Radiometer Calibration Using Comparison Instruments (CALC)

I. Purpose:

The purpose of this procedure is to describe the steps performed by the RESET team to check the calibration of the PIR, PSP, and NIP Radiometers using reference instruments. Perform this procedure in conjunction with the MFRSR comparison procedure if applicable.

II. Cautions and Hazards:

- Take care to avoid falling when climbing onto or next to the radiation stand while installing the reference instruments.

III. Requirements:

- Two people are needed for actual mounting of the reference instruments and placement of the radiation stand extension on the radiation stand.
- Calibration Datalogger.
- Reference PIR, PSP, and NIP.
- Radiation Stand Extension.

IV. Procedure:

A. Steps:

1. Mount reference PIR and PSP on radiation stand extension; the SKYCAL configuration file allows two PSPs, if available, by using the NET connector as a 6-pin PSP channel.
2. Mount one or two reference NIP to the solar tracker (optional).
3. Connect the reference IRT to the IRT stand if possible (optional).
4. Download current configuration file for the NIP, PSP, & PIRS (from ZENO menu system load menu and transmit configuration).
5. Ensure that calibration coefficients are correct for the instruments attached to the datalogger.
6. Connect instruments to Calibration Datalogger and connect the power to the datalogger. **Note**: We have found that the logger must be properly grounded and it help to have the input for the channels not under test shorted. Failure to do so can produce a 10 to 70 microvolt variable offset.
7. Enter the System Functions Menu (F) under the Users Menu (U); type “S” to reset clock (and date, if necessary) on the cal Logger.

8. Type “E” to save.
9. Download the current configuration file (from the ZENO menu system load menu; format: SKYYMMDD.cfg).
10. Transmit configuration to TWPPO and dmf.
11. **ENSURE THAT THE CALIBRATION COEFFICIENTS ARE CORRECT FOR THE PIR, PSP, AND NIP INSTRUMENTS ATTACHED TO THE CALIBRATION DATALOGGER.**
12. Collect data for at least twenty-four hours.
    a) To download using a Psion palmtop computer:
        (1) Click on Zeno, U, D data download set protocol (menu, transfer, protocol) to xmodem (1k).
        (2) Type **xl** 1440 to transfer 1 days worth of data.

            Note: 4 MB available; 1 day ~ 1MB
        (3) Type **menu, transfer, receive**.
        (4) Select A: drive (down arrow, right arrow).
        (5) Enter name (e.g., Cal1109.dat)
        (6) When done. select “HANG UP” from menu; also select “EXIT” on Psion to free up port for later data transfer using PSIWIN or Rcom.
13. Log the “start” and “end time” for comparison with the processed data for the currently tested instruments.
14. Combine the collected data from the Calibration Datalogger with the SKYRAD instrument data from ADaM. Note: under some circumstances the method of data collection can affect the linefeeds especially with the cal logger. Download using binary and not screen capture. If the line feeds are lost, open the file with Microsoft WORD and replace all “,TWP” with “,^pTWP”.
15. Send to mentor for analysis and to TWPPO and dmf.
16. Follow the Mentor’s suggestions, e.g., repeat test or replace instrument and repeat test.
17. If the instrument is replaced, fill out the Instrument Replacement Form.
18. The mentor provides TWPPO with the relevant statistics from the comparison, such as mean differences and standard deviations between serial numbered instruments, the number of samples, and instrument locations in an Excel-formatted, calibration record (Radiation Comparison Form, FM(RAD)-001 attached).

(Note: In order to complete the initial values part of this form, it is necessary to connect to the Comparison Logger and write down Radiometer Raw Voltage and Resistance values and Time of Day during periods when the sun is not obscured by clouds. Then as quickly as possible collect values from the SKYRAD Logger with the sun not obscured. The processed values required for FM(RAD)-001 can be obtained using the ARM calculator. Pressing the ARM menu button. Then press the Program (PGM) menu button, and selecting SKY RADIATION and enter, and then pressing the PIR, PSP or NIP menu button. The program is run by selecting menu buttons like VR goes to W for the PIR to calculate the PIR W/m^2 and case and dome temperatures.)

