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PYRHELIOMETER COMPARISONS 1985

Results and Symposium

Sixth International Pyrheliometer Comparisons (IPC VI)

1. - 18. October 1985

World Radiation Center Davos, Switzerland

Working Report No. 137

Swiss Meteorological Institute Zürich, Switzerland

Davos & Zürich, December 1985

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INTERNATIONAL PYRHELIOMETER COMPARISONS (IPC VI)

1. Introduction

At the decision of the Executive Council (EC XXXVI) the World Meteorological Organization (WMO) organized, in accordance with Recommendation 7 of the Commission for Instruments and Methods of Observation (CIMO-VIII), the Sixth International Pyrheliometer Comparison (IPC-VI) of WMO from 1 to 18 October at the Physico-Meteorological Observatory, Davos (PMOD), one of the World Radiation Centers (WRC) of WMO.

An International Organizing Committee for the IPC-VI was set up and held its session at Davos under the chairmanship of D.I.Wardle, chairman of the CIMO Working Group on Radiation and Atmospheric Turbidity Measurement. The Committee is composed of members of this CIMO working group participating at IPC-VI. The WRC is represented by C.Fröhlich (PMOD) and WMO by S.Klemm (WMO Secretariat).

2. Participation

A total of 22 Members were represented by 41 participants with 17 Angström pyrheliometers and 29 absolute radiometers coming from the 2 World Radiation Centers, the 17 Regional Radiation Centers, 2 National Radiation Centers (Region III and IV) of WMO and 7 other institutions (see Annex Table A1 for an overview, Table A2 for the participants, Table A3 and A4 for the instrument geometries). The calibration factors used during IPC-VI are in the heading of the listing of the results for each instrument (Table A7).

3. Data Acquisition and Evaluation

In contrast to former IPCs the data acquisiton has been made digitally. A more detailed description is given in Table A5. The measurements were organized in runs of 18 minutes, which yielded 7 to 12 irradiance values depending on the kind of instrument. The following timing and evaluation of irradiance was used for the different types of instrument:

a) Angström pyrheliometers: During the first 90 s the zero of the instrument was established. From there on every 90 s a left or right reading is performed, starting with exposing the right hand strip to the sun. This first reading is, as usual, not taken into account. The following reading are combined as L-R, R-L, etc and the irradiance calculated as $i_L * i_R * C$.

b) PACRAD type radiometers: After 225 s from the start the zero is read and the heater switched on. At 405 s the electrical power and thermopile output is recorded and used as electrical calibration. After opening the cover readings are taken at 540 s, 630 s etc. until the last reading at 1080 s. With the electrically calibrated thermopile, the irradiance is calculated in the usual way taking into account the zero reading and current lead correction. PAC-3, the Eppley-Pacrad and the H-F radiometers were operated in this way. During the second half of the comparison, however, the H-F used a shorter calibration sequence in order to increase their irradiance data from 7 to 9.

c) Active cavity radiometers: The operation started with a reference phase during the first 90 s, followed by a measuring phase during the next 90 s. This was continued for the next 16.5 minutes and a total of 6 open and closed data yielding an irradiance value each, were acquired. The calculation of the irradiance is done by multiplying the difference between the open power and the mean of the adjacent closed powers with the calibration factor. The PMO-2, as the working reference, was read at twice the speed. Hence 12 irradiance values every 90 s are available for the working reference. The shuter was closed during 38 s and open during 52 s.

In order to specify the atmospheric conditions during the comparison the following parameters have been measured simultaneously with the runs: global and sky radiation from instruments (PSP) on the roof of the institute; ambient pressure, air temperature and relative humidity as 10-minute readings from the automatic meteorological station of the Swiss Meteorological Service; the wind speed was measured with an anemometer on the roof of the hut close to the tables where the measurements were performed. It has to be noticed, that the wind speed for the instruments on the automatic WRC tracker was normally quite higher than indicated by the anemometer. The main reason is that the anemometer and the tables were located leeward of the building and were thus more or less shielded from the wind. The three standard photometers of the WRC with filters at 368, 500 and 778 nm were used to calculate the aerosol optical depths. The data are presented in Table A8.

4. Results

For the final evaluation a total of 37 runs have been selected and approved by the adhoc working group of CIMO responsible for the evaluation. These measurements were taken during the 3., 4., 7., 11., 12., 13., 14. and 17. October. All irradiance readings of PMO-2 during these runs are listed in Table A6. These values have been used to calculate ratios to each participating instrument. The mean ratio for each run and the overall statistics for the whole comparison for each instrument are listed in Table A7. The final results are summarized in Table 1 and 2 for the absolute radiometers and the Angström pyrheliometers respectively.

Instrument		No. of Measurements	Mean ratio to PMO-2	Standard deviation
CROM	2L	218	0.99618	0.00065
CROM	3	164	0.99945	0.00058
ACR	401	8	1.00069	0.00086
ACR	403	8	1.00406	0.00067
ACR	1006	167	1.00153	0.00662
EPAC	12843	433	1.00109	0.00185
EPAC	13219	202	0.99354	0.00195
EPAC	13617	233	0.99616	0.00198
HF	14915	204	1.00053	0.00153
HF	15744	318	0.99892	0.00092
HF	17142	306	1.00122	0.00099
HF	18747	113	0.99972	0.00155
HF	19746	182	0.99901	0.00119
HF	23725	156	1.00294	0.00231
MK VI	67401	394	0.99691	0.00116
MK VI	67502	434	1.00048	0.00136
MK VI	67604	397	0.99802	0.00145
MK VI	67702	391	1.00179	0.00133
MK VI	67814	436	0.99812	0.00090
MK VI	67915	409	0.99719	0.00125
MK VI	68016	427	0.99912	0.00120
PMO6	10	220	0.99650	0.00068
PMO6	80022	220	0.99872	0.00082
PMO6 D	5	129	0.99885	0.00100
PMO6 I	811106	172	0.99531	0.00142
PMO6 J	811107	137	1.00089	0.00193
PMO6 S	811108	202	0.99974	0.00158
PMO - 5		220	0.99821	0.00107
PAC - 3		254	0.99865	0.00111

Table 1: Summary of results of absolute radiometers.

Instrument		No. of Measurements	Mean ratio to PMO-2	Standard deviation
A	7	178	0.99884	0.00192
A	21	158	1.00840	0.00370
A	24	288	0.99999	0.00165
A	171	309	1.00052	0.00197
A	212	174	0.99963	0.00318
A	507	261	0.99931	0.00399
A	561	257	1.00125	0.00801
A	564	304	0.99987	0.00450
A	568	197	1.00072	0.00228
A	576	155	0.99375	0.00236
A	578	260	0.99954	0.00131
A	583	292	0.99694	0.00171
A	708	124	0.99501	0.00207
A	7636	311	0.99908	0.00139
A	9003	206	1.00621	0.00566
A	18020	282	1.00025	0.00186
A	18587	312	0.99374	0.00223

Table 2: Summary of results of Ångström pyrheliometers.

According to the decisions of CIMO IX (Ottawa, 1985) the World Standard Group (WSG) consists of PAC-3, PMO-2, PMO-5, CROM-2L, CROM-3 and one H-F and/or TMI instrument, which is not yet specified. As PMO-5 had a change of the shutter in fall 1984 and CROM-3 had not many comparison results since IPC-V, they are ommited in the following discussions. The WRR factors of the remaining three WSG instruments as determined during IPC-V are the following: WRR_{PAC-3}: 1.00081, WRR_{PMO-2}: 0.99860, $WRR_{CROM-2L}$: 1.00262. With the PMO-2 WRR factor the results of the WSG instruments can be reduced from the results of IPC-VI to WRR according to the following formula:

$$WRR(X) = WRR_X * ((X / PMO-2)_{IPC-VI} / WRR_{PMO-2}).$$

These values should be 1.0 for all three instruments, if no change occured since IPC-V. The following values are obtained for IPC-VI:

WRR(PMO-2) = 0.99860 * (1.00000/0.99860) = 1.00000
WRR(PAC-3) = 1.00081 * (0.99865/0.99860) = 1.00086
WRR(CROM-2L) = 1.00262 * (0.99618/0.99860) = 1.00019

with a mean of 1.00035. From these results the following possible changes of the three WSG instruments may be deduced with the arbitrarily assumption that the changes are distributed equally among the instruments:

PMO-2 : + 0.035 per cent
PAC-3 : - 0.051 per cent
CROM-2L: + 0.016 per cent

These changes are very small and probably of marginal significance. They demonstrate that the WSG has been maintained properly and that the realization of the WRR at IPC-VI is guaranteed. A further evidence for the stability of the WSG is that the results of most instruments participated in both IPC V and VI also indicate no significant change since then.

The results of IPC-VI, presented here will be reviewed by the International Organization Committee and the final WRR reduction factors of the WSG instruments, the new values for the reduction of the absolute radiometers to WRR and the new calibration factors of the Ångström pyrheliometers will be submitted to the president of CIMO for promulgation by WMO. The final factors will be distributed by WMO to the Members for implementation in due course.

ANNEX TO PART I:

Center/Country	Instrument	Manufacturer or designer	Owner
WORLD RADIATION CENTERS			
Leningrad	A 212	SMHI	Main Geophysical Observatory, Leningrad, USSR
Davos	PMO-2	Brusa/Fröhlich	Physikalisch-Meteorologisches Observatorium
	PMO-5	Brusa	Davos, Switzerland
	PAC-3	Kendall	
	PMO-6 10	Brusa	
	PMO-6 80022	Brusa	
REGIONAL RADIATION CENTERS			
Region I			
Algeria	A 708	SMHI	Inst. Hydrometeorol. H.L.M., Gambetta, Oran
Egypt	A 564	SMHI	Met.Authority, Koubry El-Quobba, Cairo
Nigeria	A 576	SMHI	Meteorological Dept., Lagos
Sudan	A 561	SMHI	Meteorological Dept., Khartoum
Tunisia	A 9003	Eppley	Institut National de la Meteologie, Tunis
	HF 23725	Eppley	
Region II			
India	PMO-6 811106	C.I.R.	Meteorological Office, Pune
	EPAC 13219	Eppley	
Japan	PMO-6 811107	C.I.R.	Japan Met. Agency, Tokyo
Region III			
Argentina	MK VI 67915	TMI	Servicio Meteorologico Nacional, Buenos Aires
Region IV			
Canada	HF 18747	Eppley	Atmospheric Environment Service, Downsview
USA	EPAC 12843	Eppley	Nat.Oceanic & Atmosph.Administration, Boulder
	MK VI 67502	TMI	
Region V			
Australia	A 578	SMHI	Cape Grim BAPS, Bureau of Meteorology,
	ACR 1006	Radiometrics Inc.	Melbourne
Region VI			
Belgium	A 7	SI	Institut Royal Meteorologique de Belgique,
	A 21	SI	Bruxelles
	CROM 2	Crom, IRM B	
	CROM 3	Crom, IRM B	
Germany,Fed.Rep.of	A 568	SMHI	Deutscher Wetterdienst, Hamburg
	PMO-6 5	PMOD	
France	A 24	SI	Meteorologie Centre Radiometrique, Carpentras
	A 7636	Eppley	
	MK VI 68016	TMI	
Hungary	HF 19746	Eppley	Inst. for Atmospheric Physics, Budapest
Sweden	A 171	SMHI	Swedish Meteorol. and Hydrol. Institut,
	PMO-6 811108	C.I.R.	Norrkoping
United Kingdom	A 583	SMHI	Meteorological Office, Wokingham, Berkshire
	MK VI 67604	TMI	
VARIOUS INSTITUTIONS AND NATIONAL CENTERS			
DSET, USA	HF 17142	Eppley	DSET Laboratories, Inc., Phoenix
Eppley, USA	HF 14915	Eppley	Eppley Laboratory, Inc., Newport
JPL, USA	MK VI 67702	TMI	Jet Propulsion Laboratory, Pasadena
	ACR 401	JPL	
	ACR 403	JPL	
Mexico	A 18587	Eppley	Inst. de Geofisica UNAM, Mexico
Norway	A 507	SMHI	Geophysical Institute, Bergen
	EPAC 13617	Eppley	
NTI, Sweden	HF 15744	Eppley	National Testing Institut, Boras
Peru	A 18020	Eppley	Instituto Geofisico del Peru, Lima
SERI, USA	MK VI 67814	TMI	Solar Energy Research Institut, Golden
TMI, USA	MK VI 67401	TMI	Technical Measurements, Inc., La Canada

Table A 1: Participation in IPC VI

Table A 2.1: List of participants

Participant	Phone / Telex
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Table A 2.2: List of participants (continued)

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Instrument		Dimension [mm] R	r	ℓ
ABSOLUTE RADIOMETERS				
CROM	2L	6.29	4.999	144.05
CROM	3	6.25	5.0	144.0
ACR	401	6.22	3.984	152.2
ACR	403	6.61	4.115	152.2
ACR	1006	9.1	5.6	212.0
EPAC	12843	8.32	5.64	190.5
EPAC	13219	8.32	5.64	190.5
EPAC	13617	8.32	5.64	190.5
HF	14915	5.81	3.99	134.7
HF	15744	5.81	3.99	134.7
HF	17142	5.81	3.99	134.7
HF	18747	5.81	3.99	134.7
HF	19746	5.81	3.99	134.7
HF	23725	5.81	3.99	134.7
MK VI	67401	8.2	5.65	187.6
MK VI	67502	8.2	5.65	187.6
MK VI	67604	8.2	5.65	187.6
MK VI	67702	8.2	5.65	187.6
MK VI	67814	8.2	5.65	187.6
MK VI	67915	8.2	5.65	187.6
MK VI	68016	8.2	5.65	187.6
PMO6	10	4.25	2.5	95.4
PMO6	80022	4.1	2.5	94.0
PMO6(D)	5	3.6	2.5	84.2
PMO6(I)	811106	4.1	2.5	94.0
PMO6(J)	811107	4.1	2.5	94.0
PMO6(S)	811108	4.1	2.5	94.0
PMO - 2		3.6	2.5	85.0
PMO - 5		3.7	2.5	95.4
PAC - 3		8.18	5.64	190.5

Table A 3: View limiting geometries of absolute radiometers (R: radius of front aperture, r: radius of receiver aperture, ℓ: distance between apertures).

Instrument	Dimension [mm]		
	ℓ	v	w
Å-PYRHELIOMETERS			
Å 7	150	9.5	7.5
Å 21	150	9.5	7.5
Å 24	150	7.5	4.8
Å 171	72.2	10.25	2.4
Å 212	50	11.8	2.5
Å 507	40	10	3.5
Å 561	54.7	10.3	4.1
Å 564	75.1	10.3	2.5
Å 568	55.5	10.6	4.0
Å 576	82	10	2.5
Å 578	70.5	10.3	2.5
Å 583	70.6	10.3	2.5
Å 708	70.6	10.3	2.5
Å 7190	111	10.3	4.2
Å 7636	111	10.3	4.2
Å 8418	111	10.3	4.2
Å 9003	111	10.3	4.2
Å 18020	111	10.3	4.2
Å 18587	111	10.3	4.2

Table A 4: View limiting geometries of Å-pyrheliometers (v, w: half length of the sides of the front aperture rectangle, ℓ: distance between receiver and front aperture).

Description of Acquisition System

The data acquisition for IPC VI is divided into two systems: a analog part (ADA) which acquires the reference channels and a digital part (DDA) which gathers data from the participants. The DDA consists of a daisychain of microterminals (Burr Brown TM27) that are controlled by a microcomputer (hp9816), which does also all of the data storage and reduction. The teminals have a keypad and a 8 digit display allowing input of up to eight hexadecimal digits (0..9,A..F) and a decimal point. They are identified by a unique address (terminal number). An entry consists of a number and a label 'A' to 'F' indicating the type of data. A maximum of three different values for one reading is assigned to each instrument. While typing, mistakes can be corrected by clearing and retyping the correct number; but once the data is entered, the keyboard remaines locked until the computer has read the value given. As the DDA polls the terminals many times during one reading sequence, but stores the last reading only, a wrong entry is overwritten by entering the correct value again. A check for correct dataformat is made by the DDA on each value received. If it fails, the word 'error' is written back to the offending terminal for about one second, otherwise the value is stored in memory, indexed by its terminal address, sequence number and label. At the end of a run these rawdata are saved to a diskfile.

The ADA is the same as used in previous IPC. Its minicomputer (DEC PDP8) emulates a number of microterminals and sends the raw values of the reference instruments to the DDA. The meteorologic parameters are also measured by the ADA, but evaluated on the PDP8.

A list containing the names and types of all instruments together with their calibration constants and terminal addresses is then used to evaluate the raw data, calculate intensities and ratios to PMO2. These results are printed and saved on a diskfile for later analysis.

The rawdatafile can be modified by a special editor program to correct individual readings of a given run. The editor also re-calculates the intensities and ratios, updates the resultfile accordingly and prints the new data and results.

A statistics program takes the rawdata- and resultfiles of several runs and prints a summary containing the means and standard deviations of each run and of all the individual ratios. Only ratios within two percent of unity are taken into account for this evaluation.

Table A 5: Each terminal is possibly shared by two instruments, called first and second user, each of them giving up to three values per reading. The labels 'A' to 'C' are used for the first, labels 'D' to 'F' for the second user. Depending on the type of instrument, the meaning of these labels are:

Instrument Type	Value given	Label first	second
Ångström	current	C	F
PACRAD, HF	thermopile	A	D
	heater voltage	B	E
	heater current	C	F
TMI	irradiance	A	D
PMO6	voltage	A	D
	current	B	E
PMO2	voltage open	A	no second user for this type allowed.
	current open	B	
	voltage closed	C	
	current closed	D	

Date	3-Oct-85							0310_0957
Time	9:58:30	10: 0: 0	10: 1:30	10: 3: 0	10: 4:30	10: 6: 0	Mean	Stdev
Intensity	741.4	747.3	755.8	752.1	758.2	762.5	761.46	10.60
Time	10: 7:30	10: 9: 0	10:10:30	10:12: 0	10:13:30	10:15: 0		
Intensity	764.7	767.7	769.4	770.8	773.2	774.2		
Date	3-Oct-85							0310_1112
Time	11:13:30	11:15: 0	11:16:30	11:18: 0	11:19:30	11:21: 0	Mean	Stdev
Intensity	818.8	814.8	814.9	815.9	821.8	821.6	820.15	5.41
Time	11:22:30	11:24: 0	11:25:30	11:27: 0	11:28:30	11:30: 0		
Intensity	816.1	817.1	820.0	820.1	832.1	828.7		
Date	3-Oct-85							0310_1221
Time	12:22:30	12:24: 0	12:25:30	12:27: 0	12:28:30	12:30: 0	Mean	Stdev
Intensity	848.6	851.5	847.7	846.2	842.1	840.5	850.74	5.95
Time	12:31:30	12:33: 0	12:34:30	12:36: 0	12:37:30	12:39: 0		
Intensity	854.6	857.1	852.6	855.3	852.6	860.3		
Date	3-Oct-85							0310_1454
Time	14:55:30	14:57: 0	14:58:30	15: 0: 0	15: 1:30	15: 3: 0	Mean	Stdev
Intensity	714.1	706.9	709.3	709.7	709.6	707.3	709.21	6.91
Time	15: 4:30	15: 6: 0	15: 7:30	15: 9: 0	15:10:30	15:12: 0		
Intensity	706.2	697.4	699.9	709.3	722.0	718.8		
Date	4-Oct-85							0410_0946
Time	9:47:30	9:49: 0	9:50:30	9:52: 0	9:53:30	9:55: 0	Mean	Stdev
Intensity	857.3	858.3	859.2	860.5	861.1	862.6	862.48	3.36
Time	9:56:30	9:58: 0	9:59:30	10: 1: 0	10: 2:30	10: 4: 0		
Intensity	862.5	863.8	864.7	865.1	867.0	867.8		
Date	4-Oct-85							0410_1043
Time	10:44:30	10:46: 0	10:47:30	10:49: 0	10:50:30	10:52: 0	Mean	Stdev
Intensity	899.8	902.1	900.8	901.9	900.7	900.9	898.85	3.99
Time	10:53:30	10:55: 0	10:56:30	10:58: 0	10:59:30	11: 1: 0		
Intensity	901.2	901.5	899.4	895.6	892.3	890.1		
Date	4-Oct-85							0410_1135
Time	11:36:30	11:38: 0	11:39:30	11:41: 0	11:42:30	11:44: 0	Mean	Stdev
Intensity	899.1	898.9	900.3	903.7	905.5	905.0	902.83	2.51
Time	11:45:30	11:47: 0	11:48:30	11:50: 0	11:51:30	11:53: 0		
Intensity	904.6	900.3	902.6	903.9	905.4	904.8		
Date	7-Oct-85							0710_0922
Time	9:23:30	9:25: 0	9:26:30	9:28: 0	9:29:30	9:31: 0	Mean	Stdev
Intensity	830.0	830.2	833.2	834.7	836.7	836.6	836.74	3.93
Time	9:32:30	9:34: 0	9:35:30	9:37: 0	9:38:30	9:40: 0		
Intensity	838.8	839.7	840.6	840.6	841.1	838.8		
Date	7-Oct-85							0710_0951
Time	9:52:30	9:54: 0	9:55:30	9:57: 0	9:58:30	10: 0: 0	Mean	Stdev
Intensity	854.1	855.7	859.1	861.0	865.0	865.0	863.86	5.15
Time	10: 1:30	10: 3: 0	10: 4:30	10: 6: 0	10: 7:30	10: 9: 0		
Intensity	866.4	867.3	868.2	868.0	869.3	867.4		
Date	11-Oct-85							1110_0914
Time	9:15:30	9:17: 0	9:18:30	9:20: 0	9:21:30	9:23: 0	Mean	Stdev
Intensity	908.4	910.2	912.7	913.3	915.9	917.6	917.62	5.62
Time	9:24:30	9:26: 0	9:27:30	9:29: 0	9:30:30	9:32: 0		
Intensity	918.2	920.2	921.9	923.5	924.3	925.2		
Date	11-Oct-85							1110_0947
Time	9:48:30	9:50: 0	9:51:30	9:53: 0	9:54:30	9:56: 0	Mean	Stdev
Intensity	942.4	943.2	943.5	943.8	945.7	946.3	942.02	8.72
Time	9:57:30	9:59: 0	10: 0:30	10: 2: 0	10: 3:30	10: 5: 0		
Intensity	947.0	947.7	949.5	923.5	924.3	947.4		
Date	11-Oct-85							1110_1023
Time	10:24:30	10:26: 0	10:27:30	10:29: 0	10:30:30	10:32: 0	Mean	Stdev
Intensity	963.2	964.8	961.7	966.0	966.1	967.3	967.83	3.60
Time	10:33:30	10:35: 0	10:36:30	10:38: 0	10:39:30	10:41: 0		
Intensity	968.3	970.0	970.3	970.8	972.3	973.1		
Date	11-Oct-85							1110_1050
Time	10:51:30	10:53: 0	10:54:30	10:56: 0	10:57:30	10:59: 0	Mean	Stdev
Intensity	976.1	975.9	977.6	979.1	978.8	980.1	979.36	1.90
Time	11: 0:30	11: 2: 0	11: 3:30	11: 5: 0	11: 6:30	11: 8: 0		
Intensity	980.8	980.0	981.0	981.5	981.1	980.4		

Table A 6.1: Working reference values: 3.,4.,7.,11. Oct.

