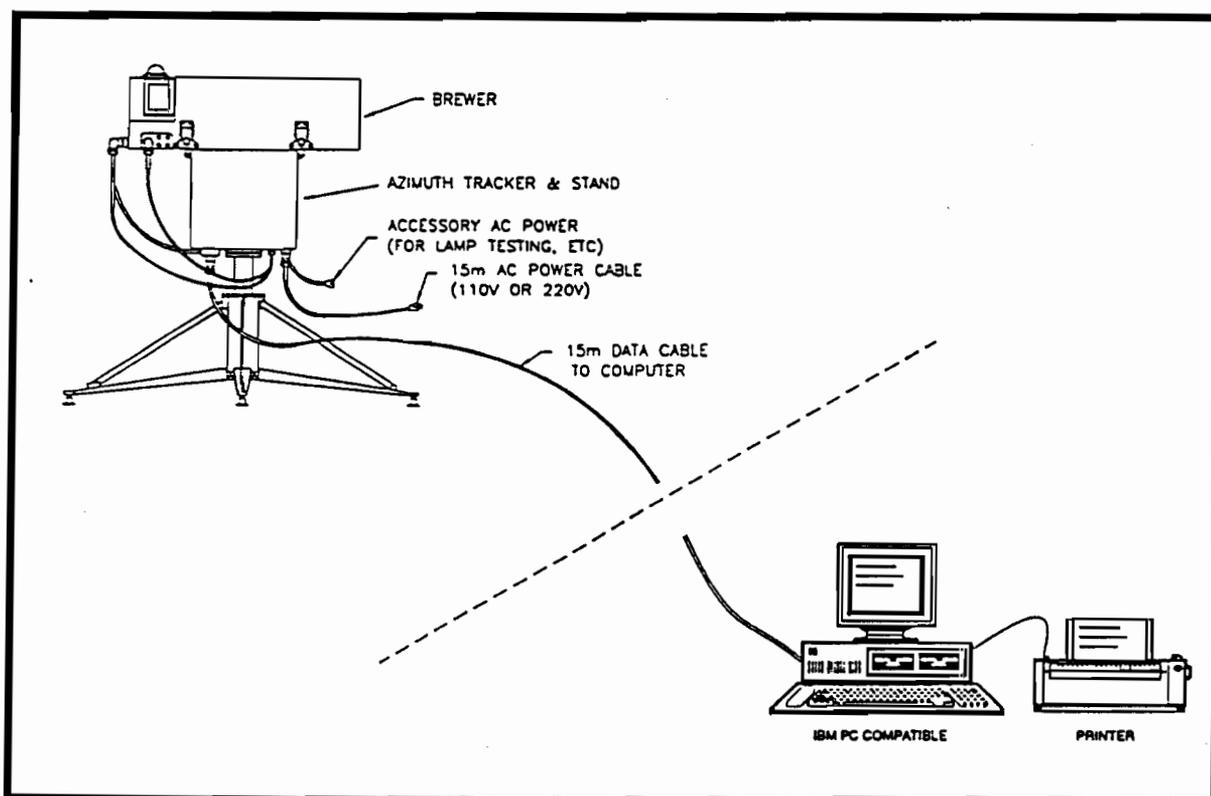
A complete Brewer System is illustrated in figure sds.0-1.

All of the above-mentioned items are available from SCI-TEC Instruments Inc., with the exception of the computer, and printer which should be obtained from a local PC dealer. The Brewer Spectrophotometer is supplied with a complete IBM BASIC program which controls all aspects of data collection and analysis. The PC is programmed to interact with an operator to control the Brewer in either a manual, a semi-automated, or fully-automated mode of operation.

In both manual and semi-automated modes the operator initiates a specific observation or instrument test by typing an instruction 'command code' on the PC keyboard. Raw data is automatically recorded on 3.5" diskettes, or stored on a hard disk drive for convenience and real-time ozone results can be printed on paper (hard copy).

In the fully-automated mode the PC performs all operations. The Brewer is automatically set to the proper observation configuration, then follows a user-defined observation schedule. Data is stored and analyzed in the same manner as in the semi-automated mode.

Figure sds.0-1 A Complete Brewer System



1. Overview and Specifications

The Brewer MKIV Spectrophotometer, hereafter referred to as the 'Brewer', is an optical instrument designed to measure ground-level intensities of the attenuated incident solar ultraviolet (UV) radiation at five specific wavelengths in the absorption spectra of ozone (O₃) and sulphur dioxide (SO₂). The MKIV version allows switching to NO₂ operation at 430-450 nm (second order). The Brewer contains a modified Ebert f/6 spectrometer with an 1200 line/mm holographic diffraction grating operated in the third order for O₃/SO₂ and second order for NO₂.

The Brewer is designed for continuous outdoor operation and is therefore housed in a durable weatherproof shell which protects the finely-tuned internal components. The instrument will operate reliably and accurately over a wide range of temperature and humidity conditions.

In order to give the reader a broad understanding of how the Brewer functions, we briefly describe the major mechanical, optical, and electronic assemblies which make up the basic instrument, then discuss the three upgrade options. (More detailed expositions of the Brewer's optical components are provided in subsequent chapters; descriptions of the electronic assemblies are provided in the Brewer Maintenance Manual.

1.1 Spectrophotometer

The Brewer system comprises the Spectrophotometer, PC and printer. These components when connected together provide for the complete operation of the system.

Figure sds.1-1 shows a top view of the Spectrophotometer. Sunlight enters the foreoptic system through the quartz inclined window adjacent to the zenith-adjustment knob. The instrument's display panel is visible through a perspex window which allows viewing of the two filterwheels and the iris lever. The entrance slit and the iris may be viewed through two viewing ports mounted in the display panel.

When the cover is removed the various optical and electronic subassemblies are readily accessible. Refer to figure sds.1-2. Both the foreoptic and spectrometer subassemblies are kinematically mounted (ie mounted to avoid over-constraint stresses) to a rigid support structure, while the photomultiplier subassembly is rigidly mounted to the support structure. This support structure is itself secured to the base of the external weatherproof container by three shock mounts to minimize mechanical vibrations

Figure sds.1-1: Top view of the left-hand corner of the Spectrophotometer.

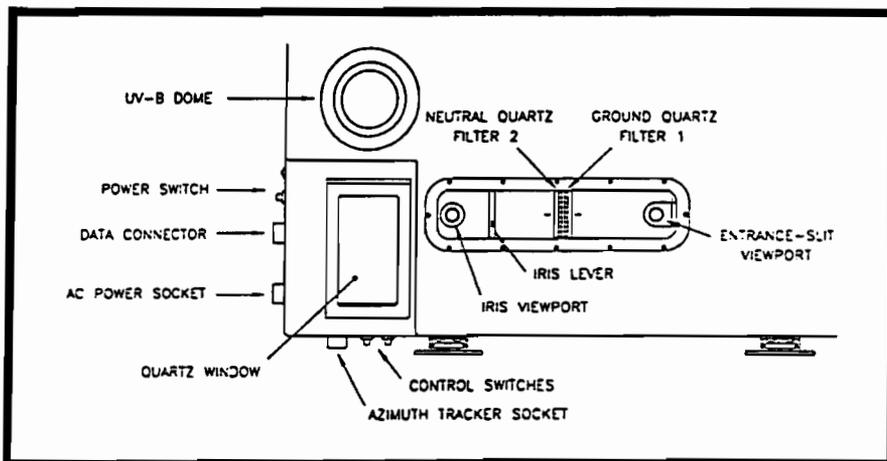
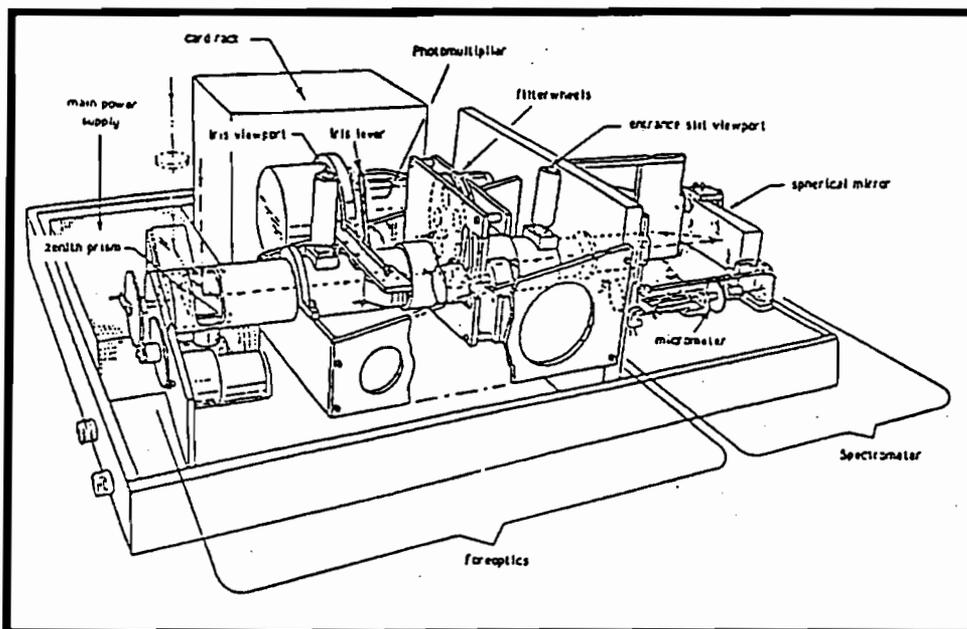


Figure sds1-2: View of Spectrophotometer with top cover removed



Optics

The Brewer Spectrophotometer consists of three major optical assemblies: the foreoptics, the spectrometer and the photomultiplier. A plan view of the MKIV is shown in figure sds.1-3.