V. References:

1. Cornwall, C., "Recommended Radiometer Calibration Procedures for ARM/ARCS," NREL June 16, 1995.

VI. Attachments:

1. Radiation Comparison Form, FM(RAD)-001.
2. Completed Calibration Form (example)
3. Radiometer calibration factors needed for step 5 above (example)
4. Calibration Process Flow Diagram (2 pages)

Attachment 1: Radiation Comparison Form, FM(RAD)-001

ARCS Radiometer Calibration Check Using Comparison Instruments Form

I. Calibration information

This is a (check which):	Calibration	Calibration Check	Field Calibration
		X	

Date:	GMT Begin Time:	GMT End Date:	GMT End Time:	ARCS #

	SKYRAD	GNDRAD	CAL Logger
Old configuration version			
New configuration version			

Instrument / System:	TWP OMS Part Number(s):	Changed?	TWP OMS Serial Number(s)	Cal Factor
PIRG	PIR			
PIRD	PIR			
PSPG	PSP			
PSPD	PSP			
UVB	501A V3			
IRT	KT19.85			
NIP	NIP			
NET	REBS Q*7.1			
PIR GNDRAD	PIR			
PSP GNDRAD	PSP			
MFRSR	MFR7-HEAD / MFRSR-Logger Board			
Tracker	Intra 2			

Verify that serial number of test instruments above are correct. (yes / no)

Location (eg. PNNL, Manus):	Participant(s):	Issued by:	Signature(s):

Spares

Reference Instrument(s):	TWP OMS Part Number(s):	TWP OMS Serial Number(s):	Calibration Coefficients
PIR1	PIR		
PSP1	PSP		
NIP1top	NIP		
PSP2	PSP		
MFRSR	MFR7-HEAD / MFRSR-Logger Board		
NIP2	NIP		
PIR2	PIR		

Verify that serial numbers of reference instruments are correct (yes/no)	
Verify with mentor that calibration coefficients and configuration file changed accordingly for PIRs, PSPs, and NIPs. (yes / no)	

II. Initial Values

note: the following are determined from sample values of voltages from the logger during unobsured sun conditions if possible (using ARM calculator or other technique)

Sensor / Element	Value Reference (usually spare	Value of SKYRAD Instr.	% Difference: SKYRAD and Spare	Time (GMT)	Sun Obscured? (Yes/No)
PIR1C & PIRG (W/m2)					
PIR2C & PIRD (W/m2)					
PIR1C & PIRG (Td oC)					
PIR2C & PIRD (Td oC)					
PIR1C & PIRG (Tc oC)					
PIR2C & PIRD (Tc oC)					
PSP1C & PSPG (W/m2)					
PSP2C & PSPG (W/m2)					
NIP1C & NIP (W/m2)					
NIP2C & NIP (W/m2)					
PIRD & PIR GNDRAD (W/m2)					
PSPG &PSP GNDRAD (W/m2)					
IRT oC					
NET (W/m2)					
MFRSR (W/m2 @615 nm)					

III. Final Values

Sensor / Element	Value Reference (usually spare instr.)	Value of SKYRAD Instr.	% Difference: SKYRAD and Spare	Time (GMT)	Sun Obscured? (Yes/No)
PIR1C & PIRG (W/m2)					
PIR2C & PIRD (W/m2)					
PIR1C & PIRG (Td oC)					
PIR2C & PIRD (Td oC)					
PIR1C & PIRG (Tc oC)					
PIR2C & PIRD (Tc oC)					
PSP1C & PSPG (W/m2)					
PSP2C & PSPG (W/m2)					
NIP1C & NIP (W/m2)					
NIP2C & NIP (W/m2)					
PIRD & PIR GNDRAD (W/m2)					
PSPG &PSP GNDRAD (W/m2)					
IRT oC					
NET (W/m2)					
MFRSR (W/m2 @615 nm)					

V. Calilbration Change(if applicable)

Sensor or Parameter	Sensor Serial No.	Internal Resistance	Original Sensitivity	Offset	Quadratic
	Old	Old	Old	Old	Old
	New	New	New	New	New

Document(s) Referenced:
PRO(RAD)-001.001

Document(s) Updated:
PRO(RAD)-001.001

PROBLEMS:

NOTES:

Attachment 2: Completed Calibration Form (example)

ARCS Radiometer Calibration Check Using Comparison Instruments Form

I. Calibration information

	Calibration	Calibration Check	Field Calibration
This is a (check which):		X	

Date:	GMT Begin Time:	GMT End Date:	GMT End Time:	ARCS #
6/29/00	20:55	7/5/00	03:30	2

	SKYRAD	GNDRAD	CAL Logger
Old configuration version	V991017.00	V000112.00	V000627.00
New configuration version	V000629.00		V000629.00