Date	11-Oct-85						1110_1118	
Time	11:19:30	11:21: 0	11:22:30	11:24: 0	11:25:30	11:27: 0	Mean	Stdev
Intensity	984.5	984.3	984.6	986.3	985.1	985.9	985.97	1.08
Time	11:28:30	11:30: 0	11:31:30	11:33: 0	11:34:30	11:36: 0		
Intensity	986.8	986.1	986.5	986.6	987.3	987.4		
Date	11-Oct-85						1110_1147	
Time	11:48:30	11:50: 0	11:51:30	11:53: 0	11:54:30	11:56: 0	Mean	Stdev
Intensity	987.6	987.4	987.3	988.6	989.4	989.0	988.55	0.74
Time	11:57:30	11:59: 0	12: 0:30	12: 2: 0	12: 3:30	12: 5: 0		
Intensity	989.2	989.2	989.2	988.5	988.7	988.6		
Date	11-Oct-85						1110_1215	
Time	12:16:30	12:18: 0	12:19:30	12:21: 0	12:22:30	12:24: 0	Mean	Stdev
Intensity	987.0	988.2	989.4	989.2	988.8	989.1	988.64	0.61
Time	12:25:30	12:27: 0	12:28:30	12:30: 0	12:31:30	12:33: 0		
Intensity	988.3	988.6	988.8	988.8	988.8	988.6		
Date	11-Oct-85						1110_1244	
Time	12:45:30	12:47: 0	12:48:30	12:50: 0	12:51:30	12:53: 0	Mean	Stdev
Intensity	985.5	985.6	983.5	980.0	983.7	982.7	983.64	2.33
Time	12:54:30	12:56: 0	12:57:30	12:59: 0	13: 0:30	13: 2: 0		
Intensity	984.5	983.1	983.6	982.4	980.4	988.6		
Date	11-Oct-85						1110_1325	
Time	13:26:30	13:28: 0	13:29:30	13:31: 0	13:32:30	13:34: 0	Mean	Stdev
Intensity	972.3	971.1	971.2	971.4	983.7	967.6	971.32	5.41
Time	13:35:30	13:37: 0	13:38:30	13:40: 0	13:41:30	13:43: 0		
Intensity	968.4	967.9	966.7	968.5	980.4	966.6		
Date	11-Oct-85						1110_1358	
Time	13:59:30	14: 1: 0	14: 2:30	14: 4: 0	14: 5:30	14: 7: 0	Mean	Stdev
Intensity	956.0	955.9	955.4	953.8	953.1	951.9	951.27	3.61
Time	14: 8:30	14:10: 0	14:11:30	14:13: 0	14:14:30	14:16: 0		
Intensity	950.9	948.9	948.9	947.3	946.9	946.1		
Date	12-Oct-85						1210_1227	
Time	12:28:30	12:30: 0	12:31:30	12:33: 0	12:34:30	12:36: 0	Mean	Stdev
Intensity	966.5	958.7	966.6	956.8	951.2	958.6	961.02	5.93
Time	12:37:30	12:39: 0	12:40:30	12:42: 0	12:43:30	12:45: 0		
Intensity	965.5	958.8	955.9	955.9	969.4	968.3		
Date	13-Oct-85						1310_1305	
Time	13: 6:30	13: 8: 0	13: 9:30	13:11: 0	13:12:30	13:14: 0	Mean	Stdev
Intensity	931.2	937.6	932.4	929.8	933.3	926.4	931.98	3.37
Time	13:15:30	13:17: 0	13:18:30	13:20: 0	13:21:30	13:23: 0		
Intensity	934.5	935.0	933.6	933.4	926.3	930.3		
Date	13-Oct-85						1310_1335	
Time	13:36:30	13:38: 0	13:39:30	13:41: 0	13:42:30	13:44: 0	Mean	Stdev
Intensity	928.4	923.9	917.8	914.4	913.1	909.0	907.93	11.57
Time	13:45:30	13:47: 0	13:48:30	13:50: 0	13:51:30	13:53: 0		
Intensity	900.9	894.0	901.8	898.1	899.0	894.7		
Date	13-Oct-85						1310_1405	
Time	14: 6:30	14: 8: 0	14: 9:30	14:11: 0	14:12:30	14:14: 0	Mean	Stdev
Intensity	900.2	899.7	900.3	894.3	896.1	895.0	889.82	11.36
Time	14:15:30	14:17: 0	14:18:30	14:20: 0	14:21:30	14:23: 0		
Intensity	890.7	880.4	879.6	876.4	899.0	866.1		
Date	14-Oct-85						1410_1230	
Time	12:31:30	12:33: 0	12:34:30	12:36: 0	12:37:30	12:39: 0	Mean	Stdev
Intensity	952.7	953.4	953.4	953.2	953.1	952.5	952.33	1.07
Time	12:40:30	12:42: 0	12:43:30	12:45: 0	12:46:30	12:48: 0		
Intensity	953.2	951.9	951.1	952.4	950.5	950.6		
Date	17-Oct-85						1710_0945	
Time	9:46:30	9:48: 0	9:49:30	9:51: 0	9:52:30	9:54: 0	Mean	Stdev
Intensity	931.3	932.6	933.1	934.9	935.1	937.3	937.49	4.14
Time	9:55:30	9:57: 0	9:58:30	10: 0: 0	10: 1:30	10: 3: 0		
Intensity	938.0	939.0	940.7	942.5	942.4	943.2		
Date	17-Oct-85						1710_1010	
Time	10:11:30	10:13: 0	10:14:30	10:16: 0	10:17:30	10:19: 0	Mean	Stdev
Intensity	947.7	951.3	950.8	952.6	952.9	953.6	954.75	3.98
Time	10:20:30	10:22: 0	10:23:30	10:25: 0	10:26:30	10:28: 0		
Intensity	954.8	956.7	957.9	958.3	959.8	960.8		

Table A 6.2: Working reference values: 11.,12.,13.,14.,17. Oct.

Date	17-Oct-85							1710_1035
Time	10:36:30	10:38: 0	10:39:30	10:41: 0	10:42:30	10:44: 0	Mean	Stdev
Intensity	964.1	963.4	964.5	964.9	964.6	964.9	965.22	1.34
Time	10:45:30	10:47: 0	10:48:30	10:50: 0	10:51:30	10:53: 0		
Intensity	964.7	964.5	965.8	965.8	967.4	968.1		
Date	17-Oct-85							1710_1102
Time	11: 3:30	11: 5: 0	11: 6:30	11: 8: 0	11: 9:30	11:11: 0	Mean	Stdev
Intensity	972.0	971.7	973.0	972.6	972.5	972.6	973.85	1.73
Time	11:12:30	11:14: 0	11:15:30	11:17: 0	11:18:30	11:20: 0		
Intensity	974.0	974.8	975.1	975.3	975.8	977.0		
Date	17-Oct-85							1710_1129
Time	11:30:30	11:32: 0	11:33:30	11:35: 0	11:36:30	11:38: 0	Mean	Stdev
Intensity	978.9	978.7	978.9	979.7	980.3	979.7	980.25	1.11
Time	11:39:30	11:41: 0	11:42:30	11:44: 0	11:45:30	11:47: 0		
Intensity	981.3	981.1	981.2	980.9	980.1	982.2		
Date	17-Oct-85							1710_1156
Time	11:57:30	11:59: 0	12: 0:30	12: 2: 0	12: 3:30	12: 5: 0	Mean	Stdev
Intensity	982.1	981.6	981.6	982.5	982.5	982.9	982.15	0.51
Time	12: 6:30	12: 8: 0	12: 9:30	12:11: 0	12:12:30	12:14: 0		
Intensity	982.8	982.1	982.3	982.4	981.6	981.3		
Date	17-Oct-85							1710_1223
Time	12:24:30	12:26: 0	12:27:30	12:29: 0	12:30:30	12:32: 0	Mean	Stdev
Intensity	980.7	980.2	980.9	979.6	979.5	979.4	979.27	1.11
Time	12:33:30	12:35: 0	12:36:30	12:38: 0	12:39:30	12:41: 0		
Intensity	979.9	979.1	978.3	978.0	977.3	978.3		
Date	17-Oct-85							1710_1250
Time	12:51:30	12:53: 0	12:54:30	12:56: 0	12:57:30	12:59: 0	Mean	Stdev
Intensity	975.6	975.8	976.1	975.1	974.9	973.2	973.59	1.91
Time	13: 0:30	13: 2: 0	13: 3:30	13: 5: 0	13: 6:30	13: 8: 0		
Intensity	973.6	972.7	972.5	971.9	971.2	970.4		
Date	17-Oct-85							1710_1317
Time	13:18:30	13:20: 0	13:21:30	13:23: 0	13:24:30	13:26: 0	Mean	Stdev
Intensity	967.4	967.3	965.5	965.4	965.5	964.3	963.14	3.36
Time	13:27:30	13:29: 0	13:30:30	13:32: 0	13:33:30	13:35: 0		
Intensity	963.3	962.5	960.8	959.5	959.1	957.1		
Date	17-Oct-85							1710_1344
Time	13:45:30	13:47: 0	13:48:30	13:50: 0	13:51:30	13:53: 0	Mean	Stdev
Intensity	953.4	952.0	951.4	950.7	950.2	950.6	948.89	2.95
Time	13:54:30	13:56: 0	13:57:30	13:59: 0	14: 0:30	14: 2: 0		
Intensity	948.3	948.2	946.8	946.0	944.8	944.2		
Date	17-Oct-85							1710_1411
Time	14:12:30	14:14: 0	14:15:30	14:17: 0	14:18:30	14:20: 0	Mean	Stdev
Intensity	934.8	934.1	931.9	930.8	928.6	929.1	926.63	5.74
Time	14:21:30	14:23: 0	14:24:30	14:26: 0	14:27:30	14:29: 0		
Intensity	925.6	923.9	922.7	920.9	919.0	918.3		
Date	17-Oct-85							1710_1438
Time	14:39:30	14:41: 0	14:42:30	14:44: 0	14:45:30	14:47: 0	Mean	Stdev
Intensity	905.9	903.2	903.2	900.7	898.2	896.6	896.09	6.43
Time	14:48:30	14:50: 0	14:51:30	14:53: 0	14:54:30	14:56: 0		
Intensity	895.8	893.6	891.6	890.3	888.2	885.7		
Date	17-Oct-85							1710_1505
Time	15: 6:30	15: 8: 0	15: 9:30	15:11: 0	15:12:30	15:14: 0	Mean	Stdev
Intensity	866.8	864.1	859.9	857.6	855.0	851.3	849.93	11.06
Time	15:15:30	15:17: 0	15:18:30	15:20: 0	15:21:30	15:23: 0		
Intensity	848.2	846.2	842.3	839.1	835.3	833.6		

Table A 6.3: Working reference values: 17. Oct.

Table A 7.1: Results of PAC-3, PMO-5, CROM 2L.

PAC3	9962.6										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9979	0.9987	0.9978	0.9979	0.9986	0.9985	0.9987	0.9985	0.9985	0.9987	
Stdev	0.0005	0.0017	0.0010	0.0009	0.0005	0.0009	0.0003	0.0008	0.0008	0.0004	
N	7	7	7	7	7	7	7	7	7	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9983	0.9988	0.9986	0.9989	0.9990	0.9987	0.9990	0.9977	0.9990	0.9966	
Stdev	0.0007	0.0005	0.0013	0.0005	0.0003	0.0003	0.0005	0.0013	0.0004	0.0035	
N	5	7	7	7	7	7	6	6	7	7	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9996	0.9993	0.9992	0.9987	0.9990	0.9986	0.9990	0.9986	0.9989	0.9991	
Stdev	0.0014	0.0021	0.0027	0.0006	0.0005	0.0003	0.0004	0.0002	0.0005	0.0003	
N	7	7	6	7	7	7	7	7	7	7	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				PAC3
Mean	0.9989	0.9990	0.9990	0.9985	0.9986	0.9985	0.9990				0.99865
Stdev	0.0006	0.0004	0.0004	0.0007	0.0007	0.0006	0.0008				0.00111
N	7	7	7	7	7	7	7				254

PMO5	31.6150										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9970	0.9979	0.9981	0.9983	0.9979	0.9975	0.9978	0.9978	0.9975	0.9974	
Stdev	0.0012	0.0011	0.0006	0.0012	0.0008	0.0003	0.0008	0.0006	0.0005	0.0020	
N	6	6	6	6	6	6	6	6	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9982	0.9989	0.9987	0.9988	0.9988	0.9981	0.9990	0.9985	0.9987	0.9967	
Stdev	0.0009	0.0009	0.0007	0.0009	0.0002	0.0007	0.0004	0.0013	0.0004	0.0021	
N	5	6	6	6	6	6	5	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9976	0.9975	0.9977	0.9987	0.9983	0.9979	0.9992	0.9981	0.9985	0.9987	
Stdev	0.0005	0.0009	0.0016	0.0007	0.0011	0.0011	0.0013	0.0008	0.0003	0.0005	
N	6	6	6	6	6	6	6	6	6	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				PMO5
Mean	0.9984	0.9986	0.9991	0.9983	0.9982	0.9984	0.9990				0.99821
Stdev	0.0003	0.0004	0.0004	0.0008	0.0007	0.0006	0.0019				0.00107
N	6	6	6	6	6	6	6				220

CROM2	127.6870										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9960	0.9962	0.9962	0.9962	0.9961	0.9960	0.9961	0.9960	0.9958	0.9969	
Stdev	0.0007	0.0006	0.0003	0.0008	0.0008	0.0004	0.0003	0.0005	0.0005	0.0005	
N	6	6	6	6	6	6	6	6	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9965	0.9966	0.9965	0.9967	0.9966	0.9963	0.9966	0.9957	0.9961	0.9952	
Stdev	0.0005	0.0004	0.0006	0.0005	0.0002	0.0002	0.0003	0.0006	0.0003	0.0008	
N	5	6	6	6	6	6	5	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9964	0.9959	0.9955	0.9962	0.9965	0.9962	0.9968	0.9959	0.9962	0.9963	
Stdev	0.0007	0.0005	0.0007	0.0005	0.0007	0.0004	0.0005	0.0004	0.0004	0.0003	
N	6	6	6	4	6	6	6	6	6	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				CROM2
Mean	0.9966	0.9961	0.9966	0.9960	0.9960	0.9961	0.9956				0.99618
Stdev	0.0002	0.0003	0.0006	0.0009	0.0008	0.0005	0.0015				0.00065
N	6	6	6	6	6	6	6				218

Table A 7.2: Results of CROM 3, PM06 10, PM06 80022.

CROM3	127.5490										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	undef	undef	0.9994	
Stdev	undef	undef	undef	undef	undef	undef	undef	undef	undef	0.0006	
N	undef	undef	undef	undef	undef	undef	undef	undef	undef	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9996	0.9995	0.9995	0.9995	0.9999	0.9991	0.9994	0.9993	0.9993	0.9985	
Stdev	0.0004	0.0003	0.0006	0.0005	0.0003	0.0004	0.0008	0.0010	0.0006	0.0005	
N	5	6	6	6	6	6	5	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9995	0.9998	0.9996	0.9992	0.9998	0.9993	0.9999	0.9995	0.9995	0.9996	
Stdev	0.0006	0.0003	0.0005	0.0006	0.0004	0.0005	0.0002	0.0006	0.0008	0.0002	
N	6	6	6	4	6	6	6	6	6	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				CROM3
Mean	0.9995	1.0001	0.9995	0.9989	0.9993	0.9991	0.9994				0.99945
Stdev	0.0003	0.0004	0.0006	0.0005	0.0005	0.0006	0.0005				0.00058
N	6	6	6	6	6	6	6				164
PMO610	22.6788										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9956	0.9965	0.9963	0.9956	0.9961	0.9958	0.9963	0.9964	0.9964	0.9969	
Stdev	0.0006	0.0005	0.0005	0.0005	0.0008	0.0003	0.0003	0.0002	0.0002	0.0002	
N	6	6	6	6	6	6	6	6	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9968	0.9966	0.9966	0.9966	0.9964	0.9965	0.9974	0.9972	0.9973	0.9959	
Stdev	0.0005	0.0004	0.0006	0.0006	0.0004	0.0003	0.0002	0.0005	0.0005	0.0011	
N	5	6	6	6	6	6	5	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9959	0.9958	0.9956	0.9965	0.9967	0.9962	0.9967	0.9964	0.9972	0.9969	
Stdev	0.0003	0.0005	0.0008	0.0005	0.0006	0.0002	0.0002	0.0003	0.0007	0.0002	
N	6	6	6	6	6	6	6	6	6	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				PMO610
Mean	0.9969	0.9972	0.9972	0.9965	0.9964	0.9969	0.9966				0.99650
Stdev	0.0006	0.0003	0.0006	0.0005	0.0004	0.0006	0.0010				0.00068
N	6	6	6	6	6	6	6				220
80022	23.9150										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9980	0.9982	0.9988	0.9985	0.9989	0.9985	0.9987	0.9990	0.9985	0.9987	
Stdev	0.0014	0.0016	0.0005	0.0018	0.0008	0.0004	0.0004	0.0006	0.0004	0.0006	
N	6	6	6	6	6	6	6	6	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9994	0.9989	0.9989	0.9987	0.9992	0.9985	0.9994	0.9988	0.9989	0.9978	
Stdev	0.0003	0.0005	0.0010	0.0009	0.0007	0.0007	0.0004	0.0008	0.0002	0.0011	
N	5	6	6	6	6	6	5	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9986	0.9983	0.9981	0.9989	0.9989	0.9986	0.9989	0.9987	0.9988	0.9989	
Stdev	0.0004	0.0008	0.0014	0.0003	0.0007	0.0009	0.0006	0.0007	0.0004	0.0006	
N	6	6	6	6	6	6	6	6	6	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				80022
Mean	0.9989	0.9989	0.9991	0.9986	0.9984	0.9988	0.9987				0.99872
Stdev	0.0003	0.0006	0.0002	0.0005	0.0005	0.0008	0.0016				0.00082
N	6	6	6	6	6	6	6				220

Table A 7.3: Results of ACR 1006, PMO6(D)5, PMO6(I)811106.

ACR1006	13.2000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	0.9998	1.0053	1.0065	
Stdev	undef	undef	undef	undef	undef	undef	undef	0.0066	0.0017	0.0068	
N	undef	undef	undef	undef	undef	undef	undef	6	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0071	1.0065	1.0030	1.0061	1.0014	1.0035	1.0043	1.0050	1.0036	0.9986	
Stdev	0.0024	0.0009	0.0022	0.0024	0.0059	0.0028	0.0026	0.0044	0.0048	0.0075	
N	5	6	6	6	6	6	5	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0047	0.9950	0.9908	1.0004	1.0036	1.0050	1.0033	1.0007	1.0013	1.0001	
Stdev	0.0069	0.0064	0.0087	0.0032	0.0045	0.0026	0.0032	0.0077	0.0080	0.0030	
N	6	6	5	6	6	6	6	6	5	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				ACR1006
Mean	0.9978	0.9989	1.0033	0.9947	0.9980	0.9933	0.9987				1.00153
Stdev	0.0077	0.0103	0.0060	0.0085	0.0076	0.0090	0.0072				0.00662
N	4	5	4	4	5	5	6				167

PMO6D	23.7290										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9973	0.9973	0.9981	0.9993	0.9997	0.9986	0.9987	0.9991	0.9990	0.9989	
Stdev	undef	0.0018	0.0012	0.0008	0.0011	0.0006	0.0005	0.0004	0.0005	0.0003	
N	1	5	5	5	6	6	6	5	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9995	0.9987	0.9990	0.9992	0.9989	0.9988	0.9995	0.9990	0.9989	0.9995	
Stdev	0.0009	0.0007	0.0005	0.0006	0.0004	0.0002	0.0002	0.0007	0.0010	0.0006	
N	5	5	6	6	6	6	3	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9984	0.9985	0.9977	0.9992	undef	undef	undef	undef	undef	undef	
Stdev	0.0022	0.0008	0.0013	0.0006	undef	undef	undef	undef	undef	undef	
N	5	6	6	6	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				PMO6D
Mean	undef	undef	undef	undef	undef	undef	undef				0.99885
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00100
N	undef	undef	undef	undef	undef	undef	undef				129

PMO6I	599.9500										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	0.9946	0.9942	0.9948	
Stdev	undef	undef	undef	undef	undef	undef	undef	0.0005	0.0004	0.0008	
N	undef	undef	undef	undef	undef	undef	undef	6	5	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9957	0.9955	0.9956	0.9952	0.9957	0.9942	0.9958	0.9959	0.9954	0.9984	
Stdev	0.0004	0.0004	0.0003	0.0009	0.0007	0.0023	0.0004	0.0006	0.0008	0.0054	
N	4	6	6	6	6	5	5	6	5	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9955	0.9949	0.9935	0.9955	0.9950	0.9950	0.9956	0.9951	0.9953	0.9954	
Stdev	0.0008	0.0007	0.0018	0.0006	0.0006	0.0006	0.0005	0.0007	0.0007	0.0007	
N	6	6	4	6	6	6	6	6	6	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				PMO6I
Mean	0.9954	0.9954	0.9960	0.9954	0.9949	0.9950	0.9946				0.99531
Stdev	0.0002	0.0005	0.0004	0.0009	0.0007	0.0007	0.0016				0.00142
N	6	6	6	6	6	6	6				172

Table A 7.4: Results of PM06(J)811107, PM06(S)811108, HF 14915.

PMO6J	24.0310										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9989	1.0024	1.0015	1.0020	1.0011	0.9999	1.0011	1.0005	1.0003	1.0009	
Stdev	0.0025	0.0020	0.0021	0.0011	0.0006	0.0017	0.0011	0.0012	0.0007	0.0010	
N	4	4	6	6	6	5	6	6	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0014	1.0007	1.0017	1.0016	0.9999	1.0011	1.0007	1.0007	1.0001	1.0028	
Stdev	0.0008	0.0008	0.0018	0.0010	0.0035	0.0019	0.0005	0.0007	0.0012	0.0040	
N	5	6	6	6	6	6	5	6	6	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9995	1.0010	1.0003	1.0015	undef	undef	undef	undef	undef	undef	
Stdev	0.0019	0.0041	0.0020	0.0004	undef	undef	undef	undef	undef	undef	
N	6	6	6	6	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				PMO6J
Mean	undef	undef	undef	undef	undef	undef	undef				1.00089
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00193
N	undef	undef	undef	undef	undef	undef	undef				137
PMO6S	120.2900										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	1.0015	0.9984	1.0017	1.0001	0.9997	1.0000	0.9993	0.9993	0.9999	
Stdev	undef	0.0042	0.0047	0.0015	0.0005	0.0006	0.0006	0.0007	0.0008	0.0010	
N	undef	6	6	5	6	6	6	6	6	6	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0006	1.0003	1.0007	1.0001	0.9990	0.9998	1.0002	0.9997	0.9991	0.9998	
Stdev	0.0007	0.0005	0.0010	0.0006	0.0018	0.0003	0.0005	0.0016	0.0006	0.0018	
N	5	6	6	6	6	6	5	6	5	5	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0001	0.9992	0.9996	0.9995	1.0000	0.9998	1.0003	0.9997	1.0001	1.0002	
Stdev	0.0009	0.0029	0.0016	0.0010	0.0008	0.0005	0.0007	0.0011	0.0006	0.0004	
N	6	5	3	6	6	5	6	6	5	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				PMO6S
Mean	0.9994	0.9992	0.9996	0.9987	0.9985	0.9988	0.9989				0.99974
Stdev	0.0004	0.0017	0.0010	0.0016	0.0013	0.0012	0.0018				0.00158
N	5	5	6	6	6	5	6				202
H14915	20010.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9995	0.9992	1.0013	1.0004	1.0007	1.0000	0.9999	0.9996	1.0008	1.0024	
Stdev	0.0005	0.0014	0.0025	0.0009	0.0008	0.0008	0.0006	0.0005	0.0005	0.0010	
N	7	7	7	7	7	7	7	7	7	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0016	1.0017	1.0009	1.0021	1.0002	0.9965	1.0013	1.0003	0.9999	0.9992	
Stdev	0.0006	0.0006	0.0005	0.0010	0.0004	0.0003	0.0004	0.0006	0.0006	0.0008	
N	8	10	10	10	10	10	9	8	10	10	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0018	1.0014	1.0008	1.0011	undef	undef	undef	undef	undef	undef	
Stdev	0.0011	0.0012	0.0012	0.0006	undef	undef	undef	undef	undef	undef	
N	10	10	9	10	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				H14915
Mean	undef	undef	undef	undef	undef	undef	undef				1.00053
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00153
N	undef	undef	undef	undef	undef	undef	undef				204

Table A 7.5: Results of HF 15744, HF 17142, HF18747.