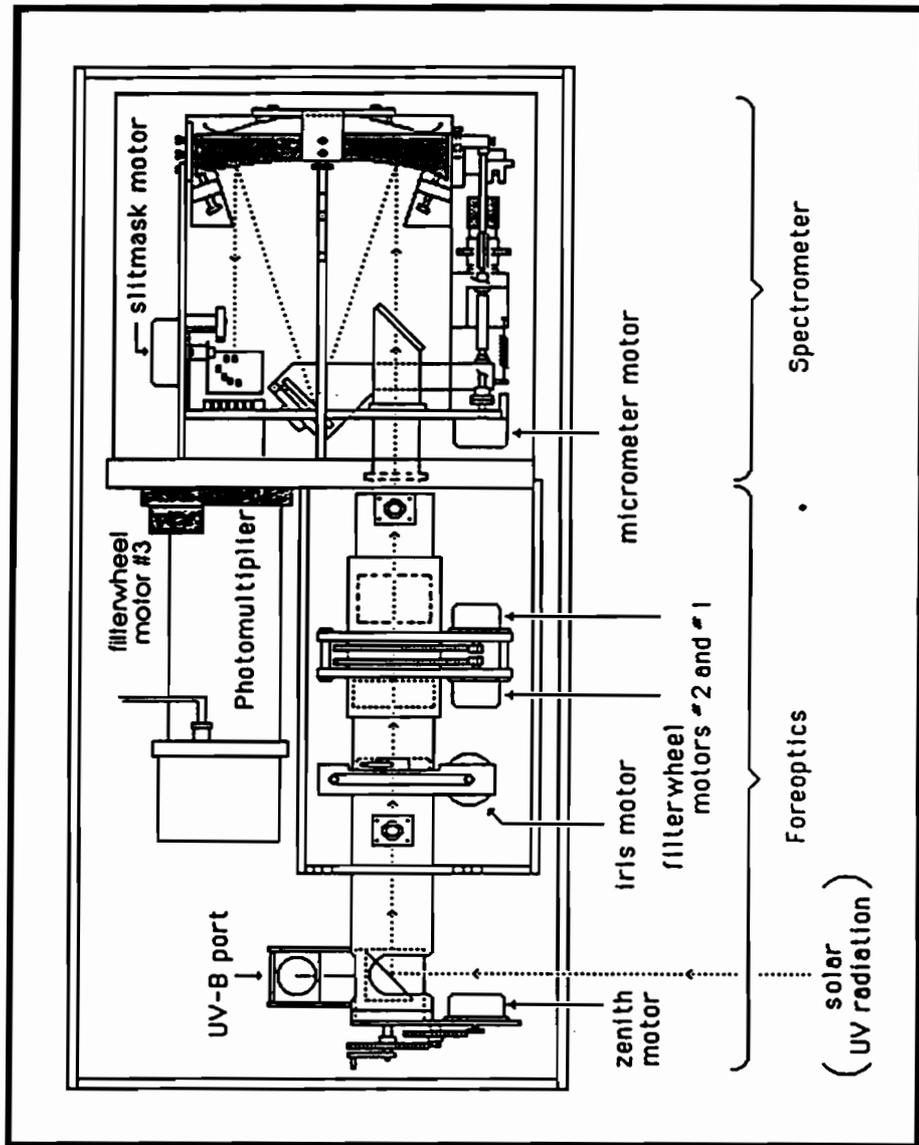


Figure sds.1-3: Plan view of the major optical assemblies. The stepper motors which drive the slit mask and micrometer are supplied with the basic instrument; the motors for the zenith prism, iris, and filterwheels are optional, as is the UV-B port. Filterwheel #3 is the major additional difference from the original MKII instrument.

Incoming light is directed through the foreoptics by a director prism which may be rotated to select light from either the zenith sky, the direct sun, or one of the two calibration lamps. A mercury lamp provides a line source for wavelength calibration of the spectrometer; a halogen lamp provides a well-regulated light source so that the relative spectral response of the spectrometer may be monitored. Elements in the foreoptics provide adjustment for field-of-view, neutral-density attenuation, and ground-quartz diffusion, and selection of a film polarizer for zenith sky measurements.

A modified Ebert grating spectrometer disperses ultraviolet light onto a focal plane. Six exit slits are positioned along the focal plane at the operating wavelengths: 303.2 nm (302.1 nm for mercury-wavelength calibration), 306.3 nm, 310.1 nm, 313.5 nm, 316.8 nm and 320.1 nm in O₃ mode with 0.6 nm resolution. 426.4 nm, 431.4 nm, 437.3 nm, 442.8 nm, 448.1 nm, 453.2 nm in NO₂ mode with 0.85 nm resolution. Wavelength is adjusted by rotating the grating with a stepper motor which drives a micrometer acting on a lever arm.

The exit-slit plane is shielded by a cylindrical mask which exposes only one wavelength slit at a time. The mask is positioned by a stepper motor which cycles through all five operating wavelengths approximately once per second.

Light passing through the exit slits is collected on the cathode of a low-noise EMI 9782Q905 photomultiplier. The photon pulses are amplified, discriminated, and divided before being transmitted to a counter. The resulting photon count is registered in one of six wavelength channels.

Electronics

The Brewer Spectrophotometer contains its own microprocessor board, an RCA COSMAC 18S601, which controls all internal instrument operations.

Specifically, the microprocessor is responsible for -

- * positioning the diffraction grating: the microprocessor controls a stepper motor which drives a micrometer connected by a lever arm to the grating
- * positioning the slit mask to allow light to pass through one of six exit-plane slits to the photomultiplier: this mask is driven by a second microprocessor-controlled stepper motor
- * synchronizing the photon-count circuitry with the movement of the slit mask
- * turning the halogen and mercury calibration lamps on or off
- * reading photo-diode optical sensors.

In addition, the microprocessor provides an RS-232C communications link to an external terminal or computer.

The microprocessor is programmed to accept commands from the external control console, execute the commands, and return results to the user. Normally an IBM

PC compatible computer is used as the control console to facilitate programmed command sequencing as well as automatic data logging and processing. Raw data is recorded on 5.25-inch / 3.5-inch diskettes or hard disk drive; real-time ozone results are printed on hard copy.

The major electronic subsystems of the instrument are listed below :

- * Main and secondary power supplies
- * Microprocessor board - carries control-program EPROMs (erasable programmable read-only memories), and a serial-communications interface which runs at 300 or 1200 bps (bits per second)
- * Input/Output Interface board - provides on/off control of the calibration lamps; drives the wavelength-micrometer stepper motor and slit mask stepper motor; reads photo-diode sensors
- * Photon Counter board - provides the instrument's timebase and a remote-reset capability; accumulates the amplified and scaled photon count from the Pulse Amplifier, and transfers these counts to the microprocessor board
- * Clock-Calendar board - contains a real-time clock and calendar, plus 2K bytes of RAM (read/write random-access memory) to save instrument-status settings when the instrument is turned off; the RAM and clock are battery-protected
- * Analog-to-Digital (A/D) board - provides 16 single-ended, 8-bit A/D channels for monitoring instrument voltages, currents, and temperatures, plus two D/A (digital-to-analogue) channels permitting closed-loop computer control of instrument voltages (the D/A channels are not currently used)
- * Pulse Amplifier - mounted in close proximity to the photomultiplier; amplifies and scales the photon-pulse signal from the photomultiplier, transmits the conditioned photon signal to the Photon Counter board.

With the exception of the power supplies and Pulse Amplifier, the electronic subsystems are mounted on cards which slide in a COSMAC-compatible card frame and motherboard.

Specifications for Basic Spectrophotometer

UV wavelengths:

operational (O₃ mode): 303.2(Hg slit), 306.3, 310.1, 313.5, 316.8, 320.1 nm

operational (NO₂ mode): 426.4, 431.4, 437.3, 442.8, 448.1, 453.2 nm

mercury-calibration (both modes): 303.2 nm

resolution: 0.6 nm in UV

0.85 nm in Visible

stability: +/-0.01 nm (over full temperature range)

precision: 0.005 +/-0.002 nm

measurement range: 280 to 340 nm (O₃ mode) standard
or 290 to 363 nm extended

420 to 510 nm (NO₂ mode) standard
or 430 to 545 nm extended

Exit-slit mask cycling: 0.2294 sec/slit/cycle, =1.6 sec for one full cycle

Measurement accuracy: +/-1% (for direct-sun total ozone)

Operating temperature range

-20 to +40 C (-4 to 104 F)

-50deg to +40deg C (when cold weather kit is installed)

Physical dimensions (external weatherproof container)

size:70 by 46 by 21 cm

weight:25 kg (55 lbs)

Power requirements:

1 A @ 80 to 140 VAC, or

0.5 @ 160 to 264 VAC;

47 to 440 Hz

1.2 Automated Foreoptics

The basic Spectrophotometer provides automated stepper-motor control of the micrometer (which rotates the diffraction grating) and the slit mask. The system also controls three other stepper motors to automate three elements in the foreoptics assembly: the iris diaphragm, and filterwheels#1 and #2. The associated driving and sensing electronics are supplied on a COSMAC-compatible I/O (input/output) Interface board. The Brewer software will automatically control the new motors once the Instrument Configuration file has been appropriately reconfigured.