Instrument / System:	TWP OMS Part Number(s):	Changed?	TWP OMS Serial Number(s)	Cal Factor
PIRG	PIR	yes	31301F3	299401
PIRD	PIR	yes	30167F3	225733
PSPG	PSP	yes	31274F3	128155
PSPD	PSP	yes	31275F3	127551
UVB	501A V3			
IRT	KT19.85		868	
NIP	NIP	yes	31346E6	121050
NET	REBS Q*7.1		Q95063	top9.14 bottom11.3
PIR GNDRAD	PIR		30056F3	281690
PSP GNDRAD	PSP		31286F3	120715
MFRSR	MFR7-HEAD / MFRSR-Logger Board		head 240	
Tracker	Intra 2		WD24187	
IRT GND	KT19.85		863	

Verify that serial number of test instruments above are correct. (yes / no) **yes**

Location (eg. PNNL, Manus):	Participant(s):	Issued by:	Signature(s):
Nauru	Kornke		
	Porch		

Spares

Reference Instrument(s):	TWP OMS Part Number(s):	TWP OMS Serial Number(s):	Calibration Coefficients
PIR1	PIR	31391F3	264550
PSP1	PSP	31279F3	139548
NIP1top	NIP	31347E3	121344
PSP2	PSP	31276F3	125298
MFRSR	MFR7-HEAD / MFRSR-Logger Board		
NIP2	NIP	31352E6	122444
PIR2	PIR	31390F3	260417

Verify that serial numbers of reference instruments are correct (yes/no)	**yes**
Verify with mentor that calibration coefficients and configuration file changed accordingly for PIRs, PSPs, and NIPs. (yes / no)	**yes**

II. Initial Values

note: the following are determined from sample values of voltages from the logger during unobsured sun conditions if possible (using ARM calculator or other technique)

Sensor / Element	Value Reference (usually spare	Value of SKYRAD Instr.	% Difference: SKYRAD and Spare	Time (GMT)	Sun Obscured? (Yes/No)
PIR1C & PIRG (W/m2)	407	406	0.2		no
PIR2C & PIRD (W/m2)	401	408	-2		no
PIR1C & PIRG (Td oC)	35.4	33.9	4.2		no
PIR2C & PIRD (Td oC)	34.4	32.9	4.4		no
PIR1C & PIRG (Tc oC)	34.8	33.3	4.3		no
PIR2C & PIRD (Tc oC)	33.6	33	2		no
PSP1C & PSPG (W/m2)	903	905	-0.2		no
PSP2C & PSPG (W/m2)	902	905	-0.3		no
NIP1C & NIP (W/m2)	833	834	-0.1		no
NIP2C & NIP (W/m2)	838	834	0.5		no
PIRD & PIR GNDRAD (W/m2)					
PSPG &PSP GNDRAD (W/m2)					
IRT oC					
NET (W/m2)					
MFRSR (W/m2 @615 nm)					

III. Final Values

Sensor / Element	Value Reference (usually spare instr.)	Value of SKYRAD Instr.	% Difference: SKYRAD and Spare	Time (GMT)	Sun Obscured? (Yes/No)
PIR1C & PIRG (W/m2)					
PIR2C & PIRD (W/m2)					
PIR1C & PIRG (Td oC)					
PIR2C & PIRD (Td oC)					
PIR1C & PIRG (Tc oC)					
PIR2C & PIRD (Tc oC)					
PSP1C & PSPG (W/m2)					
PSP2C & PSPG (W/m2)					
NIP1C & NIP (W/m2)					
NIP2C & NIP (W/m2)					
PIRD & PIR GNDRAD (W/m2)					
PSPG &PSP GNDRAD (W/m2)					
IRT oC					
NET (W/m2)					
MFRSR (W/m2 @615 nm)					

IV. Statistics(if applicable)

No. of Samples:	Begin Date / Time GMT	End Daste / Time GMT

V. Calilbration Change(if applicable)

Sensor or Parameter	Sensor Serial No.	Internal Resistance	Original Sensitivity	Offset	Quadratic
	Old	Old	Old	Old	Old
	New	New	New	New	New

Document(s) Referenced:
PRO(RAD)-001.001

Document(s) Updated:
PRO(RAD)-001.001

PROBLEMS:
Had a lot of trouble with realigning NIP. Had to shim new NIP1 considerably.

NOTES:
GNDRAD remains inverted with original instruments.