H15744	20020.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	0.9985	0.9983	0.9982	0.9992	0.9986	0.9991	0.9982	0.9993	0.9998	
Stdev	undef	0.0026	0.0026	0.0004	0.0006	0.0009	0.0006	0.0003	0.0006	0.0008	
N	undef	7	7	6	7	7	7	7	7	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9998	0.9992	0.9991	0.9991	0.9993	0.9988	0.9991	0.9988	0.9994	0.9977	
Stdev	0.0009	0.0006	0.0006	0.0006	0.0005	0.0004	0.0004	0.0004	0.0002	0.0006	
N	8	10	10	10	10	10	9	8	9	7	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9992	0.9984	0.9989	0.9980	0.9994	0.9997	0.9994	0.9987	0.9987	0.9992	
Stdev	0.0009	0.0012	0.0005	0.0004	0.0008	0.0007	0.0006	0.0009	0.0007	0.0003	
N	10	10	5	10	10	10	10	10	10	10	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				H15744
Mean	0.9988	0.9986	0.9989	0.9988	0.9987	0.9984	0.9991				0.99892
Stdev	0.0002	0.0003	0.0007	0.0005	0.0006	0.0006	0.0011				0.00092
N	10	10	10	10	10	10	10				318

H17142	19982.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	1.0008	1.0002	1.0012	1.0006	1.0000	1.0012	1.0004	1.0004	1.0013	
Stdev	undef	0.0023	0.0018	0.0009	0.0009	0.0008	0.0008	0.0004	0.0008	0.0008	
N	undef	7	7	7	7	6	7	7	7	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0013	1.0008	1.0011	1.0015	1.0015	1.0014	1.0021	1.0008	1.0019	1.0011	
Stdev	0.0010	0.0006	0.0005	0.0009	0.0004	0.0005	0.0006	0.0007	0.0003	0.0007	
N	8	10	10	10	10	10	9	8	10	10	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0016	1.0005	1.0021	1.0005	1.0011	1.0015	1.0011	1.0003	1.0016	1.0014	
Stdev	0.0012	0.0016	0.0009	0.0004	0.0011	0.0008	0.0006	0.0010	0.0008	0.0005	
N	10	10	9	10	10	10	10	10	10	10	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				H17142
Mean	1.0016	1.0017	1.0023	1.0017	1.0016	undef	undef				1.00122
Stdev	0.0005	0.0004	0.0005	0.0005	0.0006	undef	undef				0.00099
N	10	10	10	10	10	undef	undef				306

H18747	1.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	0.9985	1.0001	1.0001	
Stdev	undef	undef	undef	undef	undef	undef	undef	0.0008	0.0006	0.0011	
N	undef	undef	undef	undef	undef	undef	undef	7	6	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0000	0.9998	0.9997	0.9997	0.9999	0.9999	0.9997	1.0006	1.0004	0.9985	
Stdev	0.0006	0.0004	0.0013	0.0005	0.0004	0.0006	0.0010	0.0011	0.0007	0.0034	
N	5	7	7	7	7	7	6	6	7	7	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0000	0.9996	0.9994	0.9997	undef	undef	undef	undef	undef	undef	
Stdev	0.0016	0.0032	0.0030	0.0005	undef	undef	undef	undef	undef	undef	
N	7	7	6	7	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				H18747
Mean	undef	undef	undef	undef	undef	undef	undef				0.99972
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00155
N	undef	undef	undef	undef	undef	undef	undef				113

Table A 7.6: Results of HF 19746, HF 23725, EPAC 12843.

H19746	19975.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410 1135	0710_0922	0710_0951	1110_0914	
Mean	undef	0.9973	0.9985	0.9990	0.9989	0.9978	0.9989	0.9984	0.9979	0.9996	
Stdev	undef	0.0027	0.0026	0.0012	0.0006	0.0008	0.0004	0.0002	0.0007	0.0008	
N	undef	7	7	7	7	7	7	7	7	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110 1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9993	0.9992	0.9988	0.9990	0.9991	1.0001	0.9997	0.9992	0.9989	undef	
Stdev	0.0009	0.0006	0.0009	0.0005	0.0003	0.0007	0.0003	0.0006	0.0007	undef	
N	8	10	10	9	9	10	9	8	9	undef	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0009	0.9992	0.9987	0.9989	undef	undef	undef	undef	undef	undef	
Stdev	0.0007	0.0012	0.0008	0.0005	undef	undef	undef	undef	undef	undef	
N	8	10	9	10	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				H19746
Mean	undef	undef	undef	undef	undef	undef	undef				0.99901
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00119
N	undef	undef	undef	undef	undef	undef	undef				182
H23725	20050.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	1.0011	1.0021	1.0032	1.0012	1.0030	1.0044	undef	1.0011	1.0049	1.0004	
Stdev	0.0007	0.0010	0.0019	0.0015	0.0012	0.0019	undef	0.0020	0.0015	0.0011	
N	7	7	7	7	7	7	undef	7	7	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0034	1.0047	1.0046	1.0063	1.0061	1.0030	1.0027	1.0008	1.0056	1.0003	
Stdev	0.0017	0.0010	0.0021	0.0016	0.0014	0.0014	0.0011	0.0019	0.0011	0.0014	
N	5	7	7	7	7	7	6	6	7	7	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0018	1.0037	1.0009	1.0018	undef	undef	undef	undef	undef	undef	
Stdev	0.0012	0.0019	0.0014	0.0017	undef	undef	undef	undef	undef	undef	
N	7	7	6	7	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				H23725
Mean	undef	undef	undef	undef	undef	undef	undef				1.00294
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00231
N	undef	undef	undef	undef	undef	undef	undef				156
P12843	10.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	1.0012	1.0024	1.0009	1.0021	1.0019	1.0014	1.0022	1.0020	1.0029	1.0023	
Stdev	0.0016	0.0016	0.0021	0.0014	0.0010	0.0013	0.0009	0.0007	0.0008	0.0008	
N	12	12	12	12	12	12	12	11	12	12	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0019	1.0017	1.0022	1.0012	1.0016	0.9999	0.9995	0.9994	1.0005	0.9978	
Stdev	0.0006	0.0007	0.0013	0.0009	0.0012	0.0012	0.0010	0.0012	0.0010	0.0017	
N	10	12	12	12	12	12	11	10	12	10	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0012	1.0008	0.9999	1.0014	1.0020	1.0035	1.0034	1.0037	1.0000	1.0020	
Stdev	0.0011	0.0021	0.0016	0.0005	0.0008	0.0009	0.0005	0.0010	0.0010	0.0011	
N	12	12	11	11	12	12	12	12	12	12	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P12843
Mean	1.0010	1.0006	0.9994	1.0000	0.9983	0.9982	0.9991				1.00109
Stdev	0.0008	0.0011	0.0009	0.0013	0.0015	0.0013	0.0018				0.00185
N	12	12	12	12	12	12	11				433

Table A 7.7: Results of EPAC 13219, EPAC 13617, MK VI 67401.

P13219	10024.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	0.9915	0.9922	0.9933	
Stdev	undef	undef	undef	undef	undef	undef	undef	0.0012	0.0014	0.0009	
N	undef	undef	undef	undef	undef	undef	undef	7	6	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9943	0.9959	0.9964	0.9961	0.9945	0.9956	0.9955	0.9939	0.9947	0.9917	
Stdev	0.0006	0.0006	0.0014	0.0008	0.0003	0.0008	0.0008	0.0016	0.0009	0.0027	
N	5	7	7	7	5	7	6	6	7	7	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9925	0.9939	0.9952	0.9939	0.9927	0.9900	0.9916	0.9918	0.9931	0.9921	
Stdev	0.0014	0.0018	0.0013	0.0010	0.0008	0.0004	0.0009	0.0005	0.0011	0.0009	
N	7	7	6	7	7	7	7	7	7	7	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P13219
Mean	0.9926	0.9930	0.9917	0.9926	0.9955	0.9949	0.9945				0.99354
Stdev	0.0010	0.0008	0.0003	0.0013	0.0007	0.0010	0.0014				0.00195
N	7	7	7	7	7	7	7				202

P13617	10024.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9979	0.9940	0.9986	1.0005	0.9956	0.9974	0.9946	0.9964	0.9965	0.9959	
Stdev	0.0026	0.0017	0.0021	0.0010	0.0015	0.0011	0.0014	0.0011	0.0011	0.0009	
N	7	7	7	7	7	7	7	7	7	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9962	0.9967	0.9950	0.9950	0.9955	0.9951	0.9964	0.9946	0.9956	0.9935	
Stdev	0.0005	0.0007	0.0015	0.0018	0.0013	0.0019	0.0011	0.0020	0.0010	0.0034	
N	5	7	7	7	7	7	6	6	7	7	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9954	0.9966	0.9965	0.9956	0.9965	0.9983	0.9970	0.9948	0.9981	0.9955	
Stdev	0.0016	0.0022	0.0022	0.0003	0.0007	0.0007	0.0012	0.0011	0.0015	0.0011	
N	7	7	6	7	7	7	7	7	7	7	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P13617
Mean	0.9965	0.9959	0.9960	0.9961	undef	undef	undef				0.99616
Stdev	0.0010	0.0016	0.0008	0.0012	undef	undef	undef				0.00198
N	7	7	7	7	undef	undef	undef				233

P67401	10.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9972	0.9953	0.9965	0.9967	0.9958	0.9959	0.9962	0.9967	0.9966	0.9986	
Stdev	0.0006	0.0012	0.0018	0.0013	0.0006	0.0008	0.0006	0.0007	0.0008	0.0009	
N	12	12	12	12	12	12	11	12	12	12	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9969	0.9970	0.9970	0.9969	0.9969	0.9972	0.9976	0.9969	0.9967	0.9958	
Stdev	0.0008	0.0006	0.0009	0.0008	0.0004	0.0005	0.0005	0.0008	0.0003	0.0017	
N	9	12	12	12	12	12	11	9	12	11	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9970	0.9961	0.9965	0.9962	0.9972	0.9962	0.9978	undef	0.9972	0.9975	
Stdev	0.0013	0.0020	0.0011	0.0007	0.0008	0.0011	0.0004	undef	0.0008	0.0008	
N	12	12	11	12	11	12	12	undef	12	11	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P67401
Mean	0.9970	0.9973	0.9978	undef	0.9982	0.9985	undef				0.99691
Stdev	0.0006	0.0007	0.0006	undef	0.0008	0.0007	undef				0.00116
N	12	12	11	undef	12	11	undef				394

Table A 7.8: Results of MK VI 67502, MK VI 67604, MK VI 67702.

P67502	10.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9992	0.9985	0.9983	1.0007	1.0018	1.0001	1.0012	1.0010	1.0007	1.0015	
Stdev	0.0013	0.0013	0.0021	0.0012	0.0009	0.0012	0.0008	0.0009	0.0010	0.0010	
N	12	12	12	12	12	12	12	11	12	12	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0013	1.0010	1.0001	0.9994	1.0003	1.0000	0.9997	1.0003	1.0007	0.9986	
Stdev	0.0009	0.0005	0.0011	0.0006	0.0007	0.0004	0.0008	0.0009	0.0006	0.0017	
N	10	12	12	12	12	12	11	10	12	11	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9998	0.9991	1.0004	1.0004	1.0011	1.0014	1.0009	1.0003	1.0005	1.0016	
Stdev	0.0009	0.0019	0.0010	0.0006	0.0009	0.0014	0.0006	0.0007	0.0005	0.0007	
N	12	12	11	11	12	12	12	12	12	12	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P67502
Mean	1.0014	1.0021	1.0022	1.0008	1.0007	1.0002	1.0002				1.00048
Stdev	0.0006	0.0008	0.0008	0.0008	0.0009	0.0008	0.0013				0.00136
N	12	12	12	12	12	12	11				434

P67604	1.0028										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9960	0.9953	0.9958	0.9946	0.9970	0.9981	0.9963	undef	0.9993	0.9989	
Stdev	0.0011	0.0015	0.0019	0.0011	0.0005	0.0007	0.0006	undef	0.0007	0.0008	
N	11	11	11	11	11	11	11	undef	10	11	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9991	0.9998	0.9988	0.9989	0.9979	0.9984	0.9995	0.9989	0.9980	0.9974	
Stdev	0.0008	0.0006	0.0011	0.0006	0.0005	0.0004	0.0007	0.0006	0.0005	0.0016	
N	9	9	11	11	11	11	9	7	11	11	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9990	0.9981	0.9989	0.9993	0.9981	0.9992	0.9986	0.9979	0.9987	0.9980	
Stdev	0.0009	0.0016	0.0009	0.0004	0.0009	0.0012	0.0005	0.0007	0.0006	0.0006	
N	11	11	10	11	12	12	12	12	12	12	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P67604
Mean	0.9988	0.9987	0.9978	0.9973	0.9977	0.9977	0.9982				0.99802
Stdev	0.0003	0.0004	0.0005	0.0005	0.0007	0.0008	0.0011				0.00145
N	12	12	12	12	12	12	12				397

P67702	10.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	1.0016	1.0013	1.0006	1.0023	1.0007	1.0015	1.0013	1.0018	1.0018	1.0031	
Stdev	0.0007	0.0014	0.0017	0.0013	0.0006	0.0008	0.0007	0.0009	0.0008	0.0009	
N	12	11	12	12	11	12	12	12	12	12	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0028	1.0024	1.0017	1.0016	1.0014	1.0014	0.9988	1.0011	1.0024	1.0016	
Stdev	0.0040	0.0006	0.0008	0.0007	0.0004	0.0005	0.0005	0.0007	0.0003	0.0018	
N	8	12	12	12	11	12	11	10	12	12	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0024	1.0011	1.0016	1.0021	1.0025	1.0003	1.0027	1.0027	1.0014	1.0020	
Stdev	0.0012	0.0018	0.0009	0.0006	0.0008	0.0010	0.0004	0.0005	0.0006	0.0004	
N	12	12	11	12	10	12	12	11	12	12	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P67702
Mean	1.0035	1.0023	1.0025	1.0025	undef	undef	undef				1.00179
Stdev	0.0005	0.0004	0.0004	0.0005	undef	undef	undef				0.00133
N	11	12	11	11	undef	undef	undef				391

Table A 7.9: Results of MK VI 67814, MK VI 67915, MK VI 68016.

P67814	10.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9978	0.9975	0.9975	0.9984	0.9984	0.9976	0.9979	0.9983	0.9980	0.9988	
Stdev	0.0006	0.0013	0.0019	0.0013	0.0004	0.0007	0.0006	0.0006	0.0006	0.0007	
N	12	12	12	12	12	12	12	12	12	12	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9987	0.9986	0.9982	0.9981	0.9981	0.9981	0.9987	0.9980	0.9981	0.9971	
Stdev	0.0005	0.0004	0.0008	0.0006	0.0004	0.0004	0.0004	0.0004	0.0003	0.0016	
N	10	12	12	12	12	12	11	10	12	11	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9981	0.9971	0.9982	0.9979	0.9989	0.9985	0.9986	0.9981	0.9984	0.9982	
Stdev	0.0011	0.0020	0.0011	0.0004	0.0007	0.0010	0.0004	0.0005	0.0006	0.0008	
N	12	12	10	12	12	12	12	12	12	12	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P67814
Mean	0.9981	0.9981	0.9982	0.9981	0.9981	0.9978	0.9979				0.99812
Stdev	0.0002	0.0004	0.0003	0.0005	0.0006	0.0006	0.0009				0.00090
N	12	12	12	12	12	12	12				436

P67915	10.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9966	0.9947	0.9953	0.9967	0.9978	undef	undef	0.9977	0.9973	0.9972	
Stdev	0.0011	0.0018	0.0022	0.0013	0.0006	undef	undef	0.0010	0.0010	0.0009	
N	11	12	12	12	12	undef	undef	12	11	12	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9982	0.9974	0.9972	0.9973	0.9961	0.9958	0.9969	0.9967	0.9975	0.9964	
Stdev	0.0008	0.0003	0.0009	0.0005	0.0005	0.0003	0.0004	0.0005	0.0003	0.0015	
N	10	11	12	12	12	12	11	10	12	11	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9974	0.9967	0.9970	0.9962	0.9986	0.9981	0.9981	0.9975	0.9971	0.9972	
Stdev	0.0011	0.0019	0.0010	0.0005	0.0011	0.0007	0.0006	0.0005	0.0008	0.0005	
N	12	12	10	12	12	12	12	12	12	12	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P67915
Mean	0.9980	0.9983	0.9983	0.9982	0.9975	0.9971	0.9974				0.99719
Stdev	0.0003	0.0004	0.0005	0.0005	0.0007	0.0006	0.0010				0.00125
N	12	12	12	12	12	12	12				409

P68016	1.0000										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9991	0.9979	0.9975	0.9990	1.0002	0.9979	0.9987	0.9995	0.9976	1.0011	
Stdev	0.0009	0.0015	0.0018	0.0016	0.0006	0.0008	0.0005	0.0007	0.0007	0.0010	
N	12	12	12	12	12	12	12	12	12	12	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9987	0.9987	0.9994	0.9995	0.9981	0.9982	0.9995	0.9995	0.9996	0.9989	
Stdev	0.0008	0.0005	0.0010	0.0006	0.0004	0.0004	0.0006	0.0005	0.0004	0.0012	
N	9	12	12	12	12	12	11	9	12	7	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9993	0.9988	0.9987	0.9996	1.0018	1.0004	0.9997	0.9990	0.9982	0.9987	
Stdev	0.0011	0.0017	0.0011	0.0004	0.0006	0.0009	0.0005	0.0006	0.0006	0.0005	
N	9	12	11	12	11	12	12	12	12	12	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				P68016
Mean	0.9991	0.9991	0.9992	0.9996	0.9995	0.9990	0.9991				0.99912
Stdev	0.0003	0.0004	0.0006	0.0006	0.0007	0.0005	0.0010				0.00120
N	12	12	12	12	12	12	12				427

Table A 7.10: Results of A 7, A 21, A 24.

A7	30041.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9977	0.9975	1.0000	0.9969	0.9974	0.9979	0.9979	0.9961	0.9974	1.0003	
Stdev	0.0012	0.0016	0.0019	0.0022	0.0012	0.0009	0.0007	0.0012	0.0012	0.0010	
N	9	9	7	9	6	9	9	5	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9986	1.0003	1.0010	1.0007	1.0004	1.0005	1.0005	0.9990	0.9998	undef	
Stdev	0.0012	0.0010	0.0011	0.0007	0.0010	0.0012	0.0011	0.0011	0.0009	undef	
N	6	5	9	9	9	9	8	5	9	undef	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9994	0.9969	0.9965	0.9986	undef	undef	undef	undef	undef	undef	
Stdev	0.0024	0.0020	0.0010	0.0005	undef	undef	undef	undef	undef	undef	
N	7	7	5	9	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A7
Mean	undef	undef	undef	undef	undef	undef	undef				0.99884
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00192
N	undef	undef	undef	undef	undef	undef	undef				178

A21	5026.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	1.0049	1.0054	1.0087	1.0107	1.0071	1.0079	1.0052	1.0066	1.0058	1.0081	
Stdev	0.0044	0.0024	0.0013	0.0018	0.0006	0.0012	0.0053	0.0010	0.0035	0.0012	
N	9	9	9	9	6	9	9	5	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0091	1.0119	1.0070	1.0124	1.0111	1.0101	1.0066	1.0154	1.0111	undef	
Stdev	0.0009	0.0008	0.0017	0.0033	0.0009	0.0033	0.0032	0.0027	0.0040	undef	
N	6	5	9	9	9	9	8	4	9	undef	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0085	undef	undef	1.0070	undef	undef	undef	undef	undef	undef	
Stdev	undef	undef	undef	0.0037	undef	undef	undef	undef	undef	undef	
N	1	undef	undef	8	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A21
Mean	undef	undef	undef	undef	undef	undef	undef				1.00840
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00370
N	undef	undef	undef	undef	undef	undef	undef				158

A24	23667.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9974	0.9972	0.9984	0.9974	0.9980	0.9991	0.9982	0.9979	0.9980	1.0009	
Stdev	0.0007	0.0006	0.0016	0.0010	0.0005	0.0011	0.0008	0.0007	0.0009	0.0008	
N	9	9	9	9	9	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0006	1.0006	1.0007	1.0011	1.0004	1.0002	1.0011	0.9996	1.0006	0.9981	
Stdev	0.0003	0.0010	0.0006	0.0005	0.0008	0.0008	0.0005	0.0013	0.0008	0.0012	
N	4	9	9	9	9	9	8	5	9	4	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0007	0.9998	1.0008	1.0019	1.0017	1.0014	1.0007	1.0012	1.0005	1.0016	
Stdev	0.0015	0.0020	0.0010	0.0006	0.0005	0.0006	0.0005	0.0007	0.0001	0.0003	
N	7	9	5	7	9	9	9	9	5	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A24
Mean	1.0004	1.0008	1.0016	1.0009	1.0011	1.0006	undef				0.99999
Stdev	0.0010	0.0005	0.0010	0.0008	0.0009	0.0010	undef				0.00165
N	9	9	9	9	3	6	undef				288

Table A 7.11: Results of A 171, A 212, A 507.

A171	5724.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	1.0002	1.0007	1.0005	1.0001	1.0001	1.0024	1.0004	1.0009	1.0012	
Stdev	undef	0.0030	0.0025	0.0019	0.0011	0.0006	0.0050	0.0018	0.0020	0.0023	
N	undef	9	9	9	9	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0012	1.0002	0.9996	1.0006	1.0007	0.9984	0.9996	1.0013	1.0003	1.0000	
Stdev	0.0024	0.0017	0.0014	0.0010	0.0009	0.0034	0.0016	0.0017	0.0014	0.0015	
N	6	8	9	9	9	9	8	5	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0014	1.0007	1.0027	0.9997	1.0008	1.0008	1.0008	1.0015	1.0010	1.0009	
Stdev	0.0020	0.0009	0.0018	0.0012	0.0010	0.0022	0.0018	0.0024	0.0007	0.0012	
N	7	9	7	9	9	9	9	9	9	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A171
Mean	0.9988	1.0006	1.0002	1.0009	1.0000	1.0000	1.0005				1.00052
Stdev	0.0020	0.0006	0.0009	0.0016	0.0009	0.0013	0.0015				0.00197
N	9	9	7	9	9	9	9				309

A212	10535.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	0.9990	0.9990	1.0004	1.0010	1.0013	1.0018	1.0024	1.0030	0.9997	
Stdev	undef	0.0059	0.0040	0.0016	0.0013	0.0023	0.0016	0.0014	0.0029	0.0012	
N	undef	9	9	7	9	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0001	1.0008	0.9993	1.0007	0.9966	0.9966	0.9977	0.9984	0.9985	undef	
Stdev	0.0013	0.0016	0.0015	0.0062	0.0015	0.0005	0.0005	0.0015	0.0009	undef	
N	6	9	8	9	7	9	6	4	8	undef	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9981	0.9957	0.9989	1.0003	undef	undef	undef	undef	undef	undef	
Stdev	0.0020	0.0028	0.0014	0.0022	undef	undef	undef	undef	undef	undef	
N	9	9	2	9	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A212
Mean	undef	undef	undef	undef	undef	undef	undef				0.99963
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00318
N	undef	undef	undef	undef	undef	undef	undef				174

A507	12187.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9958	1.0003	0.9990	0.9981	1.0051	1.0062	1.0011	1.0067	1.0049	0.9977	
Stdev	0.0051	0.0016	0.0011	0.0028	0.0067	0.0063	0.0016	0.0034	0.0041	0.0011	
N	9	9	7	9	8	7	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9975	1.0002	1.0036	0.9975	0.9983	0.9975	0.9987	0.9975	0.9966	0.9982	
Stdev	0.0006	0.0007	0.0054	0.0007	0.0011	0.0007	0.0017	0.0042	0.0015	0.0024	
N	6	9	9	9	9	9	8	5	5	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0008	0.9961	1.0001	0.9973	0.9997	0.9976	0.9979	0.9978	0.9973	0.9969	
Stdev	0.0017	0.0019	0.0019	0.0027	0.0032	0.0011	0.0004	0.0012	0.0019	0.0009	
N	9	9	7	9	8	5	8	9	7	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A507
Mean	0.9964	0.9980	undef	undef	undef	undef	undef				0.99931
Stdev	0.0032	0.0013	undef	undef	undef	undef	undef				0.00399
N	9	9	undef	undef	undef	undef	undef				261

Table A 7.12: Results of A 561, A 564, A 568.

A561	6148.0										
Run	0310_0957	0310_1112	0310 1221	0310_1454	0410_0946	0410_1043	0410 1135	0710_0922	0710 0951	1110 0914	
Mean	1.0055	1.0033	1.0039	1.0068	0.9949	0.9940	1.0057	0.9960	0.9943	0.9950	
Stdev	0.0066	0.0056	0.0099	0.0120	0.0072	0.0032	0.0111	0.0069	0.0099	0.0074	
N	7	9	9	8	7	9	6	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9938	0.9910	0.9989	0.9981	1.0049	1.0031	undef	1.0050	1.0059	0.9950	
Stdev	0.0061	0.0067	0.0072	0.0054	0.0030	0.0094	undef	0.0043	0.0047	0.0062	
N	6	9	9	9	9	7	undef	5	8	6	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0047	0.9977	1.0045	1.0048	undef	undef	1.0060	1.0014	1.0027	1.0067	
Stdev	0.0053	0.0076	0.0032	0.0089	undef	undef	0.0075	0.0044	0.0062	0.0060	
N	9	7	5	8	undef	undef	7	9	9	7	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A561
Mean	1.0028	1.0019	undef	1.0056	1.0083	1.0051	1.0004				1.00125
Stdev	0.0039	0.0070	undef	0.0061	0.0052	0.0044	0.0073				0.00801
N	7	8	undef	6	7	9	9				257
A564	5919.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	1.0024	0.9962	0.9978	0.9938	1.0033	1.0011	0.9979	1.0036	1.0048	1.0034	
Stdev	0.0080	0.0039	0.0027	0.0009	0.0020	0.0014	0.0016	0.0012	0.0014	0.0034	
N	8	9	9	9	9	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9951	1.0020	0.9940	1.0004	0.9981	0.9962	0.9970	0.9922	0.9906	0.9969	
Stdev	0.0024	0.0019	0.0018	0.0014	0.0013	0.0022	0.0009	0.0010	0.0018	0.0074	
N	6	9	9	9	9	9	8	5	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0016	1.0031	1.0013	1.0004	undef	1.0010	1.0010	1.0026	undef	1.0011	
Stdev	0.0018	0.0021	0.0059	0.0023	undef	0.0030	0.0017	0.0030	undef	0.0013	
N	9	9	7	9	undef	9	9	9	undef	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A564
Mean	1.0005	1.0030	0.9999	1.0011	1.0010	1.0029	1.0032				0.99987
Stdev	0.0014	0.0035	0.0045	0.0027	0.0018	0.0036	0.0050				0.00450
N	9	9	9	9	9	9	9				304
A568	5777.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	0.9988	0.9983	0.9995	1.0023	1.0010	1.0019	1.0024	1.0033	0.9987	
Stdev	undef	0.0013	0.0015	0.0020	0.0016	0.0013	0.0011	0.0009	0.0025	0.0012	
N	undef	9	9	9	9	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9998	0.9980	0.9994	0.9996	1.0001	0.9996	1.0018	1.0029	1.0022	1.0018	
Stdev	0.0013	0.0036	0.0019	0.0011	0.0012	0.0010	0.0008	0.0018	0.0009	0.0027	
N	6	9	9	9	9	9	8	5	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0020	1.0020	1.0015	1.0007	undef	undef	undef	undef	undef	undef	
Stdev	0.0019	0.0026	0.0025	0.0009	undef	undef	undef	undef	undef	undef	
N	9	9	7	9	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A568
Mean	undef	undef	undef	undef	undef	undef	undef				1.00072
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00228
N	undef	undef	undef	undef	undef	undef	undef				197

Table A 7.13: Results of A 576, A 578, A 583.