1.3 Azimuth- and Zenith-Pointing System

These features provide the necessary hardware and electronics to enable the Spectrophotometer to track the sun or moon across the sky automatically. Automated azimuth positioning is achieved by mounting the instrument on an Azimuth Tracker (refer back to figure sds.0-1), while automated zenith positioning is performed by driving the zenith prism with a stepper motor mounted on the front end of the foreoptic frame. Both the azimuth- and zenith-stepper motors are controlled by the COSMAC microprocessor within the Spectrophotometer from an I/O board which also controls FW # 3 on MKIV.

The Azimuth Tracker is an all-weather positioning pedestal comprising a weather-proof chassis (housing a large stepper motor, drive electronics, and gearing) mounted on the vertical axis of a tripod foundation

Specifications for the Zenith Motor:

Resolution: +/-0.13 deg.

Accuracy (24 hours): +/- 0.25 deg.

Angular range: 0..270 deg. (limited by end stops)

Specifications for the Azimuth Tracker

Resolution: +/-0.02 deg.

Accuracy (24 hours): +/- 0.2 deg

Max. slew rate: 3.91 deg/sec

Max. angular excursion: -60 deg to +420 deg

Payload capabilities:

Max. static torque: 14.9 Nm (11 ft/lb)

Max. balanced weight: 50 kg (110 lbs)

Operating temperature

range: -20 deg to +40 deg C (-4 deg to 104 deg F)

Dimensions

Chassis Enclosure:

30.5 by 30.5 by 35.6 cm (12 by 12 by 14 inch)

Height: 91.4 cm (36 inch) with tripod

45.7 cm (18 inch) without tripod

Power requirements:

120 V AC 60 Hz @ 0.5 A, or

240 V AC 50 Hz @ 0.25 A

1.4 Option Ultraviolet-B Monitor

The UV-B Monitor is an optical assembly which enables the Brewer to measure UV-B irradiance using a thin disc of teflon (cosine response) as a transmitting diffuser. The disc is mounted on top of the instrument under a 5-cm diameter quartz dome, and is thus exposed to the horizontal UV irradiance. Beneath the disc is a fixed reflecting prism which is located so that the disc is in the spectrometer field-of-view when the zenith prism is set for a zenith angle of -90.

Figure sds.1-4 shows an end view of the foreoptics with the UV-B subassembly in place; table sds.1-1 summarizes the zenith-angle settings for the various spectrometer targets. The UV measurement software routine supplied scans from 290 to 325 nm on slit 1, in .5 nm increments and then scans back to 290 nm. The irradiance at each wavelength is integrated to produce a damaging UV value (DUV) weighted to the DIFFEY action spectrum.

A slight adjustment to the DIFFEY weighting allows for UVA irradiance estimation. Therefore, printed integrated irradiance values represent both UVB and UVA. Reference attachment UVB for data collection and analysis procedures.

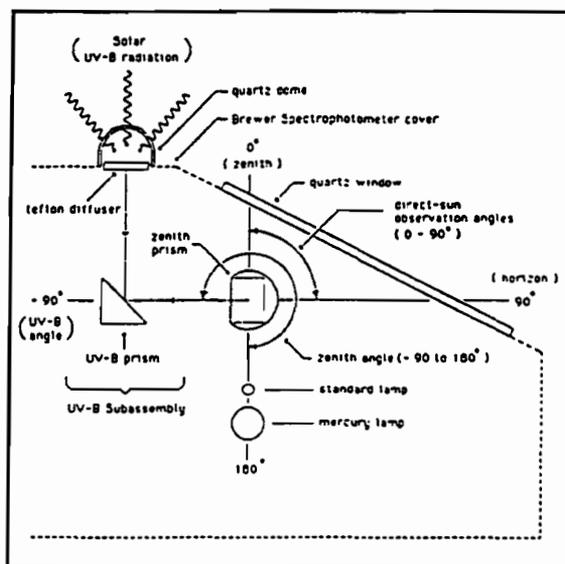


Figure sds.1-4: End view of the foreoptics with the UV-B subassembly installed. The zenith prism has been rotated to its -90 position so that the teflon diffuser is in the spectrometer's field-of-view.

Zenith angle (degrees)	Object viewed by Spectrometer
0..90	sky or sun
180	calibration lamps
-90	UV-B diffuser

Table sds.1-1 Spectrometer Targets for Various Zenith Angles

2. Mechanical Construction

The Brewer Spectrophotometer is housed in a weatherproof container constructed from two pieces: a base (to which all optical and electronic assemblies are anchored), and a removable cover. When the cover is fastened in place, a weatherproof seal is formed between the top edge of the base and a lip 5 cm up from the bottom of the cover. The nominal dimensions of the assembled container are 70 by 46 by 21 cm.

The Brewer instrument's control-panel can be viewed through a 0.95-cm perspex window in the top of the cover. The viewing ports for both the entrance slit and iris are visible through the perspex window.

When the cover is in place an adjustment knob on the outside of the container can be used to manually position the zenith prism. This knob forms a weatherproof seal through the container wall (for units with manual zenith adjustment kit only).

In one corner of the cover is a 14-cm deep, 35-degree inclined surface. A 6.35- by 14-cm hole has been cut from this surface to provide an opening which is properly positioned to pass direct sunlight or zenith skylight to the spectrophotometer. This opening is covered by a quartz window [QW 1], which is secured by a weatherproof seal. (Note: items enclosed by square brackets, [], are references to Appendix A: Selected Parts List).

Three circular weatherproof connectors are mounted on the side of the container base below the weatherproof seal. The six-pin male connector marked AC POWER connects to the 120V (or 240 V) AC power supply. The ten-pin female connector marked COMPUTER carries the RS-232C data communication signals. The ten pin male connector marked AZIMUTH carries motor control and monitor signals for the azimuth tracker.

Three foreoptic manual adjustments are provided to control:

- * filterwheel #1 (ground quartz in or out and film polarizer in or out.)
- * filterwheel #2 (neutral density filters)
- * the iris diaphragm.

The primary and secondary power supplies are enclosed within vented enclosures and secured to the base of the weatherproof container. The card frame and heatsink are also mounted to the container base.

All exposed surfaces of the spectrophotometer (including the external surfaces of the weatherproof container and the mechanical linkages) are painted with 'Dupont Imron' enamel for durability and to minimize radiative heating. All machined aluminum parts in the spectrophotometer system are black-anodized to minimize scattered light and provide a protective finish.

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3. Foreoptics

Figure sds.3-1 shows a diagrammatic view of the optical elements encountered by a light ray entering and traversing the spectrophotometer. A right-angle rotating zenith prism at the front end of the foreoptics assembly directs light from one of five sources (sky, sun, UVB port, mercury lamp, or tungsten-halogen lamp) through a set of light-conditioning elements into the spectrometer. These elements comprise

- quartz lenses and iris diaphragm to control field-of-view
- ground-quartz diffuser for sunlight and halogen lamp measurements and film polarizer to allow only one plane of polarized light to enter the spectrophotometer.
- five selectable neutral-density filters to provide up to 2.5 decades of attenuation

3.1 Zenith Prism

The right-angle zenith prism [ZP 1] reflects incoming light from the sky, sun, mercury lamp, or halogen lamp into the optical axis of the instrument. For zenith angles in the range 0 to 90 the sun or sky is viewed through an inclined quartz window, at zenith angle 180 the spectrometer views the calibration lamps, and at -90 the teflon UV-B diffuser occupies the field-of-view. Refer back to figure sds.1-4.

The prism is mounted in a retainer which rotates in a dual-bearing system which has negligible lateral play and does not bind over the operating temperature range. The 270-degree rotation range of the prism is limited by end stops. The prism is rotated either manually (basic instrument), or by the microprocessor-controlled zenith stepper motor (option B upgrade).

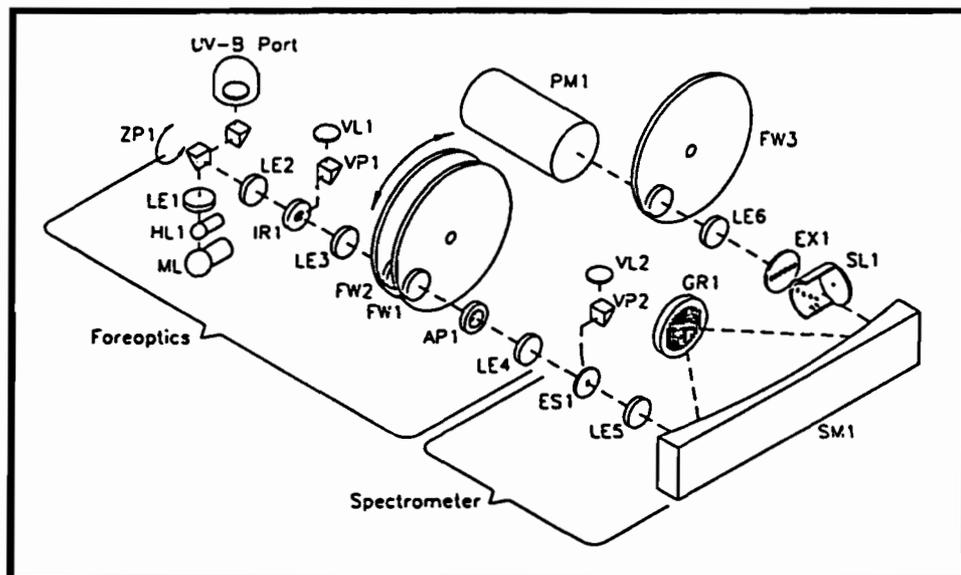


Figure sds.3-1: Diagrammatic view of the optical elements (not to scale). Zenith prism ZP1 directs incoming light into the foreoptic assembly. The three-letter identifiers are listed in Appendix A: Selected Parts List.