Attachment 3: Radiometer Calibration Factors (example)

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
				(Modify only on Sheet 2)						
PIRs										
29143F3	ARM	ES	NOAA Standard	NOAA Boulder 3/17/97						
29144F3	ARM	ES	NOAA Standard	NOAA Boulder 3/17/97						
29149F3	ARM	ES	NOAA Standard	NOAA Boulder 3/17/97						
29925F3	TWP	TB	ARCS1 sky global	Manus global 9/9/96	NOAA cal 12/95 C=3.69 D=2.86					
30012F3	TWP	TB	ARCS1 sky shaded	Manus shade 9/9/96	NOAA cal 11/95 C=3.45 D=3.47					
30056F3	TWP	ES-R	NOAA cal check - missing shield, level screws	NOAA Boulder 11/97	NOAA cal 12/01/97 C=3.53 D=3.42	Eppley refit 10/22/97 C=3.55 D=4.00	NOAA cal 2/23/96 C=3.55 D=3.44			
30084F3	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	NOAA cal 12/01/97 C=3.50 D=2.89	Eppley refit 10/22/97 C=3.59 D=4.00	NOAA cal 2/23/96 C=3.55 D=2.93			
30131F3	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	NOAA cal 12/01/97 C=3.69 D=4.24	Eppley refit 10/22/97 C=3.77 D=4.00	NOAA cal 7/17/97 C=3.69	NOAA cal 11/17/95 C=3.69 D=4.32		

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
							D=3.72			
30167F3	TWP	TB	ARCS1 gndrad	Manus gndrad 2/97	NOAA cal 11/95 C=4.37 D=4.63					
30168F3	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	Eppley refit 10/22/97 C=3.96 D=4.00	NOAA cal 2/23/96 C=3.80 D=2.97				
30169F3	ARM	Cruise	Brookhaven	Brookhaven 3/97						
31296F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NOAA cal 4/28/97 C=3.73 D=3.51					
31297F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB 11/14/97 C=3.88 D=2.34	Eppley refit 10/22/97 C=3.84 D=4.00	NOAA cal 7/17/97 C=3.82 D=2.76	Eppley orig 7/29/96 C=3.83 D=4.00		
31298F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NOAA cal 4/28/97 C=3.66 D=3.32					
31299F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB 11/14/97 C=3.63 D=3.03	Eppley refit 10/22/97 C=3.60 D=4.00	NOAA cal 7/17/97 C=3.62 D=3.04	Eppley orig 7/29/96 C=3.62 D=4.00		
31300F3	TWP	ES-R	Eppley Retrofit	NOAA Boulder 12/01/97	Eppley refit 11/17/97 C=3.41 D=4.00	Eppley orig 7/29/96 C=3.55 D=4.00				
31301F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NOAA cal 5/27/97 C=3.34 D=3.61	NOAA cal 5/5/97 C=3.32 D=4.01				
31302F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NOAA cal 6/16/97 C=3.48 D=2.96					
31303F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB 11/14/97 C=3.48 D=3.53	Eppley refit 10/22/97 C=3.48 D=4.00	Eppley orig 7/29/97 C=3.51			

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
							D=4.00			
31304F3	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	Eppley refit 10/22/97 C=3.54 D=4.00	Eppley orig 8/1/96 C=3.56 D=4.00				
31305F3	TWP	ES-R	Eppley Retrofit	NOAA Boulder 12/01/97	Eppley refit 11/17/97 C=3.70 D=4.00	Eppley orig 8/1/96 C=3.78 D=4.00				
31306F3	TWP	ES-R	Eppley Retrofit	NOAA Boulder 12/01/97	Eppley refit 11/17/97 C=3.89 D=4.00	Eppley orig 8/1/96 C=3.91 D=4.00				
31307F3	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	Eppley refit 10/22/97 C=3.49 D=4.00	NOAA cal 6/16/97 C=3.28 D=2.84	Eppley orig 8/1/96 C=3.48 D=4.00			
31308F3	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	Eppley refit 10/22/97 C=3.94 D=4.00	Eppley orig 8/1/96 C=3.89 D=4.00				
31309F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB 11/24/97 C=3.84 D=2.93	Eppley refit 10/22/97 C=3.87 D=4.00	NOAA cal 6/16/97 C=3.80 D=2.59	Eppley orig 8/13/96 C=3.91 D=4.00		
31310F3	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	NOAA SRRB 11/24/97 C=3.40 D=4.02	Eppley refit 10/22/97 C=3.50 D=4.00	Eppley orig 8/13/96 C=3.49 D=4.00			
31311F3	TWP	ES-R	NOAA cal check - missing shield, shield screws	NOAA Boulder 11/97	NOAA SRRB 11/24/97 C=3.68 D=2.80	Eppley refit 10/22/97 C=3.82 D=4.00	Eppley orig 8/13/96 C=3.82 D=4.00			
31312F3	TWP	TE	ship to Eppley batch 2	NOAA Boulder 5/28/97						