A576	5855.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	
Stdev	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	
N	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	undef	undef	undef	undef	undef	undef	undef	undef	undef	0.9941	
Stdev	undef	undef	undef	undef	undef	undef	undef	undef	undef	0.0035	
N	undef	undef	undef	undef	undef	undef	undef	undef	undef	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9966	0.9959	0.9950	0.9939	0.9930	0.9914	0.9922	0.9924	0.9918	0.9937	
Stdev	0.0031	0.0027	0.0033	0.0028	0.0016	0.0015	0.0014	0.0010	0.0010	0.0010	
N	9	7	7	7	8	9	9	9	9	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A576
Mean	0.9955	0.9923	0.9948	0.9932	0.9946	0.9936	0.9942				0.99375
Stdev	0.0018	0.0011	0.0012	0.0008	0.0027	0.0014	0.0013				0.00236
N	9	9	9	9	9	9	9				155

A578	6241.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	1.0000	1.0008	0.9987	
Stdev	undef	undef	undef	undef	undef	undef	undef	0.0018	0.0012	0.0012	
N	undef	undef	undef	undef	undef	undef	undef	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0010	0.9996	0.9995	0.9989	0.9990	0.9980	0.9995	0.9989	0.9990	1.0004	
Stdev	0.0014	0.0011	0.0015	0.0005	0.0008	0.0010	0.0007	0.0006	0.0010	0.0019	
N	6	9	9	9	9	9	8	5	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0011	1.0001	0.9999	0.9989	1.0012	0.9986	0.9992	1.0001	0.9991	0.9993	
Stdev	0.0010	0.0019	0.0018	0.0008	0.0019	0.0011	0.0013	0.0012	0.0008	0.0005	
N	9	9	7	9	9	9	9	9	9	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A578
Mean	0.9990	0.9997	0.9997	0.9990	0.9995	0.9989	0.9998				0.99954
Stdev	0.0003	0.0007	0.0004	0.0004	0.0006	0.0009	0.0005				0.00131
N	9	9	9	9	9	9	9				260

A583	5983.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9957	0.9947	0.9943	0.9960	0.9972	0.9954	0.9968	0.9979	0.9972	undef	
Stdev	0.0020	0.0035	0.0023	0.0016	0.0011	0.0006	0.0018	0.0025	0.0015	undef	
N	9	9	9	9	9	9	9	7	9	undef	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	undef	0.9968	0.9971	0.9972	0.9976	0.9967	0.9970	0.9966	0.9968	0.9979	
Stdev	undef	0.0013	0.0010	0.0005	0.0009	0.0013	0.0008	0.0008	0.0012	0.0023	
N	undef	9	9	9	9	9	8	4	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9984	0.9973	0.9985	0.9973	0.9977	0.9971	0.9971	0.9968	0.9970	0.9973	
Stdev	0.0011	0.0020	0.0021	0.0007	0.0014	0.0016	0.0009	0.0015	0.0008	0.0008	
N	9	9	7	9	9	9	9	6	7	6	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A583
Mean	0.9974	0.9969	0.9963	0.9970	0.9970	0.9971	0.9983				0.99694
Stdev	0.0003	0.0005	0.0027	0.0015	0.0007	0.0008	0.0011				0.00171
N	9	9	9	6	7	9	9				292

Table A 7.14: Results of A 708, A 7636, A 9003.

A708	6029.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	undef	undef	undef	undef	undef	undef	undef	undef	undef	0.9954	
Stdev	undef	undef	undef	undef	undef	undef	undef	undef	undef	0.0015	
N	undef	undef	undef	undef	undef	undef	undef	undef	undef	8	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9956	0.9947	0.9927	0.9941	0.9961	0.9948	0.9947	0.9947	0.9965	0.9952	
Stdev	0.0011	0.0010	0.0034	0.0008	0.0014	0.0019	0.0010	0.0007	0.0019	0.0042	
N	6	9	9	9	9	9	8	5	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9954	0.9940	0.9955	0.9960	undef	undef	undef	undef	undef	undef	
Stdev	0.0011	0.0022	0.0013	0.0006	undef	undef	undef	undef	undef	undef	
N	9	9	7	9	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A708
Mean	undef	undef	undef	undef	undef	undef	undef				0.99501
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00207
N	undef	undef	undef	undef	undef	undef	undef				124
A7636	4322.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9965	0.9967	0.9970	0.9956	0.9986	0.9983	0.9988	0.9986	0.9988	1.0000	
Stdev	0.0005	0.0017	0.0020	0.0009	0.0010	0.0006	0.0011	0.0006	0.0005	0.0006	
N	9	9	9	9	9	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0002	1.0000	0.9995	0.9997	0.9996	0.9992	0.9992	0.9986	0.9985	0.9997	
Stdev	0.0004	0.0010	0.0009	0.0009	0.0004	0.0009	0.0006	0.0007	0.0007	0.0001	
N	6	9	9	9	9	9	8	4	9	2	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9992	0.9988	0.9997	0.9998	1.0005	1.0001	1.0001	0.9997	1.0002	1.0002	
Stdev	0.0008	0.0009	0.0010	0.0008	0.0004	0.0005	0.0006	0.0010	0.0009	0.0006	
N	5	9	7	9	9	9	9	9	9	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A7636
Mean	0.9992	0.9995	0.9996	0.9992	0.9994	0.9990	0.9995				0.99908
Stdev	0.0010	0.0009	0.0006	0.0010	0.0009	0.0007	0.0008				0.00139
N	9	9	9	9	9	9	9				311
A9003	4598.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	1.0032	1.0052	0.9999	0.9921	1.0040	1.0055	1.0006	1.0023	1.0056	1.0109	
Stdev	0.0015	0.0014	0.0026	0.0009	0.0013	0.0011	0.0012	0.0012	0.0013	0.0018	
N	9	9	9	9	9	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0123	1.0141	1.0109	1.0081	1.0067	1.0029	1.0035	1.0027	1.0014	1.0053	
Stdev	0.0006	0.0008	0.0011	0.0007	0.0012	0.0010	0.0010	0.0008	0.0008	0.0015	
N	6	9	9	9	9	9	8	5	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0107	1.0135	1.0146	1.0151	undef	undef	undef	undef	undef	undef	
Stdev	0.0013	0.0029	0.0012	0.0008	undef	undef	undef	undef	undef	undef	
N	9	9	7	9	undef	undef	undef	undef	undef	undef	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A9003
Mean	undef	undef	undef	undef	undef	undef	undef				1.00621
Stdev	undef	undef	undef	undef	undef	undef	undef				0.00566
N	undef	undef	undef	undef	undef	undef	undef				206

Table A 7.15: Results of A 18020, A 18587.

A18020	4580.0										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110 0914	
Mean	0.9963	0.9981	1.0024	0.9975	0.9981	0.9980	0.9990	0.9993	0.9993	1.0009	
Stdev	0.0006	0.0020	0.0032	0.0012	0.0026	0.0040	0.0037	0.0005	0.0008	0 0020	
N	7	9	7	9	8	9	9	9	9	7	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	1.0013	1.0009	1.0003	1.0011	1.0014	1.0010	1.0020	1.0010	1.0011	0.9998	
Stdev	0.0003	0.0006	0.0007	0.0003	0.0005	0.0006	0.0005	0.0006	0.0007	undef	
N	2	9	9	9	9	9	8	5	9	1	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	1.0019	undef	0.9986	1.0011	1.0015	1.0008	1.0009	1.0005	1.0009	1.0009	
Stdev	undef	undef	0.0007	0.0005	0.0008	0.0005	0.0003	0.0008	0.0004	0.0003	
N	1	undef	4	9	9	9	9	9	9	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A18020
Mean	1.0007	1.0004	1.0009	1.0007	1.0010	1.0001	1.0005				1.00025
Stdev	0.0005	0.0003	0.0004	0.0004	0.0004	0.0005	0.0007				0.00186
N	9	9	9	9	9	9	7				282

A18587	4492.8										
Run	0310_0957	0310_1112	0310_1221	0310_1454	0410_0946	0410_1043	0410_1135	0710_0922	0710_0951	1110_0914	
Mean	0.9915	0.9930	0.9897	0.9868	0.9939	0.9923	0.9915	0.9962	0.9942	0.9961	
Stdev	0.0019	0.0032	0.0019	0.0007	0.0010	0.0010	0.0009	0.0011	0.0010	0.0007	
N	9	9	9	9	8	9	9	9	9	9	
Run	1110_0947	1110_1023	1110_1050	1110_1118	1110_1147	1110_1215	1110_1244	1110_1325	1110_1358	1210_1227	
Mean	0.9969	0.9949	0.9942	0.9932	0.9925	0.9925	0.9927	0.9919	0.9915	0.9939	
Stdev	0.0009	0.0008	0.0016	0.0005	0.0005	0.0008	0.0009	0.0008	0.0011	0.0023	
N	6	9	9	9	9	9	8	5	9	9	
Run	1310_1305	1310_1335	1310_1405	1410_1230	1710_0945	1710_1010	1710_1035	1710_1102	1710_1129	1710_1156	
Mean	0.9940	0.9954	0.9939	0.9928	0.9951	0.9953	0.9958	0.9951	0.9945	0.9952	
Stdev	0.0009	0.0019	0.0002	0.0004	0.0009	0.0008	0.0008	0.0007	0.0006	0.0009	
N	9	4	2	9	9	9	9	9	9	9	
Run	1710_1223	1710_1250	1710_1317	1710_1344	1710_1411	1710_1438	1710_1505				A18587
Mean	0.9939	0.9948	0.9952	0.9949	0.9951	0.9945	0.9947				0.99374
Stdev	0.0008	0.0007	0.0005	0.0006	0.0006	0.0006	0.0007				0.00223
N	9	9	9	9	9	9	9				312

Table A 8.1: Results of auxiliary measurements: 3.,4.,7. Oct.

I P C 8 5 AUXILIARY DATA FOR 3.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
9.57	1.854	32.53	0.135	0.321	0.544	506.6	162.1	12.6	62.	849.7	0.9
11.12	1.616	38.12	0.124	0.295	0.494	609.0	168.7	15.6	48.	849.3	0.7
12.21	1.589	38.90	0.109	0.265	0.454	626.2	154.1	17.9	39.	848.5	0.8
14.54	2.262	26.12	0.129	0.310	0.564	398.5	141.8	19.9	37.	847.4	0.6

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.262 STP-CM

I P C 8 5 AUXILIARY DATA FOR 4.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
9.46	1.932	31.06	0.076	0.190	0.379	497.3	98.3	13.6	55.	846.6	0.3
10.43	1.691	36.14	0.075	0.186	0.357	590.6	106.6	15.3	44.	846.3	0.9
11.35	1.603	38.50	0.080	0.191	0.357	639.3	125.6	17.8	41.	845.9	1.0

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.258 STP-CM

I P C 8 5 AUXILIARY DATA FOR 7.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
9.22	2.165	27.39	0.072	0.180	0.381	432.1	93.6	10.1	66.	849.2	0.4
9.51	1.956	30.64	0.072	0.177	0.363	494.4	99.3	11.4	54.	849.3	0.6

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.265 STP-CM

Table A 8.2: Results of auxiliary measurements: 11.,12.,13. Oct.

I P C 8 5 AUXILIARY DATA FOR 11.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
9.14	2.336	25.23	0.030	0.120	0.314	406.6	33.5	8.3	65.	854.3	0.2
9.47	2.058	28.96	0.036	0.123	0.301	467.1	38.0	9.4	52.	854.4	0.3
10.23	1.868	32.26	0.028	0.113	0.278	533.9	34.8	11.8	46.	854.4	0.4
10.50	1.778	34.12	0.028	0.111	0.270	570.4	37.5	13.7	36.	854.4	0.6
11.18	1.721	35.43	0.028	0.109	0.269	599.5	43.0	15.9	31.	854.4	0.4
11.47	1.695	36.05	0.028	0.108	0.267	611.4	44.1	17.2	27.	854.4	0.6
12.15	1.700	35.92	0.028	0.108	0.267	609.7	43.7	18.4	23.	854.2	0.6
12.44	1.737	35.04	0.032	0.112	0.276	594.6	44.4	18.3	23.	854.1	1.0
13.25	1.852	32.58	0.031	0.113	0.284	550.3	45.5	17.4	22.	854.0	0.8
13.58	2.013	29.67	0.029	0.115	0.298	502.3	43.9	17.8	22.	853.9	0.7

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.258 STP-CM

I P C 8 5 AUXILIARY DATA FOR 12.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
12.27	1.727	35.27	0.044	0.124	0.276	601.5	58.9	16.2	35.	853.2	1.7

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.262 STP-CM

I P C 8 5 AUXILIARY DATA FOR 13.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
13. 5	1.822	33.19	0.053	0.162	0.335	565.9	68.3	7.4	72.	853.1	1.7
13.35	1.934	31.03	0.056	0.173	0.360	526.1	69.6	8.0	73.	853.1	1.6
14. 5	2.106	28.23	0.055	0.172	0.371	478.0	69.0	7.9	71.	853.1	1.7

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.281 STP-CM

Table A 8.3: Results of auxiliary measurements: 14.,17. Oct.

I P C 8 5 AUXILIARY DATA FOR 14.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
12.30	1.764	34.42	0.038	0.126	0.276	583.3	57.4	10.0	38.	853.8	1.1

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.285 STP-CM

I P C 8 5 AUXILIARY DATA FOR 17.OCTOBER 1985

MEAN VALUES FOR EACH RUN

RUN START TIME	REL AIR MASS	SOLAR ELEVA DEG	AEROSOL OPTICAL DEPTH 778NM	500NM	368NM	RADIATION GLOBAL W/M2	SKY W/M2	AIR TEMP DEG	REL HUM %	BAROM MB	WIND SPEED M/S
9.45	2.204	26.87	0.030	0.120	0.297	439.4	33.9	5.2	57.	849.6	0.5
10.10	2.042	29.21	0.029	0.117	0.285	482.8	35.8	8.0	49.	849.5	0.3
10.35	1.929	31.11	0.030	0.117	0.279	519.0	39.4	9.6	44.	849.5	0.4
11. 2	1.848	32.64	0.030	0.116	0.271	545.2	41.3	11.6	38.	849.5	0.7
11.29	1.804	33.56	0.029	0.114	0.265	571.1	45.8	12.4	38.	849.4	1.6
11.56	1.790	33.86	0.029	0.113	0.262	578.7	47.0	11.5	38.	849.4	1.4
12.23	1.807	33.50	0.029	0.114	0.266	573.3	47.0	12.1	37.	849.2	1.7
12.50						DATA MISSING					
13.17	1.939	30.93	0.030	0.117	0.278	529.1	46.3	11.6	35.	848.9	2.0
13.44	2.068	28.79	0.030	0.119	0.291	490.2	45.4	11.9	36.	848.8	2.0
14.11	2.257	26.17	0.032	0.123	0.310	440.8	43.8	11.9	35.	848.7	2.1
14.38	2.533	23.12	0.033	0.129	0.331	383.9	41.9	11.7	35.	848.5	1.5
15. 5	2.944	19.71	0.036	0.137	0.359	316.5	39.6	10.9	37.	848.6	2.1

DAILY MEAN OZONE VALUE AS DETERMINED AT AROSA: 0.274 STP-CM

PART II :

IPC VI SYMPOSIUM

LOMMEL'S THEORY OF DIFFRACTION AND ABSOLUTE RADIOMETRY

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1. INTRODUCTION

A computer code for the exact computation of the correction of diffraction is described. It is based on the theory of Lommel (1885) and takes into account the generalization to the case with extended sources as developed by Steel, De and Bel (1972). The validity of this approach is discussed by comparing experimental data reported by Boivin (1976 and 1977) with computed results. Finally the results of computations of the correction for diffraction for some of the most commonly used absolute radiometers will be given.

2. METHOD OF COMPUTATION

The view limiting aperture of modern absolute radiometers is at a distance and of a diameter that the entrance aperture is in the fully illuminated region (Fig. 1). Diffraction occurs at the view limiting aperture which is therefore also called the "diffracting" aperture. The correction of diffraction at a wavelength can be expressed as the excess over 1 of the ratio of the actual flux through the entrance aperture to the flux according to geometrical optics and has been shown by Steel et al. (1972) to be:

$$\varepsilon(\lambda) \quad = \quad \frac{1}{2}\left(\frac{u}{w'}\right)^2 \int_0^{w+w'} I(v,w,w')\, J(u,v)\, v\, dv \quad - \quad 1 \qquad (1)$$

where $I(v,w,w')$ is the correlation function of two circles of angular radii w and w' and $J(u,v)$ is the distribution of intensity on the aperture R2. The angular coordinates used in (1) are related to the geometrical parameters of the setup and the wavelength of the incident radiation as defined in Fig. 1.

Expression (1) was derived under the assumption that the angular diameter of the source as seen from the diffracting aperture is smaller than the angular diameter of the detector. This is not a severe restriction however. The theory is a geometrical one and as such does not distinguish between source and receiver, hence if the above condition is not fulfilled, the role of source and detector may simply be interchanged. This property is also known as the rule of reciprocity.

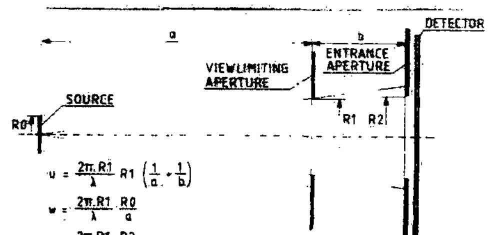

Fig. 1 The aperture geometry in radiometry and definition of terms

Lommel (1885) has shown that $J(u,v)$ can be expressed in terms of Lommel functions U_1, U_2 or V_0, V_1 where the U- resp. V-functions are defined as expansions in Bessel functions of integer order. For the case of solar radiometers $J(u,v)$ has to be evaluated in the illuminated region -

hence V-functions being an expansion in v/u are more appropriate than U-functions. Bessel functions of high accuracy also at high orders were available from the routine MMBSJ of the IMSL (1984).

An independent test of the accuracy of J(u,v) can be obtained from the fact that for u=v J(u,v) becomes (Lommel, 1885)

$$J(u,u) \quad = \quad \frac{1}{u^2}\left[(B_0(u) - \cos(u))^2 + \sin^2(u)\right] \qquad (2)$$

where $B_0(u)$ is the Bessel function of order zero. No difference within seven digits was found between the results according to (2) and the expansion at u=v=1276.

The program, written in Fortran77 uses simple trapezoidal integration with a step size of 0.5 to integrate over v. It takes typically 10 to 20 seconds on a IBM 360 mainframe to evaluate $\varepsilon(\lambda)$ according to (1).

For a source of complex radiation with spectrum $S(\lambda)$ the total correction for diffraction ε_T is:

$$\varepsilon_T \quad = \quad \int_0^\infty \varepsilon(\lambda)\, S(\lambda)\, d\lambda \;/\; \int_0^\infty S(\lambda)\, d\lambda \qquad (3)$$

Again, trapezoidal integration was used to evaluate (3). No simple rule can be given on the step size for λ, because it depends on the particular geometry of the setup.

3. DISCUSSION

Boivin (1976) gives examples of experimentally determined diffraction corrections. Using the parameters of his experimental setup computed results may thus be compared to exerimental findings(Fig. 2, left part). All the calculated corrections agree within 20 % with the experimental data, but almost all are outside the range of uncertainity of the experimental data as specified by Boivin. On a relative scale the deviations become more significant at bigger source diameters RO. This could indicate that Lommel's theory becomes inadequate when approaching the shadow line. On the other hand an underestimation of the amount of straylight leads to the same effect because scattered light becomes more important when the effect of diffraction becomes smaller. More comparisons between experimental data near to the shadow line and reported by Boivin (1977) and computational results were performed. Datapoints # 11 and # 12 shown in Fig. 2, right part, correspond to conditions where the diameter of the entrance aperture is bigger than the fully illuminated region. The experiment consists essentially in measuring the detector signal with the diffracting aperture removed and in place. For the last two points this will yield to low ratios. But the same is also true for the calculated results because when normalizing with the flux according to geometrical optics the presence of the diffracting aperture is ignored. This means that even for these two datapoints a comparison between experiment and theory is meaningful - although no practical instrument will ever use such a geometry. The validity of such a comparison will, however, critically depend on the accurate knowledge of the true geometrical parameters of the experiment. It does not come as a surprise, therefore, that we find good agreement for all except the last three points. It is noteworthy that the diffraction correction for the examples of Fig. 2, right part, is no longer - as is usually the case - proportional to the wavelength, but shows an oscillatory behaviour for wavelengths above 800 nm.

In summary we conclude that even in the immediate neighbourhood of the shadowline the agreement between experiment and the exact results according to Lommel's theory of diffraction is quite satisfactory. This gives us some confidence when applying in the following the theory to diffraction effects in solar radiometers.

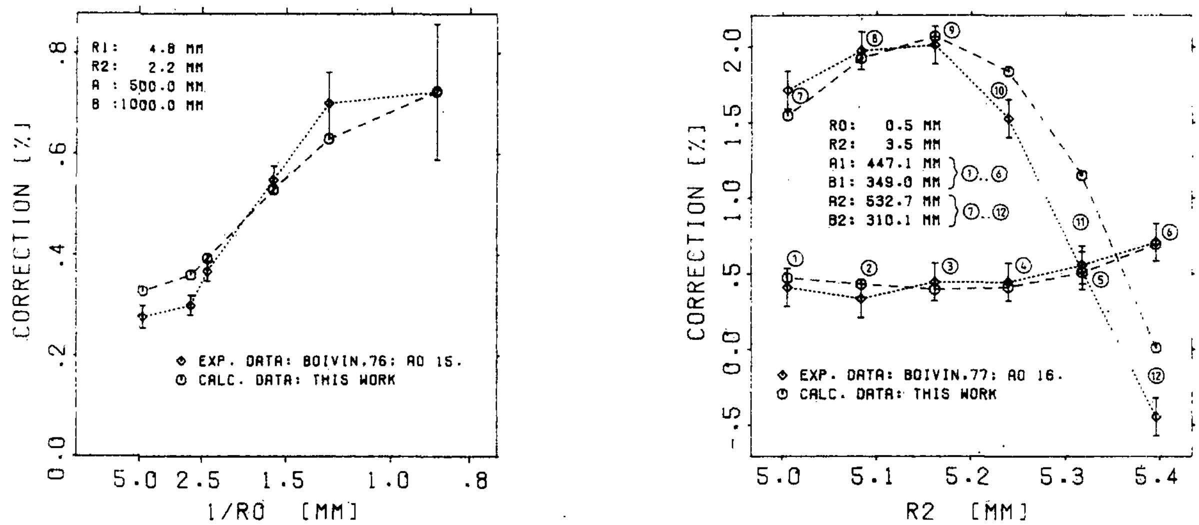

Fig. 2, left half, Comparison of computed results with experimental data of Boivin (1976). The source having an equivalent temperature of 3000 K consists of a diffuser plate illuminated by a tungsten lamp. A PIN10 silicon diode was used as detector. Error bars of experimental data as quoted by Boivin. In order to evaluate ε_T for the experiment configuration $S(\lambda)$ has to be thought of as being the product of the spectral radiance of a black body radiator at 3000 K and the relative sensitivity of the detector used in the experiment.