3.2 Lamp Assembly: Quartz-Halogen and Mercury Lamps

The quartz-halogen lamp [HL 1] provides a well-regulated light source which is used as a reference for relative sensitivity measurements; the mercury lamp [ML 1] provides the line source used for wavelength calibration. The halogen lamp is powered by a constant-current source of nominal value 1.5 A, held constant to within 0.5% over a temperature range of -20 to +40 C. The intensity of the ultraviolet light from the lamp under these conditions is stable to within 5%. The filament of the lamp is placed at the focal point of a double-convex lens [LE 1] so that the light from the lamp is directed along the optical axis of the spectrometer by the zenith prism.

Behind the halogen lamp is a mercury lamp. Ultraviolet light from the mercury lamp is diffuse and passes through the halogen lamp to the zenith prism. While the actual light intensity of the lamp is not critical (a variation of 50% over the operational temperature range is normal), the intensity must remain stable to within 5% for short time periods (10 minutes).

When the lamp is off, a quiescent current of 100 mA through the bulb is maintained; this ensures that the lamp will light reliably at temperatures as low as -15°C.

3.3 Iris-Diaphragm Assembly

An iris diaphragm [IR 1] is mounted in the foreoptics at the ultraviolet focus of a plano-convex lens [LE 2]; thus the lens focuses ultraviolet objects at infinite distance onto the plane of the iris. A lever arm which protrudes through the wall of the foreoptic tubing controls the iris: at one limit of the lever arm the iris aperture is 5 mm (iris 'closed'), at the other limit the aperture is approximately 15 mm. The lever is actuated either manually (basic instrument), or by the iris stepper motor (option A upgrade).

When the instrument is aligned to view sunlight an ultraviolet image of the sun is focused at the center of the iris. With the iris closed, about three solar diameters of skylight around the sun pass through the iris aperture into the spectrometer; with the iris open, about 10 degrees of skylight enters the spectrometer.

On the spectrometer side of the iris there is another plano-convex lens [LE 3]. This lens is positioned such that its focal point is in the plane of the iris: light passing through the iris aperture is therefore collimated along the optical axis.

Both lenses [LE 2, LE 3] in the iris-diaphragm assembly are mounted with their plane side facing the iris.

3.4 Filterwheels

Two filterwheels [FW 1, FW 2] are mounted on bronze bearings in a filter-wheel housing. Each wheel has six 25.4-mm-diameter holes spaced at 60-degree intervals. Each hole retains a filter which can be selected to intersect the optical axis by rotating its filterwheel. The filterwheels are rotated either manually (basic instrument), or by two microprocessor-controlled motors (option A upgrade).

Filterwheel #1 contains one open hole (position 3), two film polarizers (position 0, 5), a ground-quartz disk (position 1), and an opaque blank (position 2) and a second ground quartz disk and neutral density filter (position 4). The ground-quartz disk is used as a diffuser for direct-sun and lamp measurements. The opaque disk is used for dark count tests. The film polarizer (position 0) is used for all zenith sky and Umkehr measurements. This film polarizer is mounted such that the polarizer's axis is perpendicular to the entrance slit. The second film polarizer (position 5) is mounted such that the polarizers axis is parallel to the entrance slit. It is presently for research and development purposes only. The open position (# 3) is used for moon and UVB observations. The second ground quartz / N.D. filter is used for NO₂ operation.

Filterwheel #2 contains an open hole (position 0) and five neutral-density filters providing 0.5, 1.0, 1.5, 2.0 and 2.5 orders-of-magnitude attenuation (positions 1 through 5 respectively).

All filters are retained in their filterwheels by Dow 3140 RTV bonding agent.

An 11.18-mm fixed aperture [AP 1] located on the spectrometer side of the filterwheel housing limits the field-of-view of the spectrometer to $f/6$.

3.5 Foreoptic Viewing Ports

There are two viewing ports along the foreoptic assembly: through one port the operator may view the iris diaphragm and any images which are focused onto it; through the other the operator may view the entrance slit.

At the bottom of each viewing port is a glass right-angle prism [VP 1, VP 2] mounted inside the foreoptic tubing. The prisms are aligned so that the object to be viewed (iris or entrance slit) appears centered in the viewing port. A plano-convex glass lens [VL 1, VL 2] is placed in each viewing tube to magnify the image.

3.6 Rear Fore-Optics.

A plano-convex lens [LE-4] whose plane surface faces the entrance slit of the spectrometer and focuses the polarized, collimated ultraviolet light coming from infinite objects onto the entrance slit of the spectrometer.

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4. Spectrometer

The purpose of the spectrometer optical subassembly is to accept light at the entrance slit and disperse it into a high-quality spectrum along the exit-slit focal plane. The spectrometer is a modified Ebert type with focal length 16 cm, and aperture ratio $f/6$.

Light enters the entrance slit and passes through a tilted lens [LE 5] which corrects for the coma and astigmatic aberrations inherent in an Ebert system. The light is then collimated by a spherical mirror onto the grating where it is dispersed. A second mirror reflection focuses the spectrum onto the exit-slit focal plane. Six exit slits are located along the focal plane at the appropriate wavelength positions. A slotted cylindrical slit mask positioned in front of the exit slit plane serves as the wavelength selector.

4.1 Entrance- and Exit-Slit Plates

The entrance slit and six exit slits [ES 1, EX 1] are laser-etched into 0.1-mm-thick disks of hard shim steel. One of the six exit slits is used for wavelength calibration against the 302-nm group of mercury lines; the other five are for intensity measurements and are normally set at 306.3, 310.1, 313.5, 316.8, and 320.1 nm. The dimensions for the entrance and exit slits are listed in Appendix A of this section. This information can also be found in the Acceptance Manual which accompanies each instrument.

Both slit plates are positioned on their respective housings by locating pins which orient the slit axis to within 0.1 degrees. Both plates are blackened to minimize light reflections.

4.2 Correction Lens

The correction lens [LE 5] has a convex-cylindrical surface (radius 170.0 mm) and a concave-spherical surface (radius 230.0 mm).

Both surfaces are coated with a layer of magnesium fluoride to minimize reflectance at 315.0 nm for an incidence angle of 29 degrees. The lens is mounted in the entrance-slit housing at an angle of 29 degrees to the optical axis with the concave-spherical surface facing the entrance slit. The axis of the cylindrical surface is positioned in the horizontal plane.

4.3 Spherical Mirror

The spherical mirror [SM 1] has a 324-mm radius-of-curvature. The spherical surface is ground from a rectangular pyrex blank; the surface is polished, coated with aluminum, then coated with magnesium fluoride to maximize reflection at 315.0 nm.

A spring-loaded mount secures the spherical surface of the mirror against three adjustment screws which are normal to the spherical surface in the horizontal plane of the spectrometer. The mirror is allowed to move on a spherical surface defined by the three adjustment screws, up to a limit of 0.25 mm in the horizontal and vertical. Nylon screws prevent the mirror from moving beyond this limit.

4.4 Diffraction Grating

The diffraction grating [GR 1] is an 1200 line/mm holographic plane-reflectance type operated in the second order for NO₂ and in the third order for O₃/SO₂. The grating has optimum efficiency at 900 nm in the first order.

The grating is secured with high-quality adhesive (such as 3M EC-801) to three small blocks which provide a kinematic mount for the grating as well as fine adjustment for rotation of the grating about the two axes perpendicular to the grating grooves. The three blocks are thus part of the grating and are the basis of a point, slot, and plane mount which allows adjustment by three screws fixed in the grating-mount plate. This plate is suspended on a set of cross-springs which constrain the grating to rotate in the vertical axis (the axis parallel to the grating grooves). The cross-spring suspension acts as a frictionless bearing. Rotation of the grating is controlled by a micrometer acting at the end of a lever arm such that a 0.03-mm adjustment of the micrometer represents approximately a 0.1-nm wavelength change at the exit-slit plane.

4.5 Micrometer

A metric micrometer head clamped to the spectrometer frame is used to adjust the grating rotation. The micrometer shaft is ground to a 60-degree cone which inserts into a bearing at one end of a pushrod. A conical depression with a tetrahedral corner at the other end of the pushrod locates a 60-degree cone mounted on the end of the grating lever arm. The pushrod is secured between the micrometer shaft and lever arm by a tension spring. The material of the pushrod has been selected to minimize differential temperature expansion effects.

The micrometer is rotated by a stepper motor [ST 1]. The motor drives a 10-tooth gear which is kinematically linked to a 60-tooth gear on the micrometer shaft. The drive shaft is coupled to the motor shaft with a universal joint.

One motor step represents 0.006 nm on the exit-slit plane. Backlash of the micrometer and cross-spring bearing system has been measured at 0.002 nm. The temperature range of operation for the stepper motor and micrometer adjustment is -20 deg to +40 deg C.

4.6 Slit Mask Assembly

Directly in front of the exit-slit plane is a slotted mask [SL 1] which may be located in one of eight positions (see figure sds.4-1). Six of the eight positions allow light to enter one of the six exit slits. The second mask position blocks light from all slits so that a dark measurement can be made. The eighth mask position exposes two of the exit slits so that the dead time of the photon counting system may be determined. The correspondence between slit mask position and selected wavelength is summarized in table sds.4-1.

The axis of the cylinder is attached to the shaft of a stepper motor [ST 2]. The mask is aligned with the exit slits by adjusting the vertical position of the motor and adjusting the horizontal position of the cylinder on the motor shaft.