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
31389F3	TWP	TE	ship to Eppley batch 2	NOAA Boulder 5/28/97						
31390F3	TWP	ES-R	Eppley Retrofit	NOAA Boulder 12/01/97	Eppley refit 11/17/97 C=3.84 D=4.00	Eppley orig 8/13/96 C=3.98 D=4.00				
31391F3	TWP	TE	ship to Eppley batch 2	NOAA Boulder 5/28/97						
32040F3	NSA	ES-C	SHEBA spare	SHEBA 10/9/97	NOAA CMDL 10/97	Eppley 9/97				
32041F3	NSA	ES-C	SHEBA gndrad	SHEBA 10/9/97	NOAA CMDL 10/97	Eppley 9/97				
32042F3	NSA	ES-C	CMDL Calibration	NOAA Boulder 9/17/97	Eppley 9/97					
32043F3	NSA	ES-C	CMDL Calibration	NOAA Boulder 9/17/97	Eppley 9/97					
32044F3	NSA	ES-C	CMDL Calibration	NOAA Boulder 9/17/97	Eppley 9/97					
32045F3	NSA	ES-C	CMDL Calibration	NOAA Boulder 9/17/97	Eppley 9/97					
32046F3	NSA	ES-C	CMDL Calibration	NOAA Boulder 9/17/97	Eppley 9/97					
32047F3	NSA	ES-C	CMDL Calibration	NOAA Boulder 9/17/97	Eppley 9/97					
32048F3	NSA	ES-C	CMDL Calibration	NOAA Boulder 9/17/97	Eppley 9/97					

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
32049F3	NSA	ES-C	Barrow sky diffuse	Barrow 10/6/97	NOAA CMDL 10/97	Eppley 9/97 C=3.84				
32050F3	NSA	ES-C	Barrow gndrad	Barrow 10/6/97	NOAA CMDL 10/97	Eppley 9/97 C=3.77				
32051F3	NSA	ES-C	Barrow sky global	Barrow 10/6/97	NOAA CMDL 10/97	Eppley 9/97 C=4.02				
32052F3	NSA	ES-C	Barrow spare	Barrow 10/6/97	NOAA CMDL 10/97	Eppley 9/97 C=				
32053F3	NSA	ES-C	SHEBA sky diffuse	SHEBA 10/9/97	NOAA CMDL 10/97	Eppley 9/97				
32054F3	NSA	ES-C	SHEBA sky global	SHEBA 10/9/97	NOAA CMDL 10/97	Eppley 9/97				
NIPs										
29868E6	TWP	TB	SNL storage	AIS 10/22/97	NREL cal 9/5/96 C=8.063 +/- 2.1%	NREL cal 12/20/94 C=8.104 +/- 1.6%				
29869E6	TWP	TB	SNL storage	AIS 10/22/97	NREL cal 9/5/96 C=8.408 +/- 2.1%	NREL cal 12/20/94 C=8.420 +/- 1.6%	Eppley orig C=8.47			
29934E6	TWP	TB	SNL storage	AIS 10/22/97	NREL cal 7/14/97 C=8.495 +/- 1.8%	NREL cal 7/27/95 C=8.530 +/- 2.5%	NREL cal 12/20/94 C=8.523 +/- 1.6%			
29937E6	TWP	TB	SNL storage	AIS 10/22/97	NREL cal 7/14/97 C=7.895 +/- 1.8%	NREL cal 7/27/95 C=7.903 +/- 2.4%	NREL cal 12/20/94 C=7.857 +/- 1.6%			
31343E6	TWP	TE	ARCS1 8/97	Manus 8/97	NREL cal 5/9/97 C=8.285 +/-					

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
					2.5%					
31344E6	TWP	TE	ARCS1 8/97	Manus 8/97	NREL cal 5/9/97 C=8.243 +/- 2.1%					
31345E6	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB 11/6/97 C=8.34	NREL cal 7/4/97 C=8.315	Eppley orig 7/11/96 C=8.45			
31346E6	TWP	TE	AIS needs retrofit	AIS 8/7/97	NREL cal 5/9/97 C=8.168					
31347E6	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	NREL cal 7/4/97 C=8.054	Eppley orig 7/11/96 C=8.09				
31348E6	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	NREL cal 7/4/97 C=8.188	Eppley orig 7/18/97 C=8.69				
31349E6	TWP	TE	awaiting cal	NREL 12/17/96	NREL cal 7/14/97 C=7.769 +/- 2.0%					
31350E6	TWP	ES-R	ARCS2 Alpha spare	AIS 1/27/98	Eppley orig 7/11/96 C=8.27					
31351E6	TWP	TE	awaiting cal	NREL 12/17/96	NREL cal 7/14/97 C=8.226 +/- 1.9%					
31352E6	TWP	TE	awaiting cal	NREL 12/17/96	NREL cal 7/14/97 C=8.131 +/- 1.8%					
31361E6	TWP	ES-R	NOAA cal check	NOAA Boulder 11/97	NREL cal 5/9/97 C=8.355 +/- 2.3%	Eppley orig 7/11/96 C=8.42				
31757E	NSA	ES-C	CMDL	NOAA	Eppley 9/97					