Fig. 2, right half, Comparison of computed results with experimental data reported by Boivin (1977). Source and detector are the same as before. The size of the entrance aperture is close to (datapoints # 1-10) or even bigger than the fully illuminated region.

4. DIFFRACTION IN SOLAR RADIOMETERS

In previous examples we have learnt that the dependence of $\varepsilon(\lambda)$ on λ may deviate from simple proportionality. It was verfied for all instruments mentioned in Table 1 that up to a wavelength of 5000 nm, corresponding to more than 99 % of the power in the solar spectrum no significant deviation from proportionality did occur. For solar radiometers it seems to be sufficient to calculate $\varepsilon(\lambda)$ at a single wavelength in order to determine the factor of proportionality. Results are given in Table 1.

5. CONCLUSIONS

A computer code for the exact evaluation of the effect of diffraction according to Lommel's theory was developed. It was demonstrated that it agrees well with experimental data. The program was then used to calculate the corrections of diffractions for some of the most widely used or known types of absolute radiometers. The outcome of the calculations demonstrates that diffraction is a significant correction for solar radiometers - typically in the order of 0.1 to 0.2 %. This rules out approximation methods, the reliability of which is largely unknown, and stresses the need for an accurate method to calculate the correction of diffraction.

Table 1 - Results of the computation of the corrections of diffraction for some commonly used absolute radiometers at several altitudes. The solar spectrum at the specified altitude was calculated from the extraterrestrial spectrum (Fröhlich and Wehrli, 1981) by Lowtran4 (Selby et al. 1978) assuming a solar elevation of 60 degrees. The references for the instruments are: PMO2 (Brusa and Fröhlich, 1975), PMO6 (Brusa, 1983), PAC II (Kendall and Berdahl, 1970), Crom2 (Crommelynck, 1975), Crom6 and Crom7 (Crommelynck, 1984), ACRIM (Willson, 1979). The ACRIM type instrument is on the Solar Maximum Mission spacecraft and together with Crom6 it was also flown on Spacelab 1.

parameter		PMO2	PMO6	PACIII	Crom2	Crom6	Crom7	ACRIM
R1: [mm]		3.6	4.175	8.18	6.25	11.25	6.514	6.647
R2: [mm]		2.5	2.5	5.640	4.0	4.0	4.0	3.989
b: [mm]		85.0	95.4	190.5	140.0	140.0	140.0	152.2
ε_T	0.0 km [ppm]	1719	1334	748	895	328	808	841
	0.5 km [ppm]	1705	1322	742	888	325	802	834
	1.5 km [ppm]	1693	1313	737	882	323	796	828
	3.0 km [ppm]	1698	1317	740	886	324	799	831
	30 km [ppm]	1778	1379	778	932	341	840	873
	40 km [ppm]	1773	1375	776	930	340	837	871
	oo km [ppm]	1763	1368	772	925	338	833	866

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THE IRMB/SSD ABSOLUTE RADIOMETRIC BASE

OBJECTIVES AND DEVELOPMENTS *

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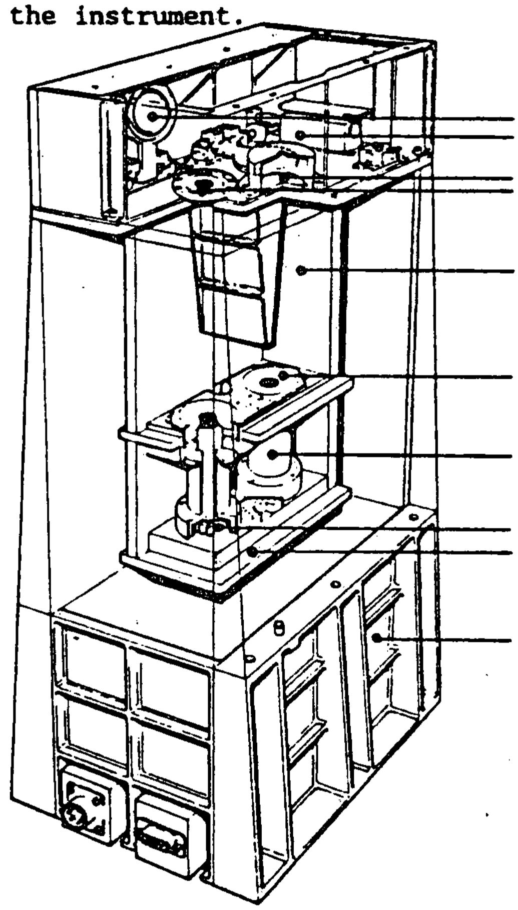
Description of the absolute radiometer.

The heart of the radiometer is a set of two cylindrical flat bottom cavities attached to two heat flux sensors mounted on a common heat sink. The innerside of the cavities are painted with diffuse velvet black (3M) and the outer side of the silver walls are polished and golded. On the bottom of the cylinder, underneath the absorption coating is fixed the electrical flat heater with its four wire leads. Each radiometric channel is provided with its calibrated aperture. The innerside of the view limiting volume is groved and painted black. The whole dual sensor is constructed to be as symetric as possible for all radiative conductive and convective effects. The radiometer can be operated actively on one or the other side with a linearised servosystem. Altough the measurements are generally made in the self calibration mode, it is also possible to operate it in the compensation (Ångström) mode as well as in a serie of "radiometric states" usefull for consistency and accuracy tests. The radiometric characterization coefficients are based on measurements performed in air and vaccum on the instrument.



* Reprinted from *Advances in Absolute Radiometry,* Proc. of an International Meeting, 24./25. June 1985, Massachusetts, ed. Peter V. Foukal.

<u>The Absolute Radiometric Base of IRMB/SSD</u>

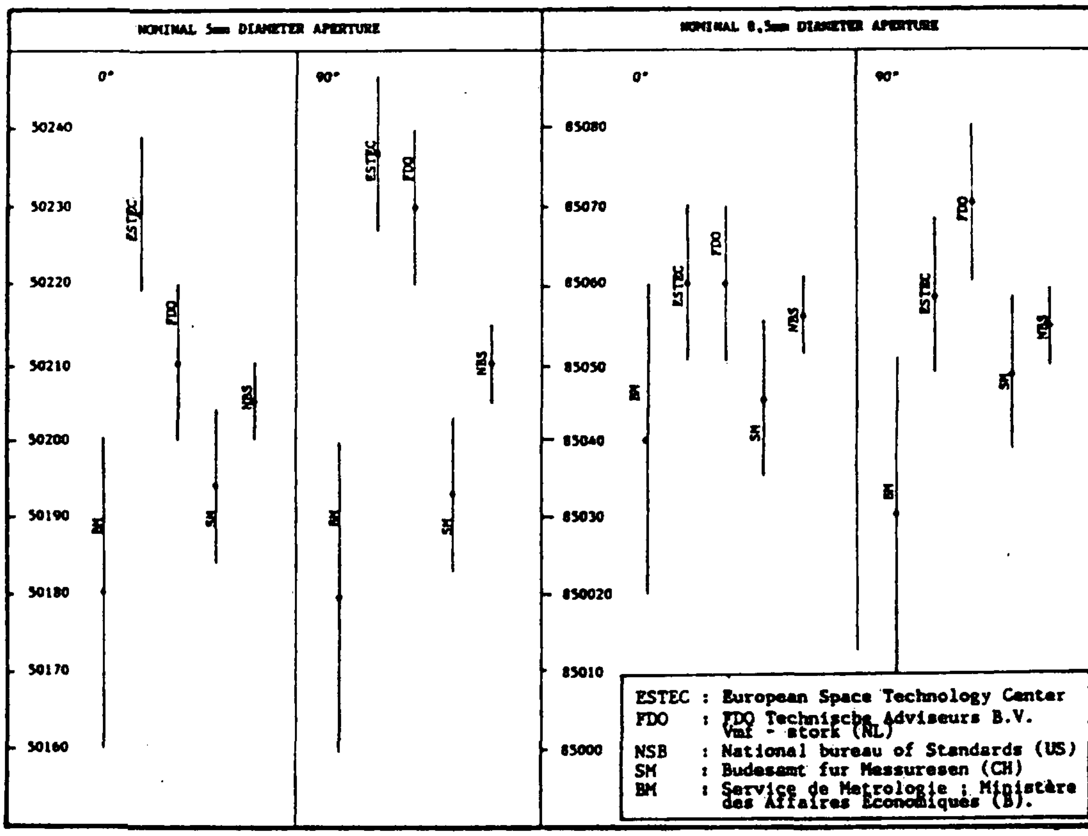
It is made of a set of five dual channel absolute radiometers which can be used on either channels. It has been the usual practise to work with four instruments mounted together on a Solar pointer and to refer the individual normalised measurements to their arithmetic mean.
The oldest instruments, with estimated characterization coefficients, are CROM2 and CROM3. The mean of the objectively characterised set of CROM9, EU and FL1 fixes actually the IRMB/SSD Absolute Radiometric Base.

New instruments will be added to update the base whenever available and conforming to our internal acceptance criteria. Let us note that by definition the measurements obtained with CROM2L multiplied by 1.00290 represents the World Radiation Reference. At Table Mountain Obsevatory in 1984 the IRMB/SSD Absolute Radiometer Base gave measurements 1.00329/ 1.00290 = 1.00039 higher than the WRR by CROM2L.

INSTRUMENT	RELATIVE NORMALISATION COEFFICIENT					ABSOLUTE NORMALISATION COEFFICIENT ☆
	TMO 82	ODEILLO 83	ODEILLO 84	CARPENTRAS 84	TMO 84	
CROM2L	1.00163	1.00362(158)	1.00281(64)	1.00333(631)	1.00291(647)	1.00329
CROM2R	1.00491	1.00537(27)	-	-	-	-
CROM3L	0.99762	0.99734(107)	-	0.99689(126)	-	-
CROM3R	-	1.00322(78)	-	-	-	-
CROM9L *	-	-	0.99984(73)	0.99896(247)	0.99912(373)	0.99943
CROM9R *	-	-	0.99860(64)	0.99889(258)	0.99928(274)	0.99952
EUL *	0.99940	0.99972(65)	-	0.99985(362)	-	-
EUR *	1.00000	0.99989(117)	1.00000	1.00015(269)	1.00016(121)	1.00047
FL1L *	0.99930	-	0.99932(32)	0.99987(286)	0.99984(145)	1.00015
FL1R *	0.99925	-	1.00027(70)	1.00022(345)	1.00012(176)	1.00043

<u>Improvement of the absolute accuracy of irradiance measurements</u>

The dispersion of our new generation instruments in air is such (0.001) that it is pertinent to wonder what needs to be done to improve it more and what can be said about the absolute accuracy. The critical factor entering in the radiometric formula seems to us to be the exact knowledge of the sensitive area. Indeed the table shows that a metrological incertitude of up to 0.002 exists on an area of 5mm nominal diameter which reduces to 0.001 when the diameter is 8.5mm. The two stainless steel reference holes used for this demonstration never exceeded a roundness departure of 0.5μm. If one considers the error announced by NBS (3σ) it should be possible to know the area of the holes with a relative accuracy respectively of 0.00040 and 0.00024. Systematic differences are observed between the different metrological laboratories and it seems appropriate to initiate an action to investigate the used measuring procedures. Nevertheless, new radiometric designs should operate with holes of a diameter equal or larger than 10mm. They should have the appropriate thickness so that their diameter can be measured to the state of the art without dammage



The determination of the electrical heating power equivalent to the unknow radiative energy should be better than 0.0001. However this requires skill, well designed circuitry with appropriate groundings and high quality instrumentation. Of course the electrical measurements (made simultaneously on the current and the voltage) should be performed when the instrument has reached its servo equilibrium within the required accuracy. This means that for a given OPEN/CLOSE chronology with the associated measurement sampling pattern, the rise time of the active radiometer is a most important characteristic. We recommend that it be as fast as possible. In addition, to support high accuracy claims, the radiometric formula should include explicitly the effect of the servosystem as used with or without linearization circuit.

About the characteristics of the radiation sensor, itself metrology can only be rewarded with the clear definition of concepts and perturbating effects to be corrected for. The experimental characterization procedures performed in air and vacuum are, of course, based on these definitions. The design of our new instruments actually under construction, is based on the preceding considerations ; our objective is to obtain a relative accuracy on a single irradiance determination of 0.0003 which seems near to the ultimate feasible.

Radiometric comparisons

It is a fact that radiometric comparisons are a main tool to demonstrate that instruments of a same design present a dispersion within their accuracy claim. In addition, comparisons of independently designed absolute radiometers with their incertitude margins, can alone, for the benefit of metrology, trigger doubts and discussions between the different applied concepts. The comparisons on the Sun being performed from the Earth surface, the atmosphere is the cause of the spatial distribution of the aureole as well as its time variability. The interpretation of the observed differences at the level of concern depends thus on the geometry of the radiometers (slope and limit angles), as well as on their time response and on the organization of the measurements. The normalization of some radiometric characteristics is therefore required.

PYRANOMETER RESPONSE TO GLOBAL RADIATION

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INTRODUCTION

A variety of instrument types is used to measure solar radiation around the world. In the U.S.A., for example, the NOAA radiation network uses Eppley PSP and Spectrolab pyranometers; other networks operated by states, universities or electric power companies use these and other instruments such as the Eppley model 8-48, Kipp CM-6 and CM-10, Schenk star and LiCor silicon cell. Networks frequently contain a mix of two or three different instrument types. Usually the measurements from the networks are accepted as accurate without any corrections being applied or without regard to the characteristics of the instruments used. The purpose of this paper is to describe the nature and magnitude of errors that can be directly attributed to specific instrument types.

COMPARISON METHODS

In order to assess the response of pyranometers it is necessary to have an accurate measure of the global radiation that is essentially free of the usual pyranometer characteristics. The most accurate measurement of global radiation particularly under cloudless skies is by means of the component method which combines the direct component as measured by a cavity radiometer with the diffuse component measured with a disk-shaded pyranometer. The pyranometer must have good linearity and be free of spectral response errors. The absolute accuracy of such a measurement of global radiation is:

$$\text{Cavity}, \pm 0.5\% + \text{pyranometer}, \pm 2.0\% = \pm 2.5\%$$

Under the special cloudless sky conditions, the ratio of diffuse/direct radiation is about 0.10 so that:

$$\text{Cavity}, \pm 0.5\% + \text{pyranometer (diffuse)}, \pm 0.2\% = \pm 0.7\%$$

Finally, if the cavity radiometer and the pyranometer are linear and if the cavity error may be assumed to be mostly a bias error, then the relative accuracy over a wide range of sun angles in the course of one day is:

$$\text{Global radiation relative accuracy} = \pm 0.3\%$$

In the procedures followed at the Solar Radiation Facility (SRF) in Boulder, the cavity radiometer is read every 30 seconds and the pyranometer alternately shaded and unshaded with a disk on a schedule of 5 minutes shade, 6 minutes unshade. This provides a direct sun-shade calibration of the pyranometer and a measurement about each 12 minutes of the global radiation. This discrete measurement of the global radiation is then used with the simultaneous voltage output of each of the test pyranometers to calculate the sensitivity ($mv/10^3 w\text{-}m^{-2}$) of the test pyranometer. In the analyses, all pyranometers are corrected for temperature (to 25C) from individual temperature response curves.

RESULTS

Four different instrument types are presented in this report: Eppley PSP, Eppley 8-48 (black and white), Kipp and Zonen CM-6, and Schenk star (black and white). Data are available on about 8-10 other pyranometer types but the analyses are incomplete. Calibration curves for the 4 instruments from component method calibrations are shown in figures 1-4; each instrument is represented by three figures (a-c) so as to retain the individual features on each day. The curves for the different days for the same instrument do coincide and present a single sensitivity or calibration curve for that instrument. Curves for different instruments of the same type show similar features so that they can be considered generic. For example, the PSP data (figures 1a-1c) show anomalous peaks at about 22-23° sun elevation both in the AM and PM. This is characteristic of the PSP and appears in all instruments of this type which we have tested (more than 50) although the peak can lie between about 20 and 30° for different instruments. Also, all PSPs exhibit the low sensitivity at low sun elevation angles and high sensitivity at high angles although the range of the two extremes can vary by as much 5-10%. All Schenk stars and Eppley 8-48s we have tested give curves similar to those presented here. The Kipp CM-6 instruments frequently show the asymmetry between morning and afternoon that is evident in the curve for the one shown here. It would be natural to assume that this results from a lack of coincidence between the spirit level and the sensing level but the frequency with which this particular asymmetry occurs suggests that the cause may be in the orientation of the thermopile element.

On May 30 a solar eclipse occurred between sun elevation angles of 37° and 59°. The eclipse was about 50% of total and the effect on the different instruments is apparent for the Kipp CM-6 and Schenk star, less evident for the Eppley 8-48 and not evident at all on the PSP. The increase in sensitivity is about 2.5% for the CM-6 and 3.5% for the Schenk, and the most likely cause is non-linearity.

Two conclusions may be drawn from these data:

1. Different instrument types have distinct, generic response curves to cloudless sky global radiation,
2. The cosine response is the predominant instrument characteristic controlling response to cloudless sky global radiation.

For analysis purposes, the average AM and PM sensitivity at 45° sun elevation was selected as the normalization angle. Figure 5 presents smoothed representations of the calibration curves with the ordinate being the response to the average 45° sun elevation value. These curves include 5 or 6 additional days of data not shown in figures 1-4. Figure 5 illustrates that close agreement between instruments occurs only near the normalization point of 45°. At other angles which represent different times of the day or different seasons of the year large differences occur. For example, at sun angles of 60-70° (noon in summer) the PSP is 1 to 1.5% high and the Schenk and 8-48 are about 2% low; at sun angles of 20-25° (noon in winter) the PSP is 1 to 2% low and the Schenk and 8-48 are 2.5 to 4% high. The CM-6 exhibits AM to PM asymmetry but is within 1-2% for most sun elevation angles.

Figure 6 replots the data for the CM-6, 8-48 and Schenk as response to the Eppley PSP, an instrument frequently used as a comparison standard. In fact, the Eppley PSP in this report has been used since 1982 as the working standard pyranometer for side by side calibrations at the SRF in Boulder. Because the PSP has an absolute response curve (figure 5) which is opposite to those of the other types, the other types will show exaggerated response when compared with the PSP. This is evident in figure 6 where at high sun angles the Schenk and 8-48 are 3-3.5% lower than the PSP and at low angles are 3-5% higher.

The curves presented so far represent sensitivity or response to cloudless sky global radaition. Depending, of course, on the climate of the observing location the most frequent sky condition is partly cloudy not cloudless. Under partly cloudy skies one might expect the pyranometer to respond to the frequently large diffuse component of the radiation with a sensitivity roughly the same as the 45° sun elevation sensitivity. Thus the cloudless sky response curve is probably the extreme case. To examine the response to all sky conditions we have chosen to compare continuous exposure measurements from June and December with the cloudless responses.

Figures 7 and 8 show such data for the Schenk star instrument. The all sky condition data are hourly totals of global radiation for the month for the Schenk divided by those for the PSP 19918; the cloudless sky values are the angular responses at mid month (June 15 and December 15). The solar noon elevation angles on those dates are 73.4° at 1202MST on June 15 and 26.7° at 1157MST on December 15, 1984.

The shapes of the cloudless and all skies curves are similar in each month but the details are not. Excepting for the sunrise and sunset hours in June the cloudless curve appears to confirm it as the extreme case. In December this is true only for the hours around noon. Apparently other instrument characteristics are at work and they may account for the differences. All data have been corrected for temperature so that this characteristic probably is not a factor. Regardless, the curves illustrate the large effect that generic instrument characteristics (biases) have on the resulting measurements. In these illustrations the cosine errors explain much although not all of the measurement differences b etween instrument types even for the general all sky conditions case. It is questionable whether these characteristics can be corrected for in routine measurement programs but they must certainly be considered when measurements from different networks or within networks using different instrument types are compared or when accuracy limits are assigned to instruments or network measurements.