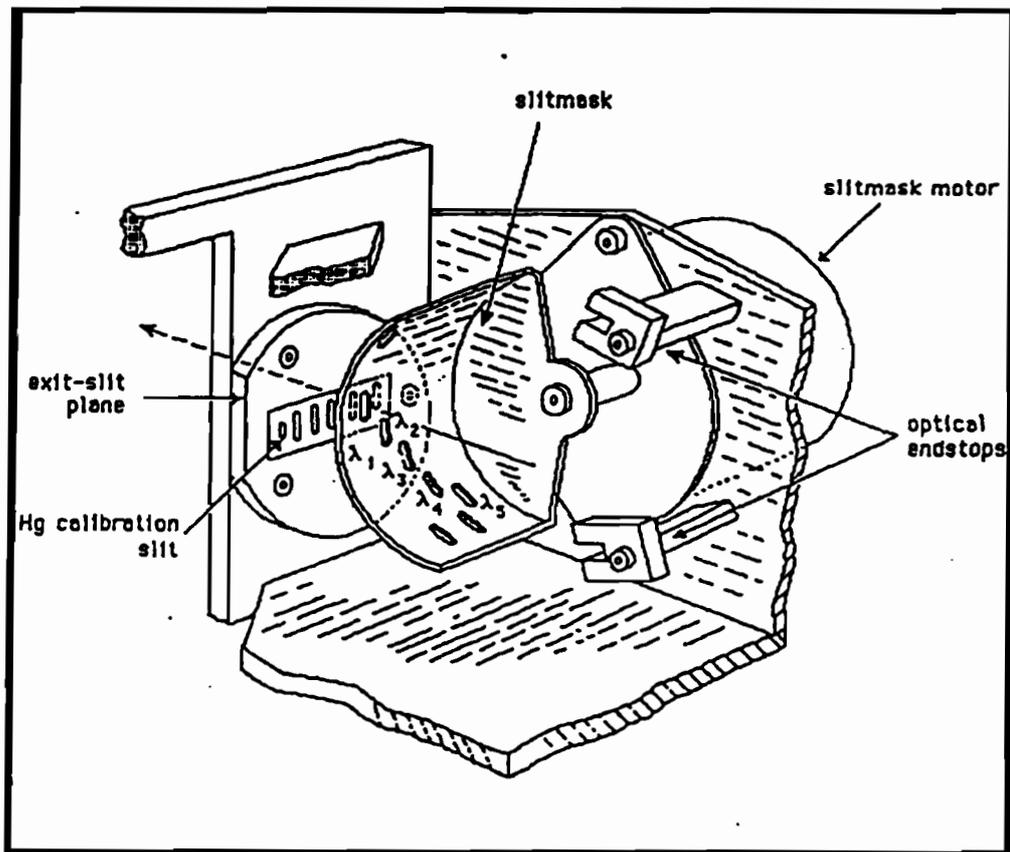


Figure sds.4-1: slit mask assembly. By rotating the slit mask each of the mask slots will align with a corresponding slit in the exit plane, effectively selecting a single wavelength. During an HG test the topmost slot in the slit mask aligns with the Hg calibration slit in the exit plane. The dual-slot position allows dead time of the photomultiplier to be determined.

Table sds.4-1: slit mask position versus selected wavelength. (This table assumes that an HG calibration test has recently been performed.)

Slit Mask Position	Wavelength Setting (nm)	
	<u>UV</u>	<u>Visible</u>
0	Hg Calibration: 303.2	426.4
1	Dark Count: -----	
2	Wavelength 1: 306.3	431.4
3	Wavelength 2: 310.1	437.4
4	Wavelength 3: 313.5	442.8
5	Wavelength 4: 316.8	448.1
6	Wavelength 5: 320.1	453.2
7	Wavelength 2 & 4 for Deadtime Test	

5. Photomultiplier

Light passing through the exit slits is focused onto the cathode of the photomultiplier [PM 1] by a 38.1-mm-focal-length quartz Fabry lens [LE 6].

Located between the Fabry lens and the photomultiplier is FW #3 with a blocking filter combination: a 10-mm-thick nickel sulphate crystal [BF 1] packaged between two - 1mm thick UG11 filters [BF 2] and a [BG 12] (blue) filter for NO₂ in a different FW position. Because of the hygroscopic nature of the nickel sulphate crystal, it is sandwiched in an O-ring seal between the quartz lens and the UG11 filters.

The cathode of the photomultiplier [PM 1] is located at the ultraviolet focus of the Fabry lens. The spacing between the lens and the photomultiplier takes into account the apparent change in focal length due to the presence of the filters. The photomultiplier is enclosed in a magnetic shield which is maintained at cathode potential (approximately -1300 V) to minimize dark noise in the photomultiplier. The photomultiplier and its shield are spring-loaded against a teflon ring which locates the cathode at the center-of-focus of the Fabry lens and also insulates the magnetic shield from the photomultiplier housing.

Do not dismantle the photomultiplier assembly: small displacements of these optical components can produce apparent intensity variations of the order of 1% from wavelength to wavelength resulting in degraded ozone measurement accuracy. (These variations arise from the slight spatial non-linearities in both the response of the photomultiplier cathode and the transmissivity of the blocking filters.) The photomultiplier housing has been designed to allow access to the photon amplifying and discriminating circuitry without disturbing the photomultiplier optics.

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Appendix A: Selected Parts List

Identification Description

AP	1	Fixed aperture, 11.18 mm
ES	1	Entrance slit plate, dia: 26.37 mm, width: 0.10 mm Slit, length: 3.30 mm, width: 0.34 mm.
EX	1	Exit slit plate, dia: 43.18 mm, width: 0.10 mm Slits, length: 5.08 mm, width(3): 0.589 mm, width(3): 0.632 mm.
FW	1	Filterwheel #1 made from aluminum gear material, with two ground G1-quartz disk, dia: 25.4 mm, width: 1.59 mm, and two film polarizers, dia: 25.4 mm, width: 1.59 mm.
FW	2	Filterwheel #2, made from aluminum gear material with 5 neutral-density filters; each with dia: 25.4 mm, width: 1.59 mm; attenuations: 0.5, 1.0, 2.0, 2.5 decades
FW	3	Filterwheel #3, made from aluminum gear material (4 openings), and holds BF1/2 and BF3.
BF	1	Blocking filter, nickel sulphate crystal, dia: 25.4 mm, width: 10 mm
BF	2	Blocking filter, UG11, dia: 25.4 mm, width: 1 mm, (2 pieces) packaged with BF1.
BF	3	Blocking filter, BG12, dia: 25.4mm, width: 2 mm
GR	1	Grating, 1200 line/mm holographic plane reflectance, dia: 50 mm, thickness: 10 mm (Jobin-Yvon)
HL	1	Tungsten-halogen lamp, 12 V, 20 W, Osram 64425, mounting: Amel Socket for #28-8341 light source
IR	1	Iris diaphragm, aperture range: 2 to 12 mm (Edmund Scientific catalogue #40997)

Identification	Description
LE 1	Lens, double-convex, G1-quartz, focal length: 25.4 mm, dia: 25.4 mm
LE 2	Lens, plano-convex, G1-quartz, focal length: 76.2 mm, dia: 25.4 mm
LE 3	Lens, plano-convex, G1-quartz focal length: 50.8 mm, dia: 25.4 mm
LE 4	Lens, plano-convex, G1-quartz, focal length: 76.2 mm, dia: 25.4 mm
LE 5	Correction lens G1 quartz, dia: 25.4 mm, radius 1: 170.0 mm, convex cylindrical, radius 2: 230.0 mm, concave spherical, coating: magnesium fluoride
LE 6	Fabry lens, double-convex, G1 quartz, dia: 38.1 mm focal length: 38.1 mm
MI 1	Micrometer, metric, Starrett #463 MP, 13-mm head, EDP #52444
ML 1	Mercury lamp, ozone-producing, General Electric G4S11; mounting: 14-71 intermediate screw socket
PM 1	Photomultiplier, EMI #9789QB05
QW 1	Quartz window, G1 quality 7.62 by 15.24 by 0.48 cm
SL 1	Slit mask, cylindrical sector, dia: 25.4 mm, thickness: 0.038mm
SM 1	Spherical mirror, radius: 324 mm, ground from pyrex blank of dimensions 25.4 by 165.1 by 50.8 mm, aluminized reflecting surface, coated with magnesium fluoride
ST 1	Stepper motor, 2-watt, 12-volt (AIRPAX reference #LK82201-P2)
ST 2	Stepper motor, 2-watt, 12-volt (AIRPAX reference #K82401-P2)

Identification	Description
VL	1,2 Viewing lens, plano-convex, glass. dia: 15 mm, focal length: 112 mm (Edmund Scientific catalogue #95738)
VP	1,2 Viewing prism, right-angle, glass 7 by 8 by 7 mm (Edmund Scientific catalogue #30575)
ZP	1 Zenith prism, right-angle, G1-quartz, 31.75- by 31.75-mm square face

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COMMUNICATING WITH THE BREWER

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1. Overview

The Brewer Spectrophotometer has an onboard RCA 1802 microprocessor which controls the host of low-level functions performed by the instrument: positioning the stepper motors, turning the standard (tungsten-halogen) and mercury lamps on or off, synchronizing photon counting with slit mask position, accumulating and transmitting photon counts, monitoring instrument temperature.

The Brewer instrument communicates with the outside world via a simplified RS-232C serial interface which can run at 300 or 1200 bits per second (bps). (The detailed specifications of the interface are provided in the next section.) In normal operation, the 'outside world' is a IBM PC compatible microcomputer with a serial port, connected to the Brewer's 25-pin DB-25S serial interface socket.

Commands are usually transmitted to the instrument by the Brewer program running on the PC. Alternatively, the user may control the instrument directly by setting the program to its 'teletype' mode (select TT from the Operating Menu), then typing the appropriate low-level command sequences. Any ASCII (American National Standard Code for Information Interchange) terminal with an RS-232C interface may be used in place of the PC for these low-level diagnostic tests.