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
6			Calibration	Boulder 10/01/97						
31758E6	NSA	ES-C	SHEBA spare	SHEBA 10/9/97	NOAA CMDL 10/97	Eppley 9/97				
31759E6	NSA	ES-C	SHEBA skyrad	SHEBA 10/9/97	NOAA CMDL 10/97	Eppley 9/97				
31762E6	NSA	ES-C	CMDL Calibration	NOAA Boulder 10/01/97	Eppley 9/97					
31763E6	NSA	ES-C	CMDL Calibration	NOAA Boulder 10/01/97	Eppley 9/97					
31764E6	NSA	ES-C	CMDL Calibration	NOAA Boulder 10/01/97	Eppley 9/97					
PSPs										
29913F3	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	NOAA SRRB cal check 12/01/97	Eppley refit 10/22/97 C=8.09	NREL cal 7/4/97 C=7.926 +/- 2.0%	NREL cal 9/25/94 C=8.053 +/- 3.1%		
29914F3	TWP	ES-R	Ship to NREL for cal	NOAA Boulder 11/97	NOAA SRRB cal check 12/01/97	Eppley refit 10/22/97 C=8.27	NREL cal 7/4/97 C=8.168 +/- 2.8%	NREL cal 9/15/95 C=8.203 +/- 3.1%	NREL cal 3/1/96	NREL cal 9/25/94 C=8.274 +/- 3.2%
29915F3	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	Eppley refit 10/22/97 C=8.39	NREL cal 7/4/97 C=8.256 +/- 2.2%	NREL cal 7/27/95 C=8.423 +/- 3.5%	NREL cal 9/25/94 C=8.407 +/- 3.1%		
29916F3	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	Eppley refit 10/22/97 C=8.02	NREL cal 7/4/97 C=7.858 +/-	NREL cal 6/8/96 C=7.942	NREL cal 9/25/94 C=8.037 +/- 3.3%		