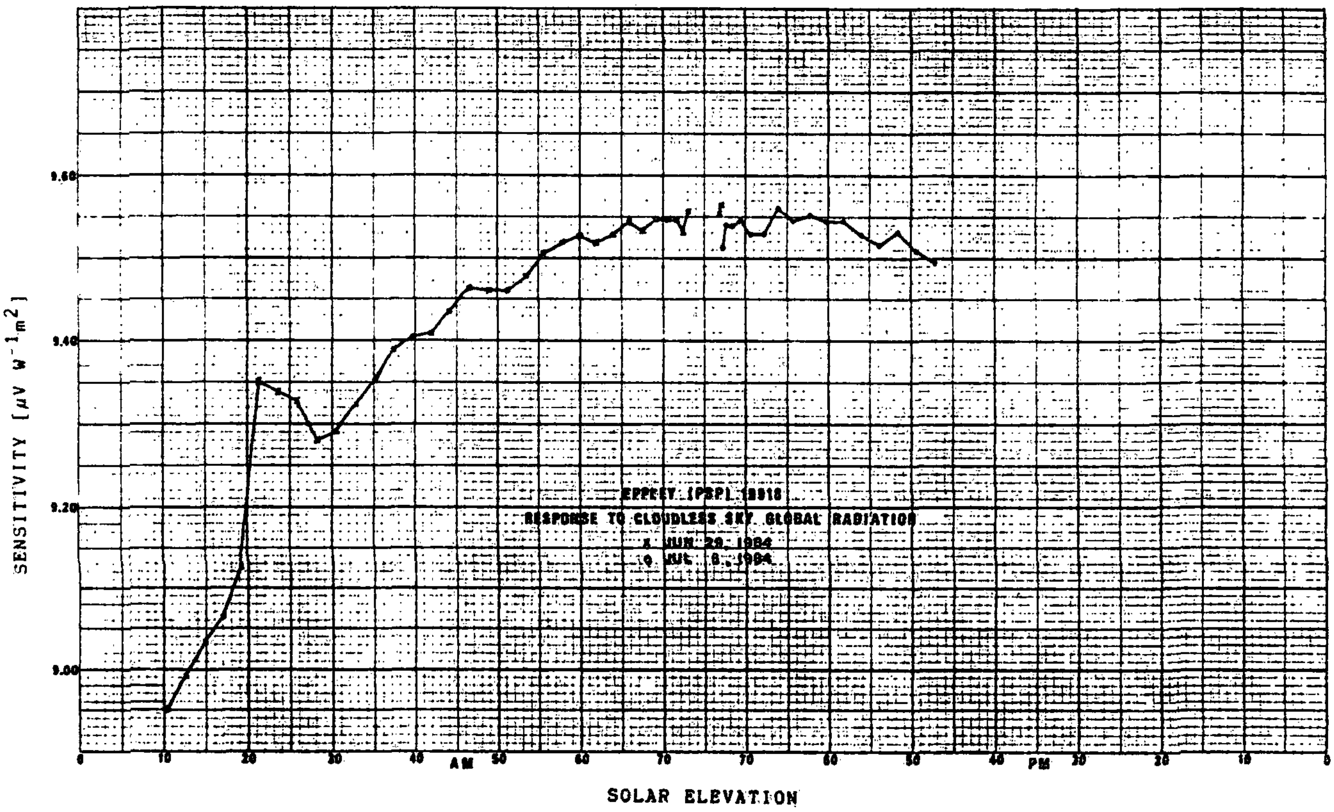

FIGURE 1a

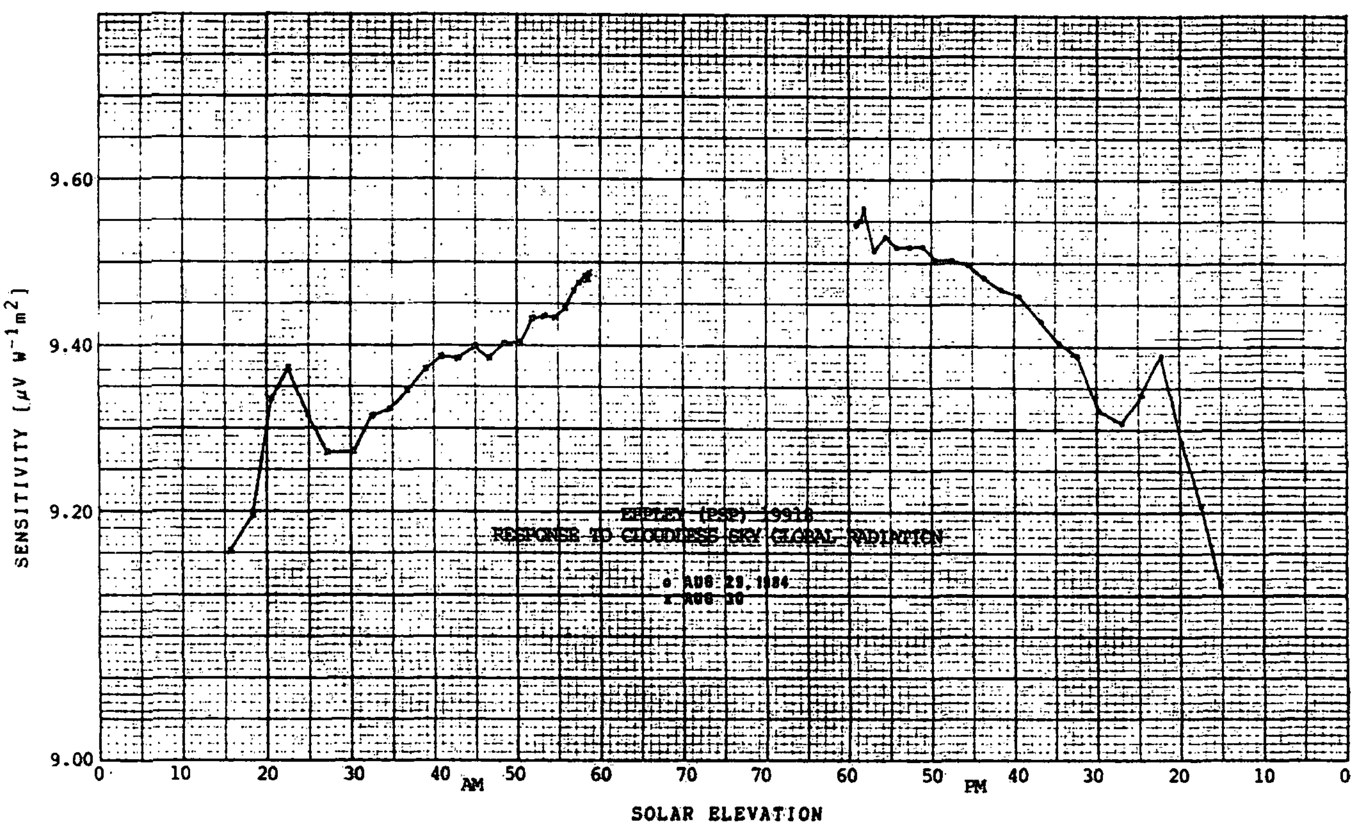

FIGURE 1b

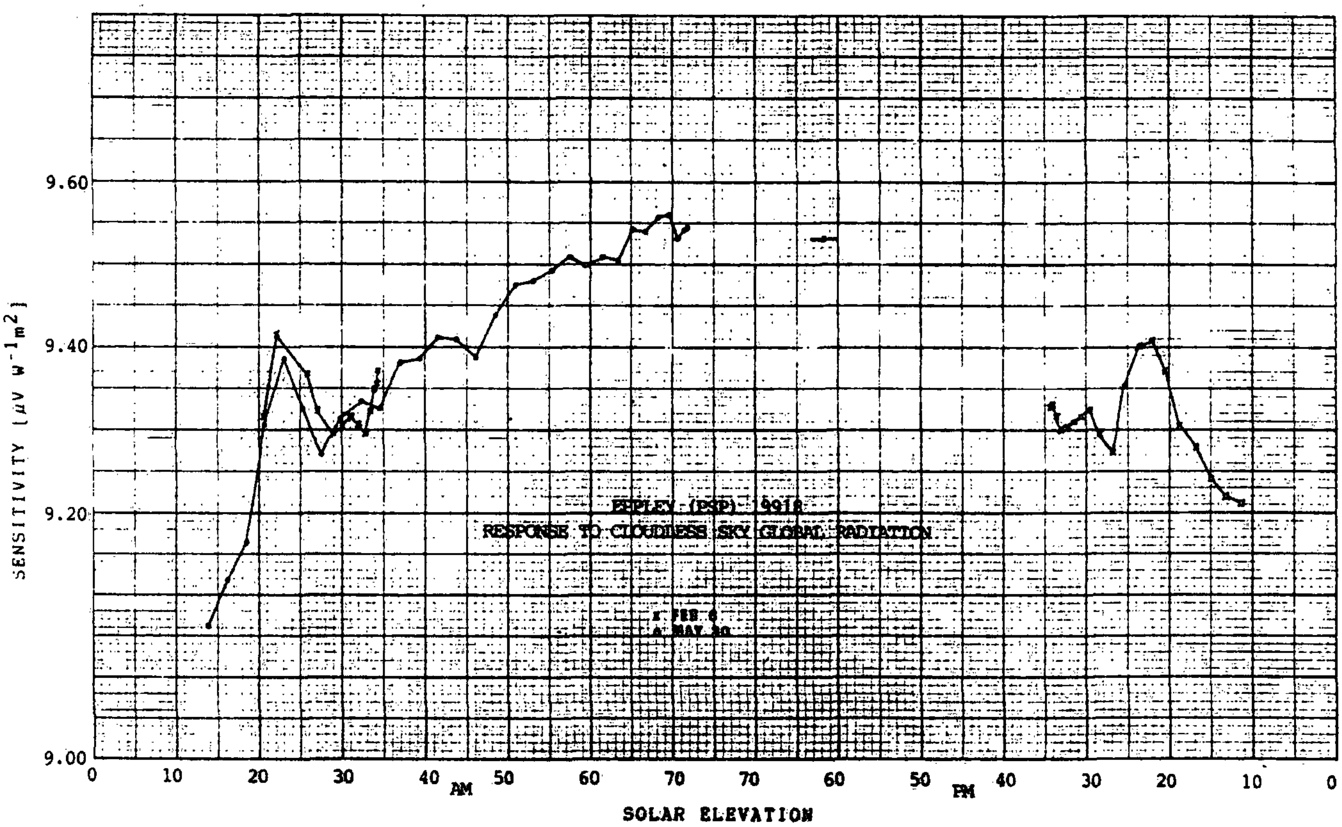

FIGURE 1c

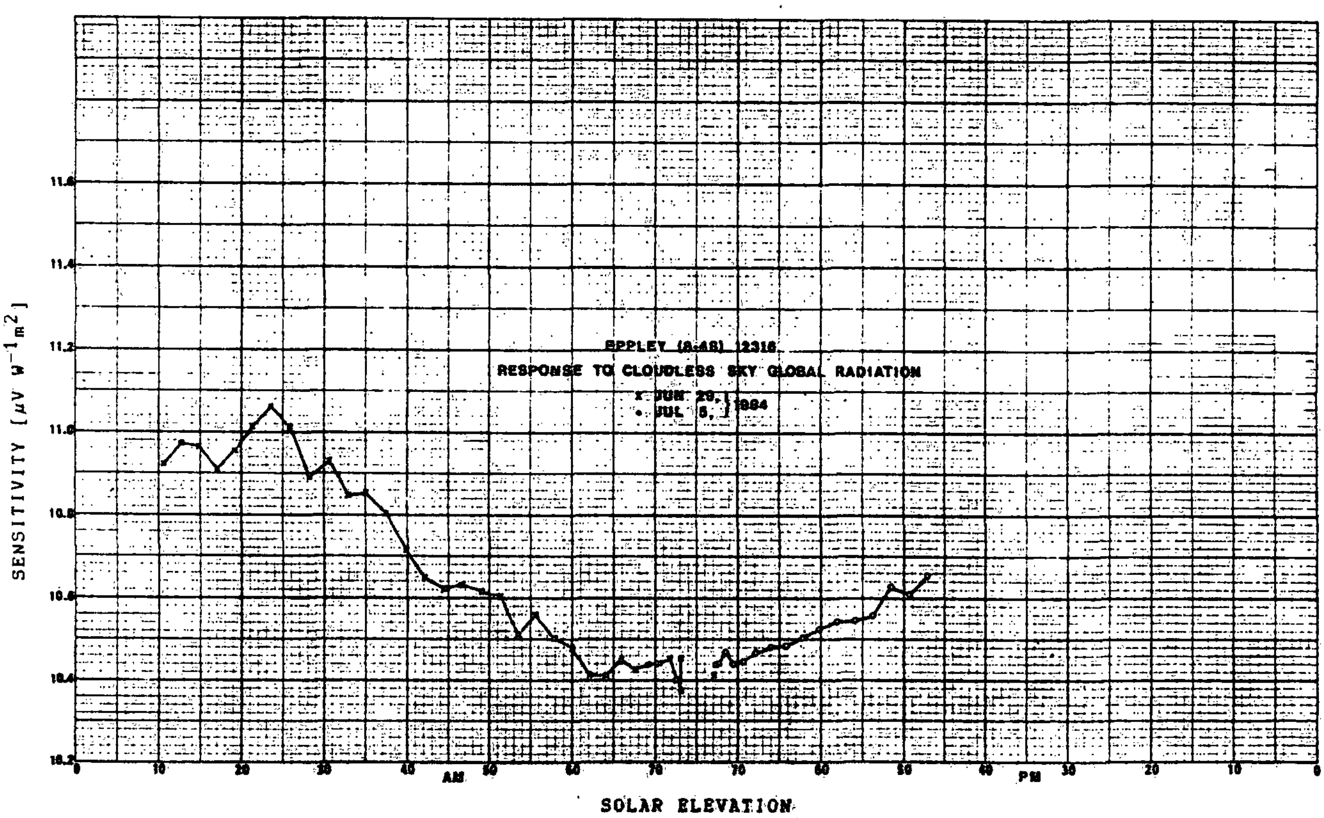

FIGURE 2a

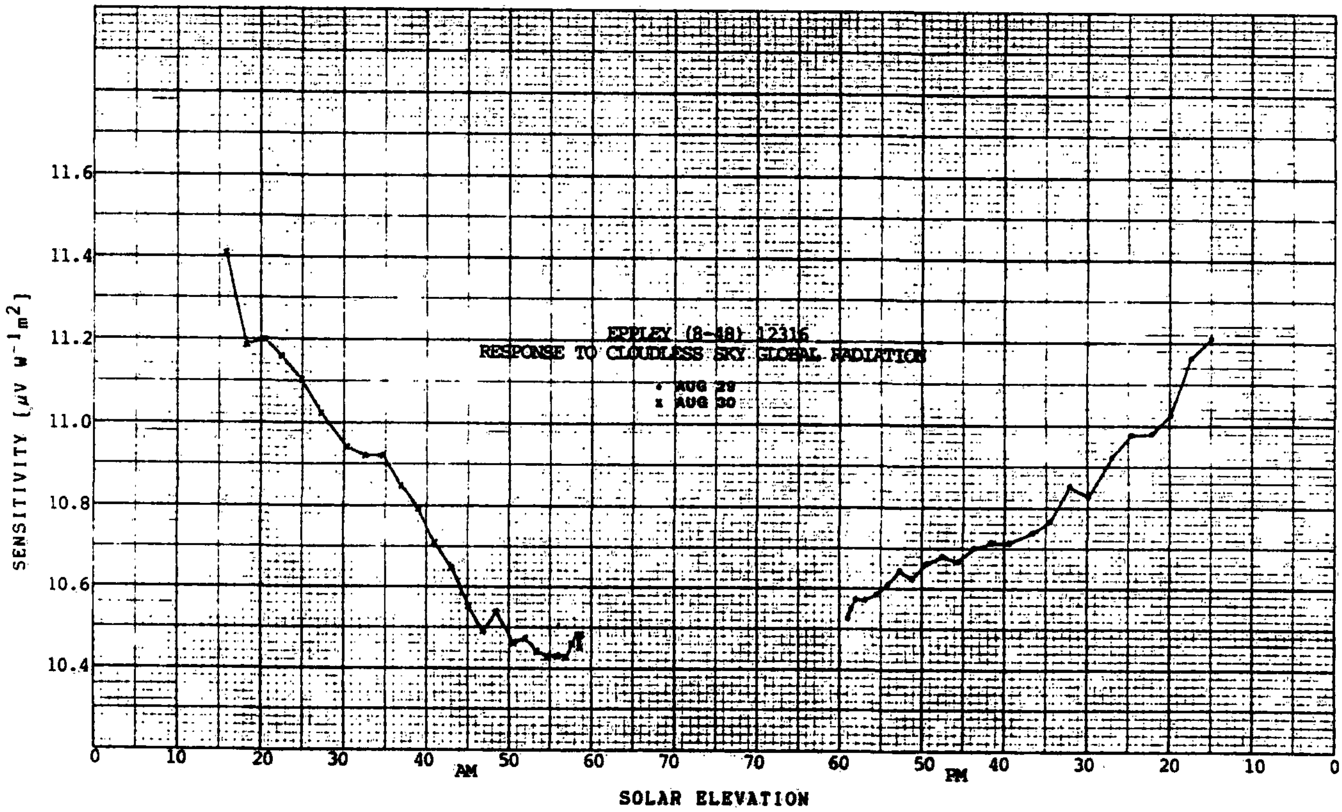

FIGURE 2b

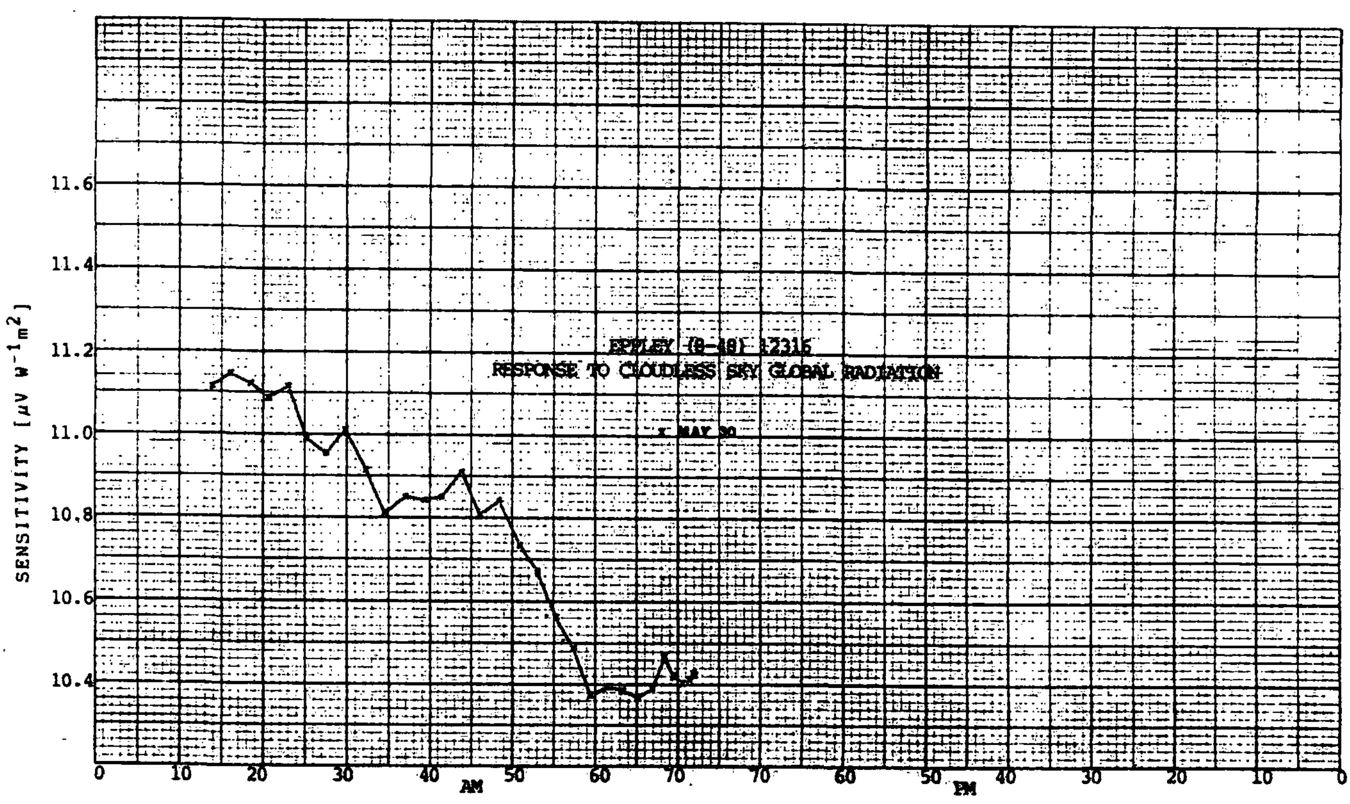

FIGURE 2c

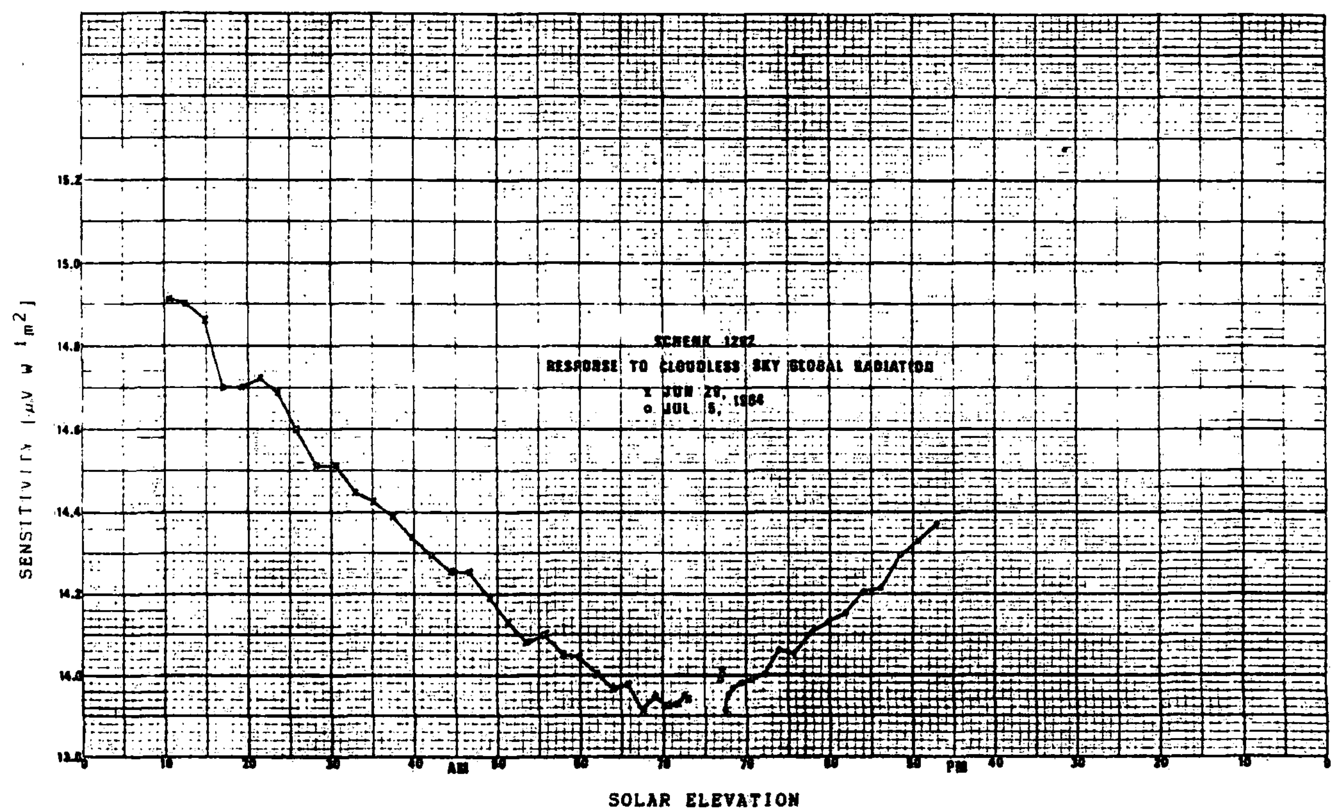

FIGURE 3a

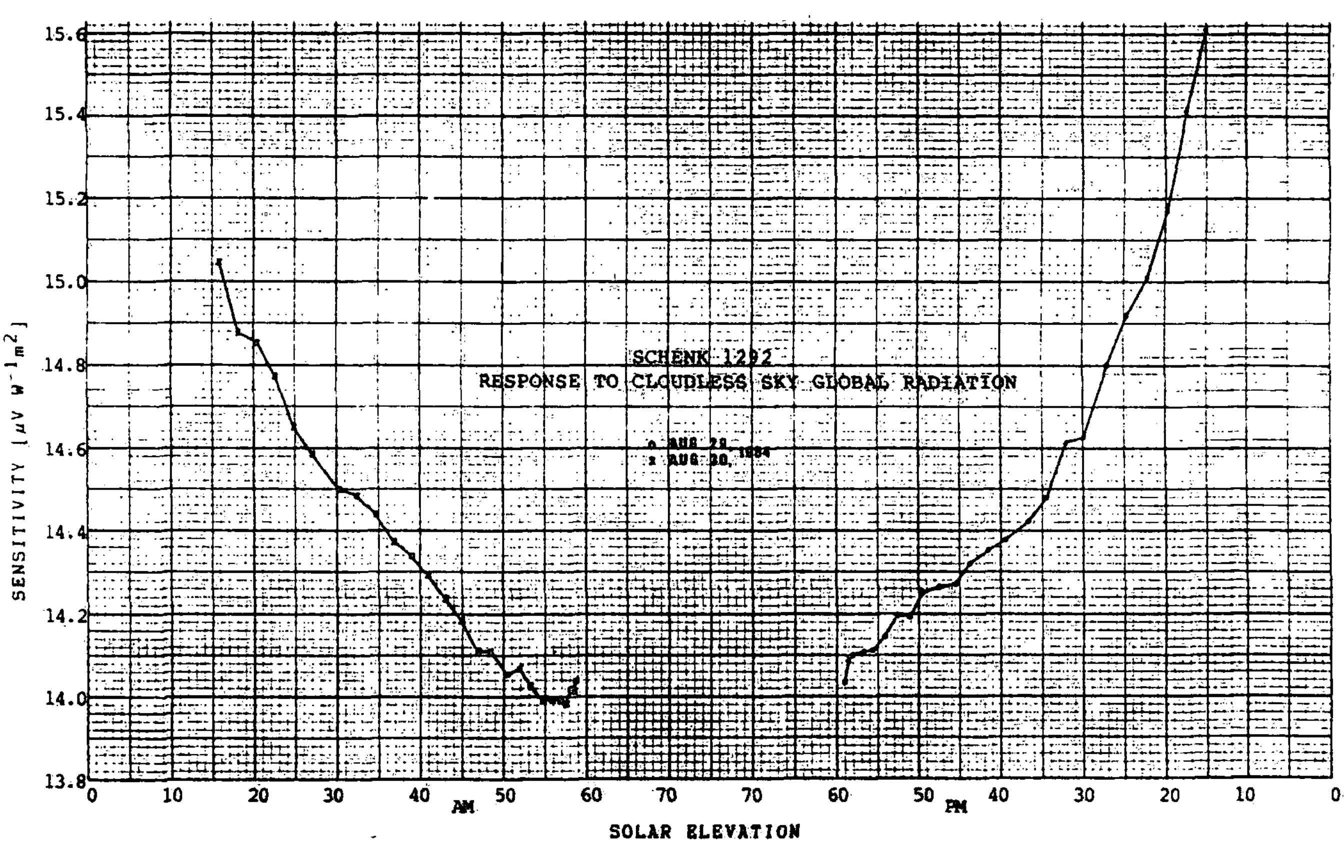

FIGURE 3b

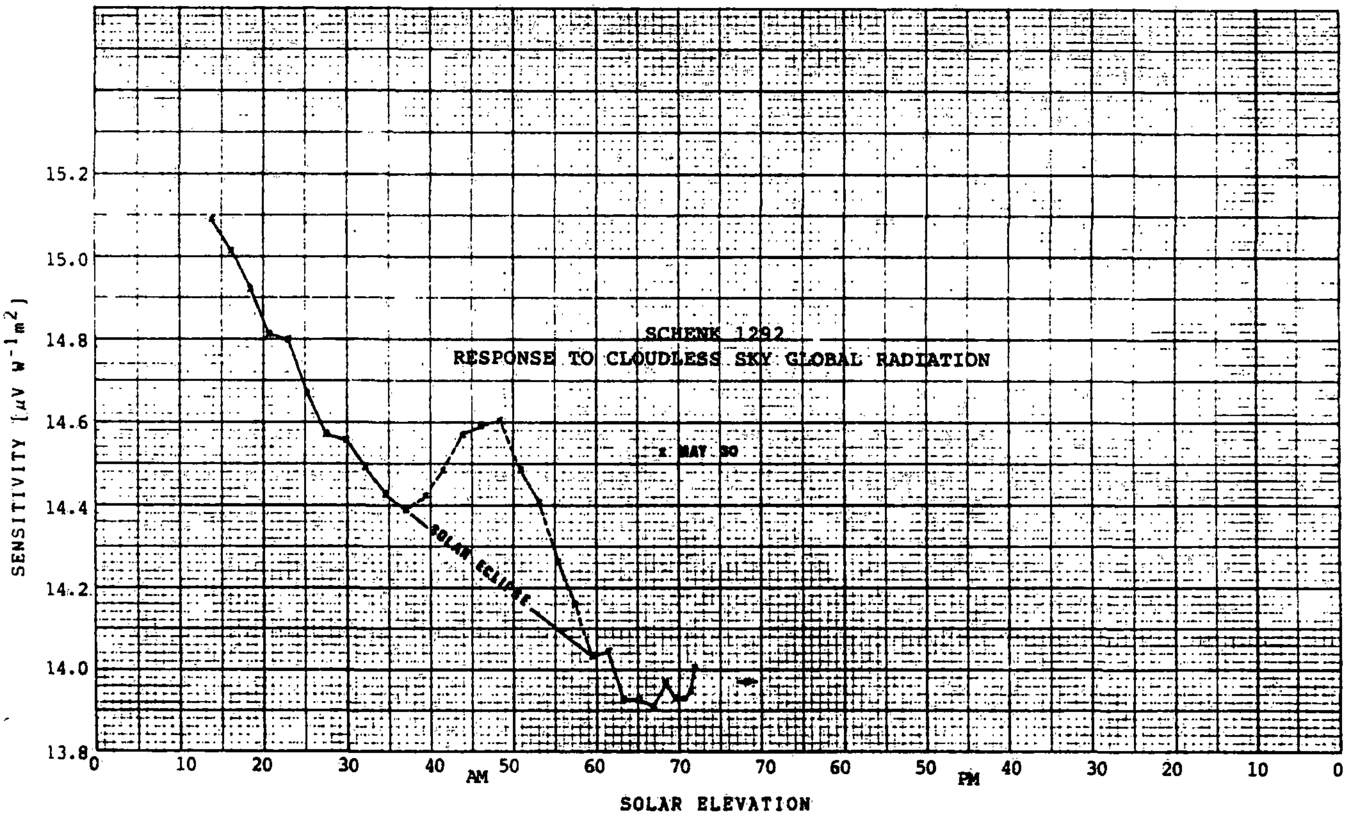

FIGURE 3c

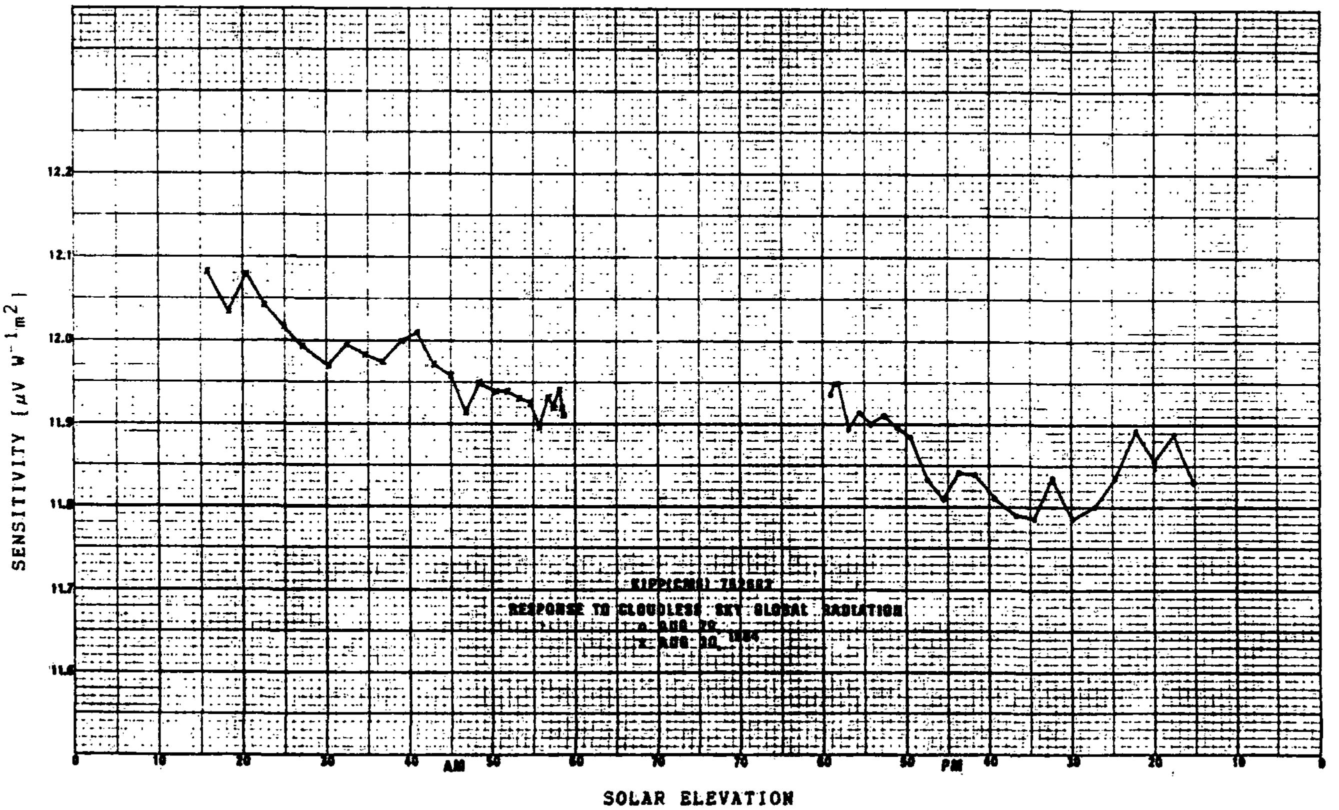

FIGURE 4a

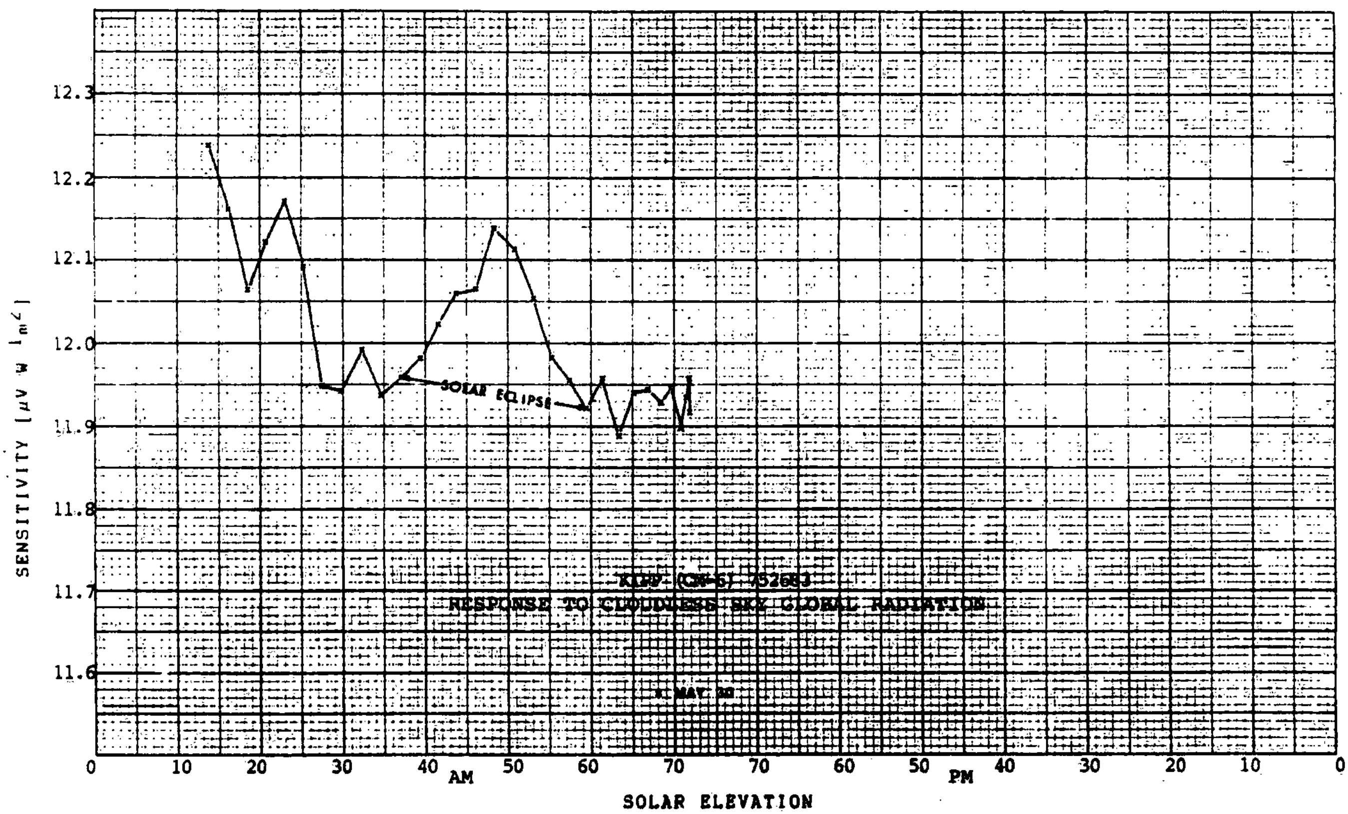

FIGURE 4b

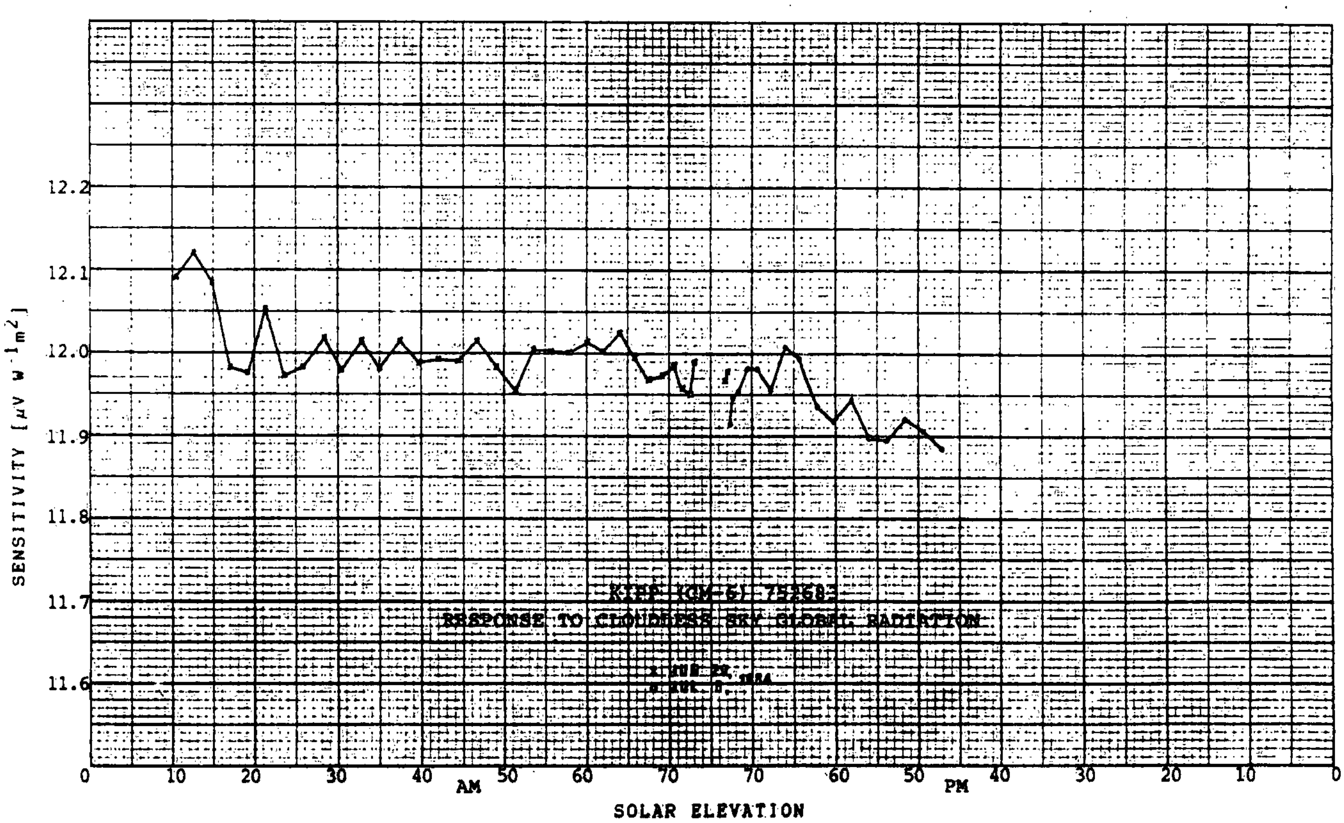

FIGURE 4c

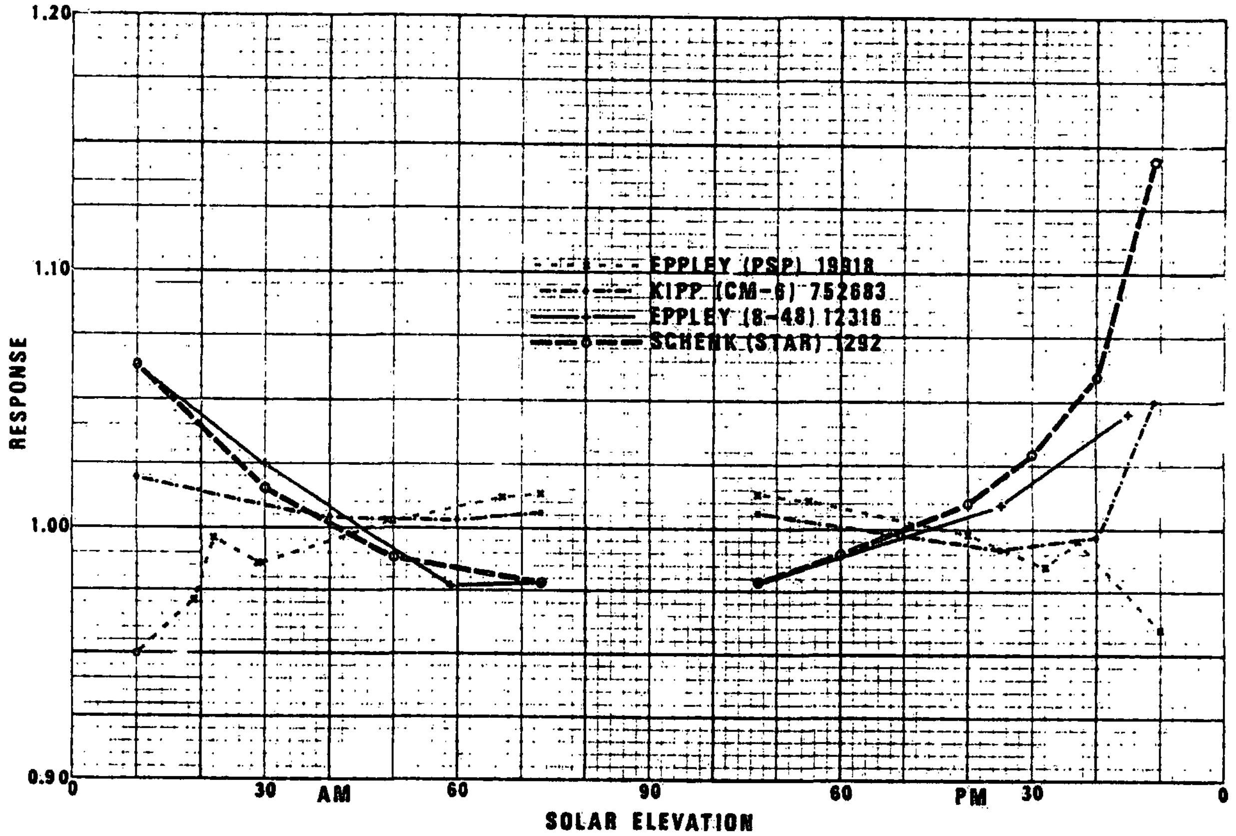

FIGURE 5

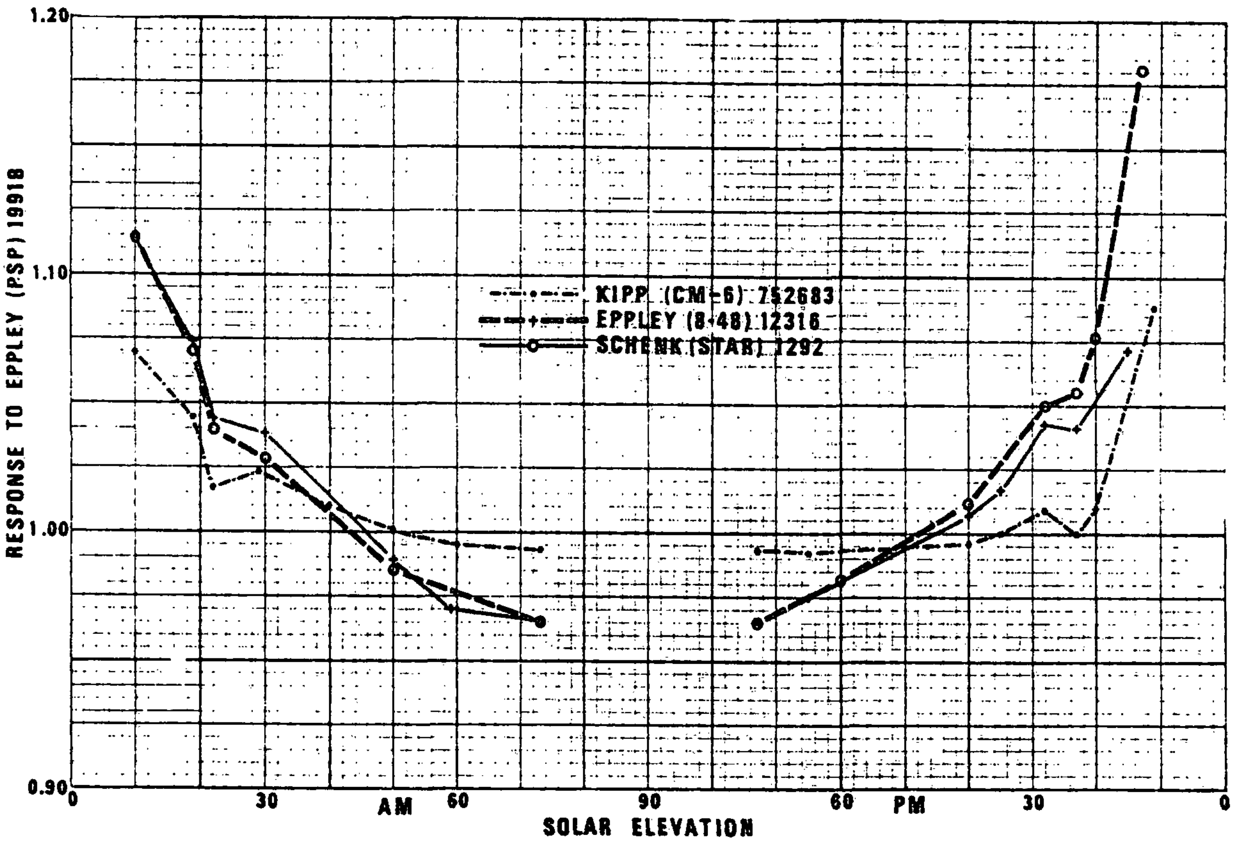

FIGURE 6

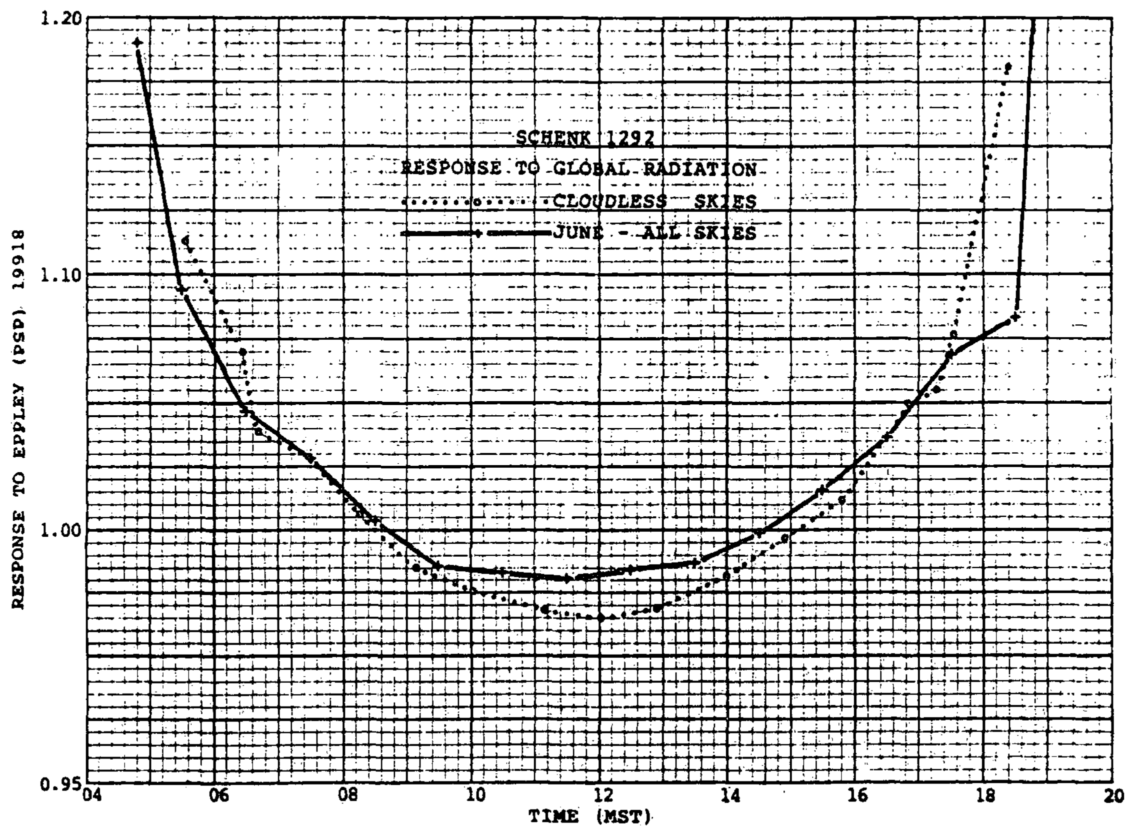

FIGURE 7

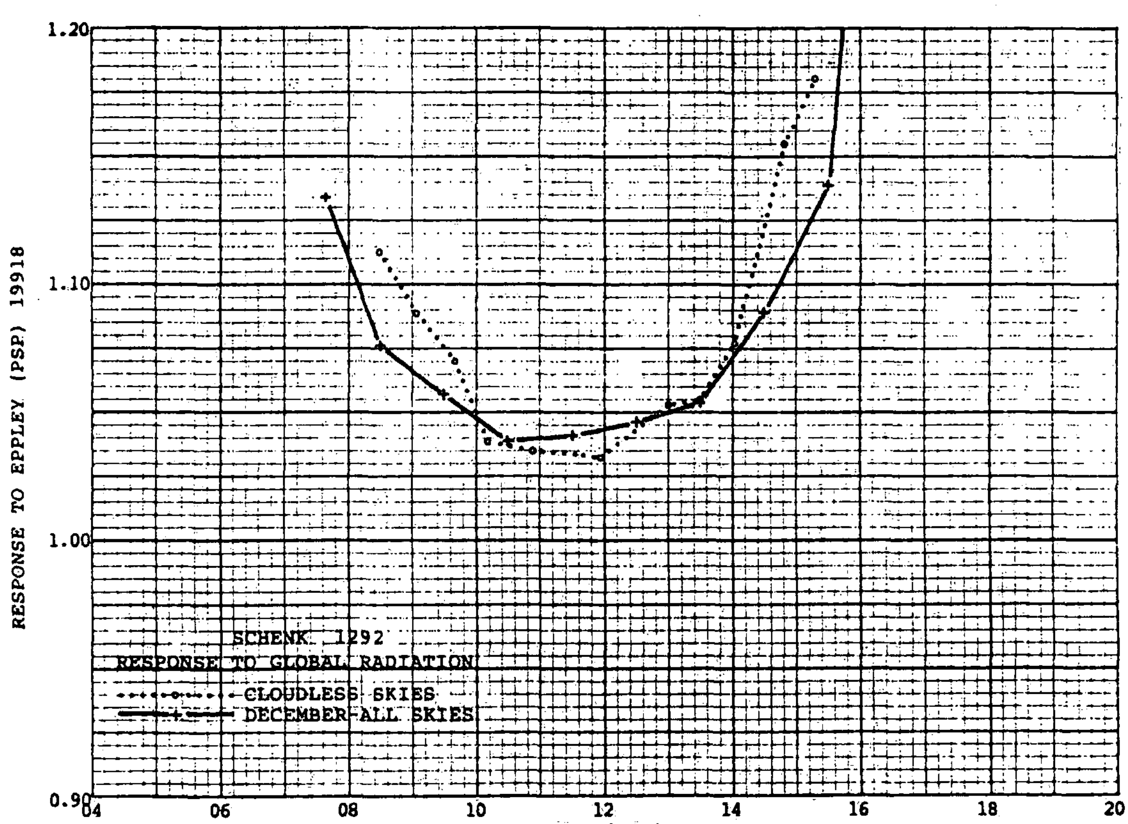

FIGURE 8

RADIOMETRY AT PMOD AND THE WORLD RADIOMETRIC REFERENCE *

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INTRODUCTION

The design and construction of absolute radiometers at PMOD started in the early seventies. Due to their primary use - the measurement for solar irradiance - these radiometers are optimized to measure irradiances around one kWm^{-2}. The first model was the so-called PMO-2, which is since 1975 one of the World Standard Group realizing the World Radiometric Reference (WRR). The WRR is the base for all solar measurements within the meteorological community. It was established in 1977 as a result of comparisons of many different types of absolute radiometers for solar measurements. Since then a more refined version of the PMO radiometers (PMO-6 type) has been developed. Such instruments are used for the solar constant experiments of PMOD and for the subsistence of the World Standard Group.