When the Brewer spectrophotometer is powered up or reset it transmits a message similar to the following at 300 bps:

BREWER SPECTROPHOTOMETER

#022

AES SCI-TEC

CANADA

VERSION 39.10 FEB 1, 1994

(The serial number, version number, and version-release date will probably be different for your instrument.)

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2. Description of the Brewer Serial Port

The specifications for the serial port are summarized below:

Baud rate:	300 (default) or 1200 bps
Word length:	8 bits
Parity:	none
Stop bits:	1
Configuration:	DCE (data communications equipment - i.e. modem-like)

The baud rate and echo setting can be altered with the V command - see section 5.15 (V: Set Baud Rate and Echo). The Brewer's DB-25S socket is wired to appear as a modem to any connecting terminal: refer to figure cwb.2-1.

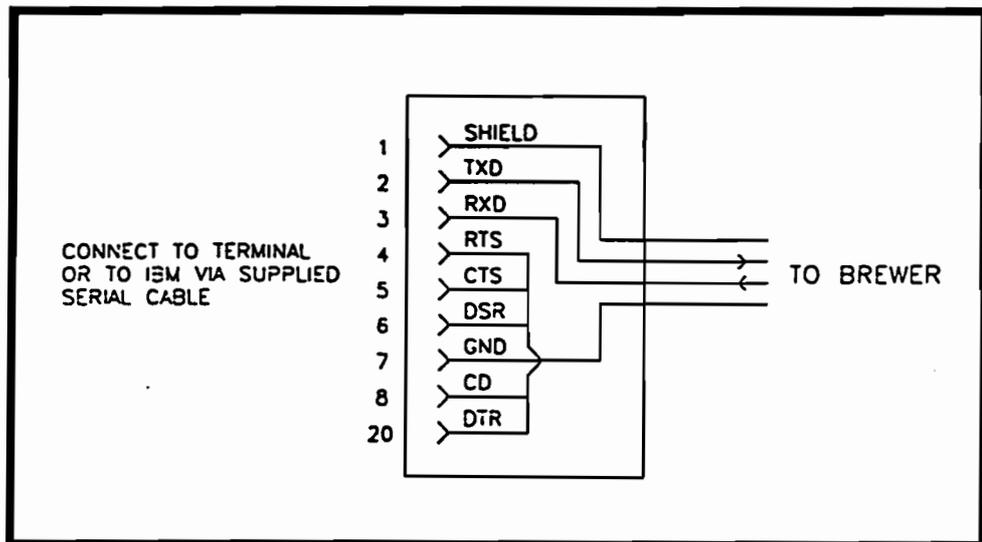


Figure cwb.2-1: Wiring diagram for Brewer Spectrophotometer DB-25S Data Cable socket.

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3. Communicating via an ASCII Terminal

The communications software stored in the COSMAC ROM (read-only memory) was originally designed for an uppercase-only printing terminal which had keys for the special characters DEL (delete: ASCII character 127), BREAK (holds the TXD line low as long as the Break key is depressed), LF (linefeed: ASCII character 10), CR (carriage return: ASCII character 13), and ^X (control-X: ASCII character 24 - hold down Control key, then type X; this can be used to cancel a misspelled or partially entered command). Any video or printing ASCII terminal with a RS-232C serial interface can be used as the command console.

Once the terminal has been set to full duplex, 300 bps and connected to the Brewer serial port you should confirm that the Brewer is communicating. Hit the Return key (sometimes labeled Enter) several times; you should receive a fresh Brewer prompt

->

for each Return typed. Request a status report from the Brewer by typing

S <Return>

(This is an uppercase S; lower-case characters are echoed to the terminal but otherwise ignored by the Brewer means 'hit the Return key'.) The Brewer will respond with a comma-separated list of six numbers:

0, 4, 0, 32, 0, 0,

The numbers returned depend on what operations the Brewer has been performing previously - see section 5.13 (STATUS) for details. You will observe that the response is printed on the same line as the S command. To improve readability, modify the command sequence slightly by typing a Linefeed before the Return:

S <Linefeed> <Return>

The Brewer echoes (but otherwise ignores) the Linefeed, causing the terminal to advance one line, and interprets the Return to mean 'end of command string, execute the command(s)'.

The command-string syntax takes the form

<Command>, <arguments>; <command>, <arguments>; ... <Return>

Example:

R, 0, 7, 4; 0; A <Return>

(Run the slit mask motor from position 0 through 7 and back again accumulating photon counts in 8 separate accumulators, repeat this cycle 4 times; Output (transmit) the 8 photon-count totals to the Brewer as a comma-separated list; Again: repeat the entire count-then-transmit sequence until the operator types Break.)

The semicolon (;) is the command separator; comma (,) is the argument separator; carriage return (<Return>) is the command-string terminator.

A modest editing facility is available: use the Delete key to erase the last character typed (the Brewer will transmit the 'deleted' character back to the terminal); use control-X (hold down the Control key then type X) to cancel the command currently being typed. Note that the Brewer ignores Backspace (ASCII character 8) as an editing key.

The Break key provides two important functions: if Break is held down for less than five seconds (approximately) the Brewer will abort any command currently being executed and display the - prompt. If Break is held down for more than 5 seconds the Brewer will perform a complete instrument reset (slit mask motor returns to its zero position, all internal counters are cleared, baud rate set back to 300 bps, startup message transmitted to the terminal).

If you wish to set the baud rate to 1200 bps, use the V command with an argument of 120:

```
V, 120 <Return>
```

(A baud rate of 1200 bps implies a character transfer rate of approximately 120 characters per second.) Set the terminal to 1200 bps, then press Return. The Brewer should respond with the usual → prompt.

If your terminal appears to be character-doubling (for example, typing S produces SS on the display) then the terminal is incorrectly set at 'half-duplex' (sometimes called 'local echo'). Set the terminal to full-duplex to clear the problem. An alternative, less satisfactory, solution is to set the Brewer to 'no echo'. Listed below are four V-command permutations:

V, 120, 1	(1200 bps, no echo)
V, 30, 1	(300 bps, no echo)
V, 120	(1200 bps, echo enabled)
V, 30	(300 bps, echo enabled)

4. Communicating: The PC-to-Brewer Interface

This section details how the PC is used as a terminal to control the Brewer instrument. (The reader is assumed to be familiar with the previous section which described usage of a standard ASCII terminal.)

Ensure the 15 metre serial communications cable is installed: the DB25s end plugs into the Serial Port at the back of the PC, the other end mates with the appropriate circular connector on the Brewer instrument. (The wiring schematics for this cable, appear in the Maintenance Manual, page 7.1-7)

From any of the Brewer Software menus select the TT (teletypewriter) option. The TT program automatically sets the communications link to 300 bps, full duplex (that is, the instrument will 'echo' all characters transmitted by the PC). If you would like a printed record of the TT communications session then respond 'y' (yes) to the prompt:

do you want hard copy?

The PC keyboard lacks several important keys such as Linefeed, Break. The TT routine compensates for these deficiencies by redefining three keys:

The DEL key functions as a toggling Break: hit DEL to generate a Break 'character' when the slit mask is running, for example.

If you make a mistake typing a command, then note:

(Control-X cancels any text on the current command line.)

Press the HOME key when you wish to terminate the TT communications session and return to the previously displayed main menu.

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5. The Low-Level Brewer Command Set

A command string may consist of one or more commands, each command separated by a semicolon (;) or colon (:). Each command may have associated with it one or more comma-separated parameters. The end of a command string is indicated by typing Return.

The syntax for a single command is:

```
<Command>, <arguments> <Return>
```

Examples:

```
S <Return>
```

Transmit current status.

```
R, 0, 7, 5 <Return>
```

Run slit mask motor from position 0 to 7 and back; repeat this sequence 5 times, accumulating photon counts.

The syntax for a multiple-command string is:

```
<Command>, <arguments>; <Command>, <arguments>;...<Return>
```

Example:

```
R, 0, 7, 5; O; A <Return>
```

Run the slit mask motor from position 0 to 7, repeat sequence 5 times; output accumulated photon counts; repeat this accumulate-then-output sequence indefinitely.

5.1 AGAIN

Syntax: ...; A

Description:

Repeat the command(s) (...) until the user either hits the Break key, or repeatedly types any character key.

Examples:

R, 0, 7, 3; O; A <Return>

Continue re-executing the command subsequence 'R, 0, 7, 3; Q' until a Break is detected. The subsequence means 'Run the slit mask motor from position 0 through position 7 (accumulating the photon counts in 8 separate channels) and back again, repeat this to-and-fro motion 3 times; transmit (Output) the accumulated photon counts as a comma-separated list.

M, 3, 0; M, 3, 75; A <Return>

Repeatedly move the Motor #3 (Iris motor) from one extreme position to the other.

5.2 BULB

Syntax: B, p1

Description:

Turn on or turn off the standard lamp and/or the mercury lamp.

Parameter:

Parameter p1 is a 2-bit decimal control code: bit-0 controls the mercury lamp, bit-1 controls the standard lamp.

p1	standard lamp	mercury lamp
0	off	off
1	off	on
2	on	off
3	on	on

Example:

B, 2 <Return>

Turn the standard lamp on, turn the mercury lamp off.

5.3 DUMP

Syntax: D, p1, p2, ...

Description:

Transmit to the Terminal the byte values located at COSMAC memory addresses p1, p2, ... (Distinguish this command from Get which fetches byte values located at COSMAC I/Q addresses - see section 5.5 (GET)).