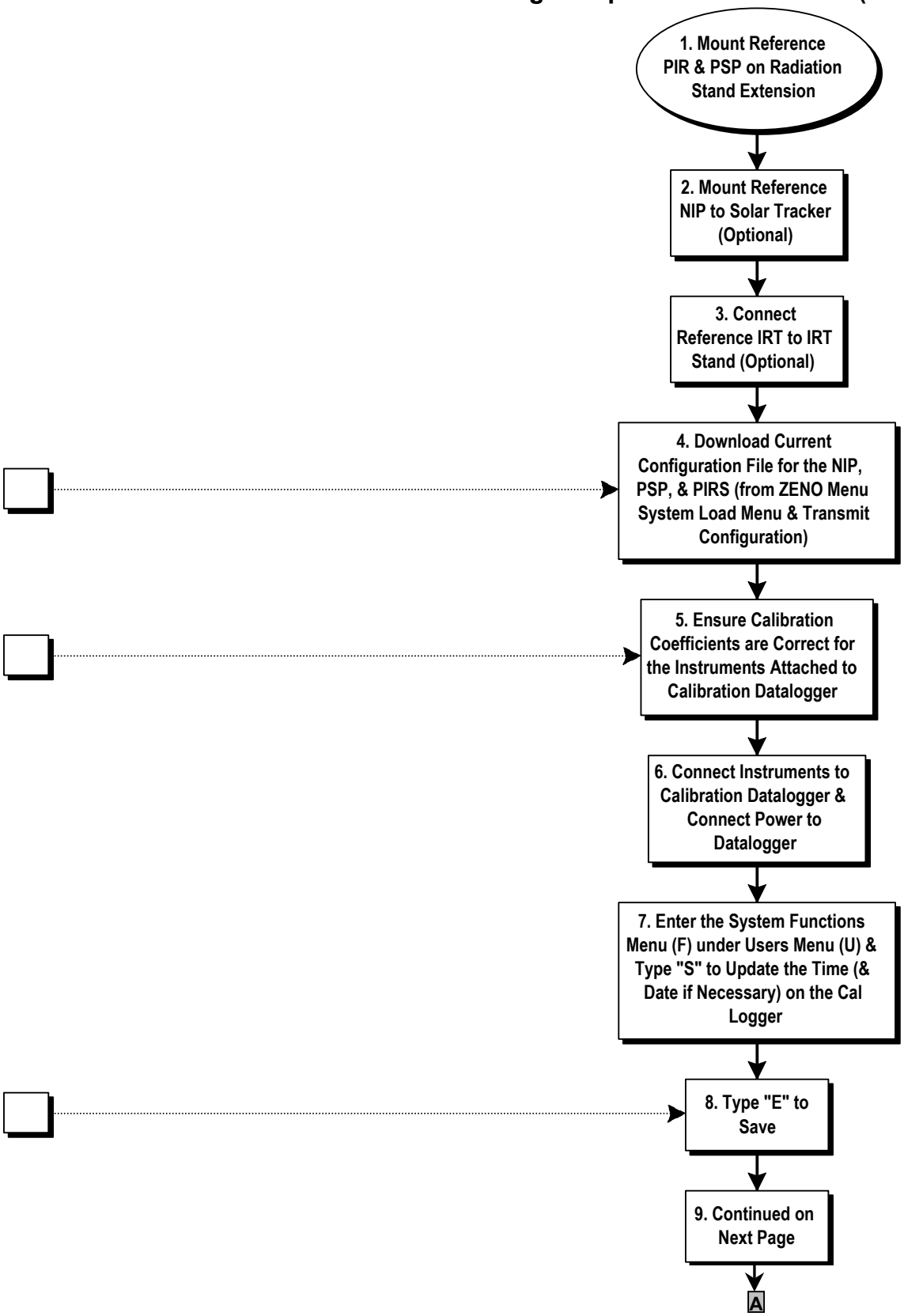
S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
						2.3%				
29917F3	TWP	TB	ARCS1 spare 1/97	Manus 1/97	NREL cal 9/5/96 C=8.440 +/- 3.2%	NREL cal 9/25/94 C=8.553 +/- 3.2%				
30006F3	TWP	ES-R	NOAA cal check 11/97	NOAA Boulder 11/97	Eppley refit 10/22/97 C=8.51	NREL cal 7/4/97 C=8.174 +/- 2.2%	NREL cal 9/25/94 C=8.421 +/- 3.1%			
31274F3	TWP	TE	ARCS1 global 1/97	Manus 1/97	NREL cal 9/23/96 C=8.178 +/- 3.1%					
31275F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NREL cal 5/9/97 C=8.084 +/- 1.5%	NREL cal 8/22/96 C=0.318 +/- 108.3%				
31276F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NREL cal 5/9/97 C=8.363 +/- 1.5%					
31277F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB cal check 11/11/97	Eppley refit 10/22/97 C=8.06	NREL cal 7/4/97 C=7.927 +/- 1.9%	NREL cal 9/23/96 C=7.960 +/- 3.1%	Eppley orig 6/25/96 C=7.83	
31278F3	TWP	TE	ARCS1 gndrad 1/97	Manus 1/97	NREL cal 9/23/96 C=8.562 +/- 3.2%					
31279F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NREL cal 5/9/97 C=7.404 +/- 1.6%					
31280F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB cal check 11/11/97	Eppley refit 10/22/97 C=7.58	NREL cal 7/4/97 C=7.517 +/-	NREL cal 9/23/96 C=7.531 +/- 3.1%	Eppley orig 6/25/96 C=7.65	

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
							2.5%			
31281F3	TWP	TE	AIS needs retrofit	AIS 7/21/97	NREL cal 5/9/97 C=7.909 +/- 2.0%	NREL cal 8/22/96 C=8.241 +/- 9.7%				
31282F3	ARM	Cruise	return to NREL for cal	Brookhaven 5/97						
31283F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB cal check 11/24/97	Eppley refit 10/22/97 C=8.76	NREL cal 7/4/97 C=8.624 +/- 1.9%	NREL cal 9/23/96 C=8.630 +/- 3.1%	Eppley orig 6/26/96 C=8.85	
31284F3	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	Eppley refit 10/22/97 C=8.46	NREL cal 5/9/97 C=8.999 +/- 2.3%	Eppley orig 6/26/96 C=9.15			
31285F3	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	Eppley refit 10/22/97 C=8.54	Eppley orig 6/26/96 C=8.55				
31286F3	TWP	ES-R	awaiting BORCAL 98-2 no shield	NREL 2/25/98	Eppley refit 10/22/97 C=8.48	Eppley orig 6/26/96 C=8.40				
31287F3	TWP	ES-R	awaiting BORCAL 98-2 no shield	NREL 2/25/98	Eppley refit 10/22/97 C=8.57	Eppley orig 6/26/96 C=8.64				
31288F3	TWP	ES-R	awaiting BORCAL 98-2	NREL 2/25/98	NOAA SRRB cal check 12/01/97	Eppley refit 10/22/97 C=8.88	NREL cal 7/4/97 C=8.707 +/- 2.0%	NREL cal 9/23/96 C=8.701 +/- 3.1%	Eppley orig 6/26/96 C=8.87	
31289F3	TWP	TE	ship to Eppley batch 2	NOAA 6/97	NREL cal 5/9/97 C=8.427 +/- 1.6%					