Parameters:

Parameters p1, p2, ... are 16-bit COSMAC memory addresses written as signed decimal numbers in the range -32768..32767. The decimal-to-hexadecimal mapping follows the standard twos-complement scheme:

Decimal parameter	Hexadecimal address
0	0000
1	0001
:	:
32767	7FFF
-32768	8000
-32767	8001
:	:
:	:
-2	FFFE
-1	FFFF

Each byte value returned by the Dump instruction will be an integer within the range 0..255.

Example:

D, 17, -54, 1024 <Return>

Transmit the byte contents of (hexadecimal) locations \$0011 (decimal 17), \$FFCA (-54), \$0400 (1024) as a comma-separated list to the Terminal.

The memory addresses for the Brewer motor positions are as follows:

Motor 1 Zenith:

$$16895 \text{ hi byte (value} \cdot 256) + 16896 \text{ low byte (value)} = \text{position.}$$

Motor 2 Azimuth:

$$16907 \text{ hi byte (value} \cdot 256) + 16908 \text{ low byte (value)} = \text{position.}$$

Motor 3 Iris:

16919 hi byte (value* 256) + 16920 low byte (value) = position.

Motor 4 Filter wheel #1:

16931 hi byte (value* 256) + 16932 low byte (value) = position.

Motor 5 Filter wheel #2:

16943 hi byte (value* 256) + 16944 low byte (value) = position.

Motor 10 Micrometer

16955 hi byte (value* 256) + 16956 low byte (value) = position.

Motor 11 slit mask motor

16967 hi byte (value* 256) + 16968 low byte (value) = position.

Motor 6 Filter wheel #3

16979 hi byte (value* 256) + 16980 low byte (value) = position.

Example command sent to brewer for zenith motor:

D, 16895, 16896

5.4 FILL

Syntax: F, p1, p2

Description:

Define the fill characters (those characters transmitted as a 'header' before each output message) to be p1 repetitions of character p2.

Parameters:

Parameter p1 is the repetition count (0..255), p2 is the ASCII character to be transmitted as the fill character. The default values are 6 and 0 respectively, producing 6 ASCII Nulls (ie: F, 6, 0).

Examples:

F, 1, 7 <Return>

Transmit a single Bell character as the header.

F, 0, 0 <Return>

Suppress all fill characters.

5.5 GET

Syntax: G, p1, p2, ...

Description:

Transmit to the Terminal the byte values located at the COSMAC I/O (input/output) addresses p1, p2, ...

Parameters:

Parameters p1, p2, ... are 16-bit COSMAC I/O addresses written as signed decimal numbers in the range 0..1935 (\$0000..\$078F). The I/O addresses and bit-maps are shown in tables cwb.5-1 and cwb.5-2 which follow. Each byte value returned by the Get instruction will be an integer within the range 0..255. In hexadecimal, I/O addresses take the form \$OLMN, where

L is the I/O level, with values 2..7 (only levels 2, 3, 4 are currently used)

M is a one-of-four select code with values 1, 2, 4 or 8

N is any hexadecimal digit, 0..F

Example:

G, 544, 800, 1056 <Return>

Transmit the byte contents of (hexadecimal) I/O locations \$0220 (decimal 544), \$0320 (800), \$0420 (1056) as a comma-separated list to the Terminal.

I/O Address		Description
hexadecimal	decimal	
0220	544	Status of Slit Mask & Micrometer
0320	800	Status of Zen.-prism & Az-tracker motors
0420	1055	Status of Iris & Filterwheel motors
4F18-4F21	20244-20257	A/D Table
F000-F007	61440-61447	Real-Time Clock
F800-FFFF	63488-65535	Battery-backed-up RAM

Table cwb.5-1: COSMAC I/O Address Map for Brewer Spectrophotometer. The bit-maps for the first three I/O locations are shown in table cwb.5-2.

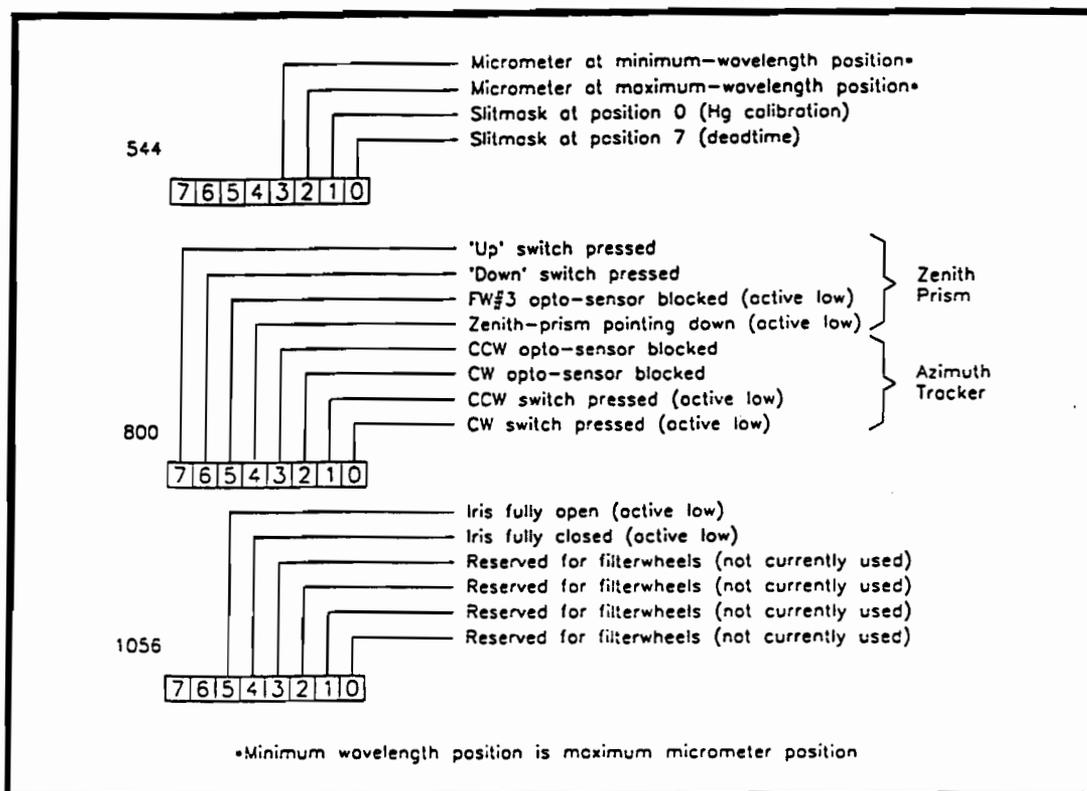


Table cwb.5-2: Bit-maps for I/O locations 544, 800, 1056 (or \$0220, \$0320, \$0420 in hexadecimal form). The bit is high when the condition is met (active low) unless otherwise specified.

5.6 INITIALIZE

Syntax: I, p1

Description:

Move the specified motor to its 'zero' position, then set the corresponding step-count accumulator to zero. (Note: the Initialize command is not used in the Brewer software.)

Parameters:

Parameter p1 is a decimal number specifying which motor is to be initialized:

Motor	Action
1. Zenith Prism	moves Zenith Prism to Standard Lamp position (ie. pointing straight down)
2. Azimuth Tracker	moves Tracker 500 steps CCW as viewed from above (not Particularly useful)
3. Iris	moves Iris to its fully closed position
4. Filterwheel 1	moves Filterwheel 1 to position #5 (zero attenuation)
5. Filterwheel 2	moves Filterwheel 2 to position #0 (zero attenuation)
6. Filterwheel 3	moves FW 3 to position for NO2 or O3 Operation

Example:

I, 3 <Return>

Move the Iris to its fully open position, then set the iris step-count to zero.

Warning: The Initialize command does not (currently) make use of the optical end stop sensors. The recommended alternative procedure is to use the Motor command followed by an appropriate Get to confirm that the stepper motor has reached the end stop.

5.7 LOAD

Syntax: L, p1, v1, p2, v2, p3, v3, ...

Description:

Store in COSMAC memory location p_i the byte value v_i .

Parameters:

Parameters p_1, p_2, \dots are 16-bit COSMAC memory addresses written as signed decimal numbers in the range -32768 .. 32767. [Refer to section 5.3 (DUMP) for details of the mapping between hexadecimal and decimal addresses.] v_1, v_2, \dots are 8-bit data values written as integers in the range 0..255.

Example:

```
L, 18073, 35, -56, 255 <Return>
```

Store \$23 (decimal 35) at memory location \$4699 (18073), store \$FF (255) at location \$FFC8 (65480 = 65536 - 56).

5.8 MOTOR

Syntax: M, p1, p2

Description:

Move the motor p1 to absolute step position p2. If p2 is negative the motor will be moved backwards by (the absolute value of) p2 steps, this new location will become the revised zero-step position.

Parameters:

Parameter p1 is a decimal number specifying which motor (1..5, 10, 11) is to be moved; p2 is a step number whose typical range for each motor is summarized in Table cwb.5-3.

Example:

```
M, 4, 256 <Return>
```

Move the ground-quartz diffuser on Filterwheel #1 into the optical path. If the filterwheel is put into the 320 position, the film polarizer is present instead of a transparent opening.

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	M,5,128
	192	3: f = 1.5	M,5,192
	256	4: f = 2.0	M,5,256
	320	5: f = 2.5	M,5,320
6: Filterwheel # 3	50	clear aperture (transparent)	M,6,50
	114	blocked aperture (opaque)	M,6,114
	178	BG-12 filter	M,6,178
	242	NiSO ₄ & UG-11 filter	M,6,242
10: Micrometer	=290	calibrated micrometer setting (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,10,xxxx
11: Slit Mask	0	0: slit 0 (HG) 303.2 - 426.4 nm	M,11,xxxx NOTE: R,0,6,2;O;A gives a real time listing of the registers from 0 to 6, press <delete> to stop.
	2	1: dark count -----	
	4	2: slit 1 306.3 - 431.4 nm	
	6	3: slit 2 310.1 - 437.3 nm	
	8	4: slit 3 313.5 - 442.8 nm	
	10	5: slit 4 316.8 - 448.1 nm	
	12	6: slit 5 320.1 - 453.2 nm	
	14	7: dead time -----	

Table cwb.5-3: Settings for each of the seven stepper motors.

5.9 OUTPUT

Syntax: Q (letter oh)

Description:

Transmit to the Terminal all photon count data accumulated by the most recent Run command, then zero the photon-count accumulators. Photon counts are displayed in a comma separated list. Each count is the decimal representation of a 24-bit number, so will lie in the range 0..16777215.

Example:

```
R, 0, 7, 3; 0 <Return>
```

Accumulate photon counts across all eight 'wavelength' channels by cycling the slit mask from position 0 through position 7 and back, repeat this to-and-fro cycle three times; transmit the photon counts to the Terminal as a comma-separated list. Typical output might be:

```
2345, 161, 124564, 345734, 456744, 234875, 566778, 574566
```

5.10 QUIT

Syntax: Q

Description:

Exit to the COSMAC monitor. (The monitor does not display a prompt.) The monitor supports a variety of very low-level functions (loading, dumping, testing) primarily intended for 1802 software development and diagnostics, and is not used or accessed in normal operation. To restart the Brewer program (and restore the - prompt), type

```
<Return> $PO <Return>
```

(the first Return sets the baud rate for the COSMAC) monitor)

or

```
<Return> $P4020 <Return>
```

The first address restarts the Brewer program from 'cold' (ie. all Brewer variables re-initialized); the second address restarts the Brewer program without altering most of Brewer variables.

5.11 RUN

Syntax: R, p1, p2, p3

Description:

Measure light intensity for each of the wavelength positions p1 through p2 by running the slit mask from position p1 to position p2 and back again, accumulating the photon counts in separate channels. Repeat this to-and-fro sequence p3 times.

Parameters:

p1 may take values over the range 0..7, p2 is an integer selected from p1..7, p3 may take values 1..255. The 8 slit mask positions are identified in the following table:

Slit Mask Position	Wavelength Setting (nm)	
	<u>UV</u>	<u>Visible</u>
0	Hg Calibration : 303.2	426.4
1	Dark Count : -----	
2	Wavelength 1 : 306.3	431.4
3	Wavelength 2 : 310.1	437.3
4	Wavelength 3 : 313.5	442.8
5	Wavelength 4 : 316.8	448.1
6	Wavelength 5 : 320.1	453.2
7	Wavelength 2 & 4 for Deadtime test	

(These wavelength settings assume an HG calibration has been performed recently.)

Example:

R, 3, 5, 2

Sample and accumulate in three channels the light intensities for slit mask positions 3, 4, 5 then in the reverse sequence 5, 4, 3. Repeat this to-and-fro sequence for 2 complete cycles. Note that this command would normally be used in conjunction with the Output command - refer to section 5.9 (OUTPUT) and section 5.1 (AGAIN) for further examples.

5.12 STATUS

Syntax: S

Description:

Transmit to the Terminal the values of six internal variables summarizing the status of the last Run command. These values are displayed as a comma-separated list:

a, b, c, d, e, f,

(a, b, d) are the (p1, p2, p3) parameters of the last Run command (ie: initial slit mask position, final slit mask position, number of measurement cycles requested); c is the actual number of cycles completed when the STATUS command was issued; e is not used (always returned as 0); f is 0 if the Run command ran to completion (in which case d, requested cycles, will be the same as c, completed cycles); f is 1 if the Run was interrupted.

Example: Assume that the following Run request is transmitted to the Brewer

R, 0, 7, 6 <Return>

and that the operator interrupts the command (by typing Break - use the DELeTe key on the PC keyboard) after 2 measurement cycles, then issues a Status request

S <Return>

The expected response from the Brewer would be

0, 7, 2, 6, 0, 1,

5.13 TALK

Syntax: T

Description:

Retransmit to the Terminal the contents of the COSMAC output buffer. This is useful if a transmission error is detected (or suspected) in the previous output record transmitted by the Brewer. There are currently five commands (other than Talk) which transmit values to the Terminal: Dump, Get, Output, Status, and Z (transmit A/D channel). T will retransmit the information placed in the COSMAC output buffer by whichever of these five commands was activated most recently.

Example:

Assume that the most recent 'transmit-request' command was

R, 0, 7, 3; 0 <Return>

which produced the following comma-separated record of 8 photon counts:

2345, 161, 124564, 345734, 465744, 234875, 566778, 344566

A subsequent

T <Return>

would retransmit the identical comma-separated record to the Terminal.

5.14 V: Set Baud Rate and Echo

Syntax: V, p1 [, p2] (the second parameter is optional)

Description:

Set the baud rate (and echo characteristics) of the Brewer end of the serial communications cable which links the Brewer instrument to the Terminal. The default setting is 300 bps (bits per second), echo enabled. Note that the V command cannot be issued unless both the Brewer and the Terminal are set to the same baud rate.

Parameters:

Parameter p1 takes one of six values [10, 15, 30, 60, 90, 120] corresponding respectively to the six baud rates [100, 150, 300, 600, 900, 1200]. The optional parameter p2 is set to 1 if character echoing by the Brewer is to be suppressed.

The expected response from the Brewer would be

0, 7, 2, 6, 0, 1,

5.13 TALK

Syntax: T

Description:

Retransmit to the Terminal the contents of the COSMAC output buffer. This is useful if a transmission error is detected (or suspected) in the previous output record transmitted by the Brewer. There are currently five commands (other than Talk) which transmit values to the Terminal: Dump, Get, Output, Status, and Z (transmit A/D channel). T will retransmit the information placed in the COSMAC output buffer by whichever of these five commands was activated most recently.

Example:

Assume that the most recent 'transmit-request' command was

R, 0, 7, 3; 0 <Return>

which produced the following comma-separated record of 8 photon counts:

2345, 161, 124564, 345734, 465744, 234875, 566778, 344566

A subsequent

T <Return>

would retransmit the identical comma-separated record to the Terminal.

5.14 V: Set Baud Rate and Echo

Syntax: V, p1 [, p2] (the second parameter is optional)

Description:

Set the baud rate (and echo characteristics) of the Brewer end of the serial communications cable which links the Brewer instrument to the Terminal. The default setting is 300 bps (bits per second), echo enabled. Note that the V command cannot be issued unless both the Brewer and the Terminal are set to the same baud rate.

Parameters:

Parameter p1 takes one of six values [10, 15, 30, 60, 90, 120] corresponding respectively to the six baud rates [100, 150, 300, 600, 900, 1200]. The optional parameter p2 is set to 1 if character echoing by the Brewer is to be suppressed.

Examples:

V, 120 <Return>

Set the baud rate to 1200 bps, echo enabled.

V, 120, 1 <Return>

Set the baud rate to 1200 bps, echo disabled. (Refer to section 3: Communicating via an ASCII Terminal for further examples.)

5.15 Z: Transmit Contents of Specified A/D Channel

Syntax: Z

Description:

Digitize the analog channels specified in a previously defined A/D (analog-to-digital) Table, then transmit to the Terminal the digitized values as a comma-separated record. The A/D Converter is a single-ended, 8-bit device whose output is a byte-value in the range 0...255, corresponding to an analog range of 0 to 5.0 volts. The list of A/D channels is shown in Table cwb.5-4.

A/D Channel	Channel Name	Conversion Factor	Offset	Typical Reading Byte Value	Engineering Value
0	Brewer Temperature 1	0.3620°C/bit	-33.27	173	29.4°C
1	Brewer Temperature 2	0.3620°C/bit	-33.27	-	24.7°C
2	Brewer Temperature 3	0.3620°C/bit	-33.27	-	23.1°C
3	H.T. Voltage	10.94 V/bit	-840.0	200	1348 V
4	+15 V Power Supply	98.5 mV/bit	0	148	+14.6 V
5	+5 V Power Supply	24.4 mV/bit	0	205	+5.0 V
6	-15 V Power Supply	97.7 mV/bit	0	150	-14.7 V
7	+24 V Power Supply	117 mV/bit	0	212	+24.8 V
8	Rate Meter	1950 pulses/bit	0	200	390000
9	Not Used	-	-	-	-
10	Not Used	-	-	-	-
11	Not Used	-	-	-	-
12	+5 V Secondary Supply	24.4 mV/bit	0	210	+5.1 V
13	-8 V Secondary Supply	38.8 mV/bit	0	213	-8.2 V
14	Standard Lamp Current	10.68 mA/bit	0	150	1.6 A
15	Standard Lamp voltage	48.5 mV/bit	0	220	+10.7 V

Table cwb.5-4: To convert the returned decimal value to engineering units multiply by the appropriate conversion factor then add the listed offset. For example, a reading of 148 for the +15 V Power Supply corresponds to $98.5 \times 148 = 14578$ mV 14.6 V.

Example:

**L, 20248, 0, 20249, 15, 20250, 2, 20251, 6, 20252, 255; Z
<Return>**

Construct a 5-byte A/D Table starting at \$4F18 (decimal 20248). The table contains four channel numbers (0, 15, 2, 6) and an end-of-table marker (255). Digitize and transmit to the Terminal the specified channels in the sequence shown. Typical output from such a command might be:

124, 56, 36, 255