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
31290F3	TWP	TE	ship to Eppley batch 2	NOAA 6/97	NREL cal 5/9/97 C=8.596 +/- 1.7%					
31291F3	TWP	TE	ARCS1 diffuse 1/97	Manus 1/97	NREL cal 9/23/96 C=8.676+/- 3.2%					
31293F3	TWP	TE	ship to Eppley batch 2	NOAA Boulder 10/28/97	NREL cal 9/23/96 C=8.246 +/- 3.1%					
31294F3	TWP	ES-R	NOAA cal check 11/97	NOAA Boulder 11/97	NOAA SRRB cal check 11/24/97	Eppley refit 10/22/97 C=9.25	NREL cal 7/4/97 C=9.022 +/- 11.6%	Eppley orig 6/27/96 C=8.34		
31295F3	TWP	ES-R	ARCS2 alpha	AIS 12/01/97	NOAA SRRB cal check 11/24/97	Eppley refit 10/22/97 C=8.81	NREL cal 7/4/97 C=8.680 +/- 2.3%	Eppley orig 6/28/96 C=8.93		
31414F3	TWP	TE	ship to Eppley batch 2	NOAA 6/97	NREL cal 5/9/97 C=8.534 +/- 1.7%					
32012F3	NSA	ES-C	Barrow gndrad	Barrow 10/6/97	NOAA CMDL 9/97 C=9.27	Eppley 8/97 C=9.55				
32013F3	NSA	ES-C	Barrow sky global	Barrow 10/6/97	NOAA CMDL 9/97 C=8.90	Eppley 8/97 C=9.13				
32014F3	NSA	ES-C	Barrow spare	Barrow 10/6/97	NOAA CMDL 9/97 C=8.85	Eppley 8/97 C=9.06				
32015F3	NSA	ES-C	Barrow sky diffuse	Barrow 10/6/97	NOAA CMDL 9/97 C=9.13	Eppley 8/97 C=9.48				
32016F3	NSA	ES-C	SHEBA sky global	SHEBA 10/9/97	NOAA CMDL 9/97 C=8.88	Eppley 8/97 C=9.26				
32017F3	NSA	ES-C	SHEBA sky diffuse	SHEBA 10/9/97	NOAA CMDL 9/97 C=9.38	Eppley 8/97 C=9.65				

S/N	Prop. of	Conn	Status	Location - Date Reported	Most Recent Cal	Previous Cal				
32018F3	NSA	ES-C	SHEBA spare	SHEBA 10/9/97	NOAA CMDL 9/97 C=8.95	Eppley 8/97 C=8.93				
32019F3	NSA	ES-C	SHEBA gndrad	SHEBA 10/9/97	NOAA CMDL 9/97 C=8.72	Eppley 8/97 C=9.02				
32020F3	NSA	ES-C	ready to use	NOAA 9/2/97	NOAA CMDL 9/97 C=8.60	Eppley 8/97 C=8.87				
32021F3	NSA	ES-C	ready to use	NOAA 9/2/97	NOAA CMDL 9/97 C=9.25	Eppley 8/97 C=9.43				
32022F3	NSA	ES-C	ready to use	NOAA 9/2/97	NOAA CMDL 9/97 C=9.31	Eppley 8/97 C=9.47				
32023F3	NSA	ES-C	ready to use	NOAA 9/2/97	NOAA CMDL 9/97 C=10.51	Eppley 8/97 C=10.70				
32024F3	NSA	ES-C	ready to use	NOAA 9/2/97	NOAA CMDL 9/97 C=8.89	Eppley 8/97 C=8.97				
32026F3	NSA	ES-C	ready to use	NOAA 9/2/97	NOAA CMDL 9/97 C=8.91	Eppley 8/97 C=9.02				
32039F3	NSA	ES-C	ready to use	NOAA 9/2/97	NOAA CMDL 9/97 C=9.24	Eppley 8/97 C=9.55				

Attachment 4: Radiometer Calibration Using Comparison Instruments (CALC)



Attachment 4: Radiometer Calibration Using Comparison Instruments (CALC) (copntinued)