In order to assess the uncertainties of this kind of absolute radiometry more accurately an important effort was put into the development of independent laboratory experiments. These are called characterization and consist in the accurate determination of all deviations of the radiometer from its ideal behaviour.

PMO-6 RADIOMETER

The design is based on the principle of an electrically calibrated differential heat flux transducer with a cavity for the efficient absorption of the radiation to be measured. The cavity has an inverted cone inside a cylindrical shield, is painted with a specular black paint and is tied to the heat sink via a stainless steel thermal impedance. The detector system is shown in Figure 1. For the measurement of the solar radiation a view-limiting baffle is mounted in front of the detector in order to provide a full field-of-view of 5 degrees. Only the primary cavity is used for radiation measurements. The temperature difference across the thermal impedance, sensing the heat flux, is measured with resistance thermometers mounted on the two cavities and not between the primary cavity and the heat sink. This differential arrangement compensates for sudden changes of the temperature of the heatsink, rapid pressure changes etc., as long as the thermal time constants of the two cavity - thermal-impedance systems are equal.

The instrument is operated in the so-called "active" mode. That is the temperature difference between the two cavities is always kept constant by an automatic control loop for the current of the heater of the primary

* Reprinted from *Advances in Absolute Radiometry*, Proc. of an International Meeting, 24./25. June 1985, Massachusetts, ed. Peter V. Foukal.

cavity. Thus the difference in electrical power during the reference phase (electrical heating only) and during the irradiated phase (electrical and radiative heating) is proportional to the incoming radiation:

$$S = k\cdot(P_{closed} - P_{open}) \quad \text{with} \quad k = E_R \cdot E_{NE} \cdot E_{ST} \cdot E_D \cdot E_{LH} / A_P .$$

E_R accounts for the radiation losses of the cavity, E_{NE} for the non-equivalence of the radiative and electrical heating, E_{ST} for scattered light, E_D for diffraction losses and E_{LE} for the lead heating effect. A_P is the area of the precision aperture. It is obvious that the uncertainty of these factors determines the achievable accuracy of the radiometer.

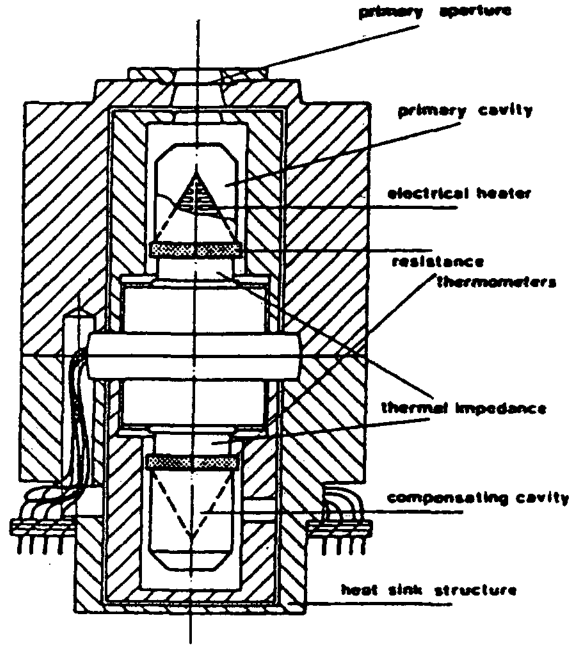

Figure 1: Schematic drawing of the PMO-6 detector assembly.

CHARACTERIZATION OF THE PMO-6 RADIOMETERS

One of the most important factors in the error budget of the radiometers is the aperture area A_P. It's determination relies on the measurement of length, which is possible with a very high accuracy. However, problems can arise, if the apertures are not perfectly circular or if they are not rigid enough. In the original design of the PMO-6 radiometers, the apertures were made from 20 μm thick copper foils. The chemically blackened diaphragms were clamped between the heatsink structure and a polished clamp ring with a slightly larger hole in order to keep the illuminated area and thus the amount of heating of the black copper aperture as small as possible. The main reason for chosing this kind of aperture was that they are easy to manufacture and the cylindrical part of the hole is short and black. However, comparisons with PMO-2 of instruments used in the solar constant work showed inconsistencies which could not be expained by the uncertainties of the characterization methods. During the characterization the apertures have to be removed from the heat sink and it turned out that the clamp ring deformed the aperture during mounting of the copper aperture. This problem was overcome by measuring the aperture after mounting it to the heat sink with a travelling microscope. But still some inconsistencies remained. Only recently the reason was found: due to the conical shape of the heat-sink structure (see Fig.1) the whole aperture case was squeezed by screwing the baffle to the heat sink and hence the aperture's diameter was reduced by as much as 10 μm. The effect could be verifyed experimentally by changing the torque applied to the screws and by monitoring the amount of radiation falling through the aperture. Indeed, the area could be changed by up to 1 per cent. This aperture construction had to be abondonned and today, precision steel apertures with a cylindical part of 20 μm length and a rounduness of better than $\pm$0.2 μm are used. The determination of the diameter is now possible with a mechanical measuring device to an absolute accuracy of better than $\pm$0.5 μm or for the area of $\pm$0.02 per cent. After replacement of the apertures on all characterized radiometers the internal consistency was reached (see also Table 1).

The <u>radiation losses</u> are due to the finite reflectivity and the infrared emission of the heated black coating of the cavity. They are measured with a conical reflectometer similar to the one designed by Blevin and Geist (1974) and a chopped laser beam as source. The pyroelectric sensor of the reflectometer is blackened with gold black and is thus sensitive to both the reflected laser radiation in the visible and to the thermal radiation emitted from the heated black coating of the cavity. In order to simulate the operation during solar measurements, which means to have the full signal from the heating of the black coating, the chopping frequency is kept low (~5 Hz) for the determination of the radiation losses. By increasing the frequency the IR-signal decreases in amplitude at a rate which is determined by the thermal capacity of the coating. From this rate the thickness of the black coating and the quality of the glueing of the heater element to the cavity can be checked. This supplementary measurement is therefore an easy way to quality-control the cavity manufacturing. For a freshly painted cavity a value for the reflectivity of the order of .008 to .01 per cent is found. During the first year they normally degrade to about 0.03 per cent and then remain constant. The precision of this determination is of the order of 0.005 per cent (1 σ-level).

The <u>non-equivalence</u> is due to the effect of different temperature distributions during electrical and combined radiative and electrical heating. Hence, the electrical and radiative heating is not equivalent. The main non-equivalence is due to the radiation reflected from the conical part to the cylindrical shield of the cavity which increases the temperature of the shield during the irradiated phase. If all heat would flow through the thermal resistor of the cavity no difference between the two temperature distributions would be sensed. If the instrument is operated under ambient pressure conditions a substantial part of this heat flows directly to the heat-sink and by-passes the thermal resistor of the cavity. If it is operated in vacuum, however, the small radiation losses from the gold-plated shield to the surrounding can be neglected. Thus the air-to-vacuum ratio of the sensitivity can be used to determine the non-equivalence. By this method all effects dealing with losses by air conduction are taken into account (e.g. also the aperture heating). The PMO-6 radiometers have a non-equivalence of the order of 0.2 to 0.3 per cent. The precision of the determination is 0.05 per cent (1 σ-level).

The scattered-light produced by the light reflected from the precision aperture to the baffle and back into the cavity is measured with a silicon diode in place of the cavity and with a collimated laser beam as source. By scanning the laser beam across the precision aperture it is possible to determine (i) in the center: the intensity of the beam, (ii) on the precision aperture: the stray light, and (iii) on the view-limiting aperture: the zero of the measurement. The measured values lie between 0.02 and 0.03 per cent. The precision of the determination is 0.01 per cent (1 σ-level).

The heating of leads feeding the current to the cavity heater adds some unmeasured electrical power to the cavity. It is determined by measuring the influence of an additional current fed through the lead of the voltage probe and the current lead on each side of the heater. The radiometer is operated in the active mode and the change in the cavity heater power due to this additional current is measured. This is repeated by changing the polarity of the additional current in order to determine the influence of the electrical resistance of the voltage probes on the heater power measurement. From these measurements the ε_H can be calculated very accurately. Typical results are of the order of 0.03 to 0.05 per cent and can be determined with a precision of 0.001 per cent (1 σ-level).

As the experimental determination of the diffraction correction is very difficult, numerical calculation have been performed. The calculations follow the assumptions of Steel et al. (1972) and use the full extensions of the Lommel functions (Brusa, 1983). The resulting correction for a PMO-6 radiometer is 0.13 per cent for solar radiation, which is an important amount (e.g. 1.8 Wm^{-2} for the solar constant). In order to check the validity of the calculations they have been compared with experimental results of Boivin (1976) by using the same algorithm for his geometry, which is somewhat different. Although the agreement is reasonable (Brusa, 1985) it is planned to perform a laboratory experiment with a geometry much closer to the one used in the radiometry of the sun in order to check the theoretical result. As diffraction corrections have normally been neglected in solar measurements and as the different radiometer have very similar corrections, this effect is still left out in the following discussions.

DISCUSSION OF THE RESULTS OF THE CHARACTERIZATION

The full characterization procedure has been applied to seven PMO-6 type radiometers with the new kind of apertures. All these instruments have been compared to PMO-2 representing the WRR. The results of the characterizations and the comparisons are summarized in Table 1. From these results it becomes evident that the accuracy of the PMO radiometry is substantially improved by the characterization. The variability of the correction factors is more than twice as big as the variability of the results of the radiometric comparisons. The total uncertainty of the PMO-6 radiometers is estimated from the uncertainties of the individual characterization experiments, of the aperture-area determination (0.02 per cent) and of the electrical calibration (0.02 per cent) to 0.06 per cent at the 1 σ-level or 0.18 per cent at the 3 σ level. The 1 σ standard deviation of the results of the comparison to PMO-2 is just equal to the 1 σ uncertainty of the radiometers. This demonstrates the repeatablity in manufacturing and supports very strongly the characterization methods and the error analysis.

Table 1: Correction factors of PMO-6 type radiometers determined by experimental characterization at PMOD and results of comparisons with PMO-2.

Instrument Ident.	Non-Equivalence	Cavity losses	Scattered light	Lead heating	Total Charact.	Ratio to PMO-2
6-9	1.0031	1.00030	.99946	1.00030	1.00316	.9973
6-10	1.0023	1.00027	.99942	1.00023	1.00222	.9976
6-11	1.0018	1.00023	.99954	1.00024	1.00181	.9982
811105	1.0029	1.00039	.99993	1.00039	1.00461	.9965
811106	1.0043	1.00046	.99982	1.00041	1.00499	.9977
811107	1.0035	1.00040	.99986	1.00065	1.00441	.9978
811110	1.0031	1.00023	.99974	1.00034	1.00341	.9968
Mean:	1.00314	1.00033	.99968	1.00037	1.00352	.99741
Std.Dev:	.00087	.00009	.00021	.00014	.00122	.00059
Uncertainty 1 σ-level:	.0005	.00005	.0001	.00001	.00032	

COMPARISON OF THE PMOD-RADIOMETRY WITH THE WRR

The mean ratio of the seven absolute radiometers to PMO-2 amounts to 0.99741 with a 3 σ standard deviation of 0.0018. As the PMO-2 is reading 0.14 per cent higher than WRR the PMO-6 scale of irradiance lies 0.12 per cent lower than the WRR, which is well within the stated uncertainty of both the WRR of ±0.3 per cent and the 3 σ standard deviation of the PMO-6 scale. This result neglects the diffraction correction, because the radiometers used to define the WRR were never corrected for diffraction. If diffraction is included the PMO-6 scale is just at the error limit of the WRR. As the accuracy of the diffraction correction is not yet proven experimentally it would be premature to judge the WRR from these preliminary results.

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COMMENTS ON SOLAR IRRADIANCE MEASUREMENTS FROM NIMBUS 7

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1 INTRODUCTION

The solar irradiance measurements from Nimbus 7 were reported at the last IPC (Hickey,1980 a.). Since that time, considerably more measurements have been made and the data products have become available to the scientific commmunity The measurements are continuing at this time, approaching seven full years in November 1985 The first five years of results have been made available on tape by NASA (Hickey et al ,1984) A tape with six years of data should be available soon (Kyle et al 1985) The measurements are made by the solar radiometer of the Earth Radiation Budget (ERB) experiment. There are 10 solar sensing channels in the ERB instrument, which view the sun as the satellite crosses the terminator at the southern end of its polar orbit. There are 14 orbits on a normal mission day During the mission the Nimbus operations schedule is such that the ERB operates on a 3 day "ON" and 1 day "OFF". This continued through the first few years. The Nimbus 7 ERB started its solar measurements on November 16, 1978. Unlike the predecessor Nimbus 6 ERB, which started solar measurements on July 3, 1975, the Nimbus 7 set includes a cavity radiometer like the Eppley model HF. This device is referred to as channel 10c or "10c". Soon after launch it was noted that the cavity was exhibiting variations greater than its own stability limits, which were interpreted as indications of variability of the total solar irradiance (Hickey et.al. 1980 b.). The initial results were published (Hickey et.al. 1980 c.). The data that was being evaluated at that time was a preliminary product called the "engineering level data". There were numerous delays in achieving the final calibrated data set, not because of problems with the solar sensors or data, but because of problems in evaluating the data from the other 12 sensors of ERB - the earth flux sensors. The value originally reported for the solar constant was found to be high by about 0.2% when the final data became available. However this did not affect the detected solar variability which was later confirmed by the ACRIM sensor aboard the SMM satellite (Willson et.al. 1981) which began measuring in February 1980, 16 months after the start of ERB/Nimbus7 measurements.

In most of the previous papers and presentations on this topic, only the results of the cavity measurements have been discussed. Here we would like also to present the measurements from the other solar channels. The data for most of this presentation will be the final 6 year values (Nov.'78 -Oct.'84) derived from a data product called "SEFDT level" data. In addition we will have to revert to the engineering level data to discuss the results (cavity only) for the seventh year (Nov. '84 - Aug.'85).

The long term trend of the total irradiance as measured by the cavity was downward for the first 3 years. SMM had also reported a negative slope. However, for mission years 4 and 6, Nov '81 - Oct.'82 and Nov.'83 - Oct.'84, the ERB results showed small positive slopes, indicating a leveling out or reversal in the trend. The preliminary data for the seventh year indicates a slightly positive trend. The question as to whether or not a trend can be assigned to long term solar variability as opposed to an instrumental effect has been raised and will be addressed.

We will discuss the total solar irradiance results and the other measurements below, with more detail in the presentation

2 DISCUSSION OF MEASUREMENTS

Table 1. lists the 10 ERB solar sensor channels with their pertinent characteristics. Also included are the irradiance values for each channel for comparison of Nimbus 6 and Nimbus 7 results. Since the filtered channels of both N6 and N7 experienced degradation the data for Nimbus 6 is from a set generated by detrending the first 600 days of the mission and rectifying to the initial data. Since Nimbus 7 also experienced a contami-

TABLE 1. ERB Solar Sensor Characteristics

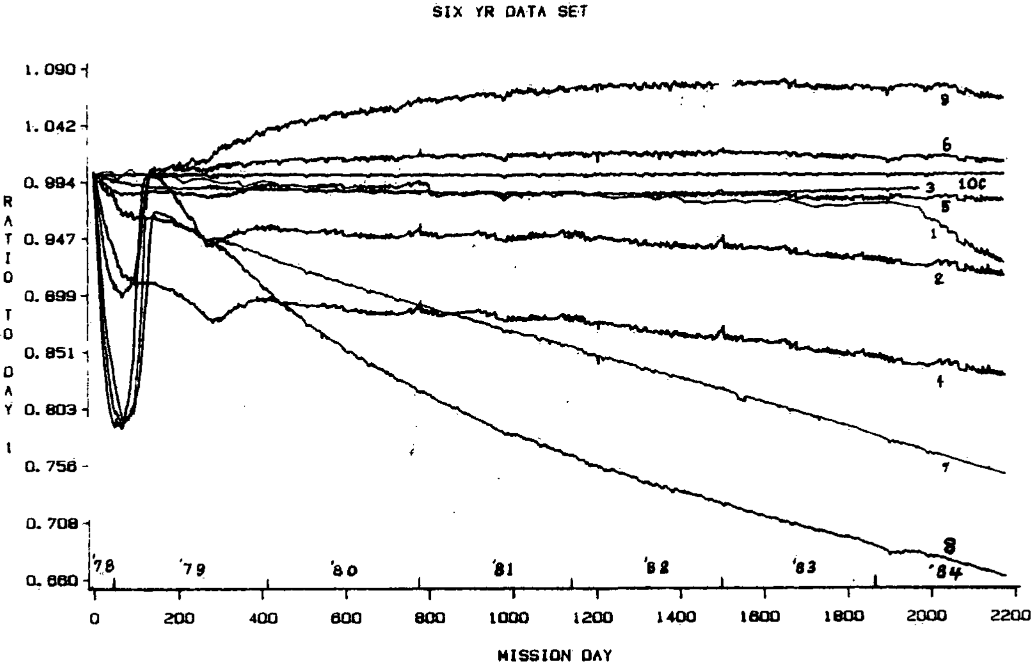
CHANNEL NUMBER	WAVELENGTH BAND (um)	FILTER TYPE	THERMOPILE TYPE	IRRADIANCE N6 (W/m^2)	N7
1s	0.2 - 3 8	2 Suprasil W discs	N3	1370 1	1369 5
2s	0.2 - 3.8	2 Suprasil W discs	N3	1370 3	1354 2
3s	<0.2 - >50	NONE (open)	N3	1393.5	1381 8
4s	0 526 - 2.8	Schott Glass with	N3	970 1	987 2
5s	0 698 - 2 8	Suprasil (4s&5s)	N3	679 1	692 5
6s	0 395 - 0 508	Interference	N3	206 3	206.0
7s	0 344 - 0 460	"	N3	166 0	166 0
8s	0 300 - 0 410	"	N3	109 4	108 1
9s	0 275 - 0 360	"	K2	57 4	60 7
10s	0 252 - 0 324	"	K2	27 0	n/a
10c	<0 2 - >50	NONE (open)	HF CAVITY	n/a	1371 4

NOTES ch 1s and 2s are duplicates with 1s normally shuttered
ch10s was on Nimbus 6 only ch 10c is cavity on Nimbus 7
Interference filters were UV burned-in before flight
Unencumbered FOV = 10 deg (slope=5) for all channels
Maximum FOV =26 deg for 1s - 8s and 10c 28 deg 9s & 10s
Schott Glass filters in channels 4s & 5s were protected from particles by 4mm of Suprasil W
Channels 4s,5s,6s,7s,8s,9s&10s had Suprasil W IR blocker between filter and thermopile
All thermopiles are EPLAB wirewoundand plated models
Nimbus 6 irradiance values from reference EPLAB 1977
Nimbus 7 irradiance values are means of first 4 days

nation event near the start of the mission, the mean of the first 4 days are shown for N7 It can be seen that the channel 1s (protected channel) values are in very good agreement The channel 1s and 2s agreement was good for N6 but ch2 appears to have been contaminated early on N7 The values for channel 3 of both sets is higher than anticipated The very high value of N6 was the reason for the Solar Constant Rocket Flights (Duncan et al 1977 and 1981) Channel 3 of N6 is generally corrected to 1367 W/m^2 based on the first rocket flight. Channel 3 of N7 also has a high value The filtered channels show generally good agreement from N6 to N7 Figure 1 is a composite plot of the 6 year daily mean data for all N7 channels ploted as the ratio to the initial value. The degradation event is clearly visible on the traces of the filter channel results The contamination was caused by outgassing of the spacecraft. The recovery of the response is due to cleaning by oxygen ions (Predmore et al 1982) The continuing changes in the filter channels after the recovery are caused by the action of UV which has a different effect for each filter It is noted that the cavity sensor 10c did not appear to be affected by the contamination (see below) The quoted values for the filter bands are in good agreement with the revised Neckel and Labs spectra (Neckel, 1985)

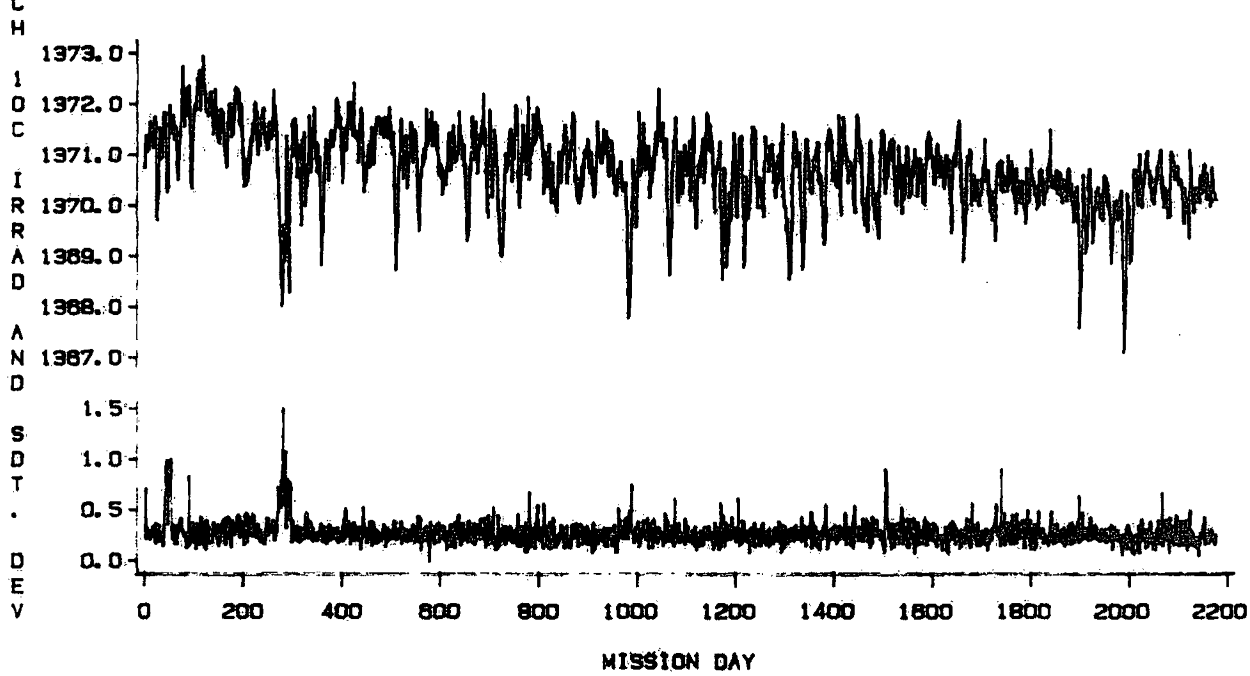
FIG1. ERB CHS 1 : 10C RATIO TO START

SIX YR DATA SET



The results of the 10c measurements for 6 years are given in Table 2. and plotted in Figure 2. The standard deviation of the daily orbital values is shown at the bottom of the plot. It allows us to identify days on which either solar variability is high or on which there is an instrument stability problem. This is one of the diagnostic tools for assessing the results. The daily mean values are plotted above. The minimum value of the daily mean is 1367.1 W/m^2 and the maximum is 1373.0 giving a range of 5.9 W/m^2 or 0.43 % of the mean. The standard error of the slope is 0.00002571 for the six year trend of -0.000569 W/m^2-day (see table). Statistical tests indicate that the slope is real by rejection of the null hypothesis. However, the slope could be an instrument or mission related effect rather than an indication of long term solar change. It is noted that the largest slope is at the beginning of the mission. Earlier we had shown that the other channels experienced an event which lowered their responses by deposition of contaminants which were later cleaned off. It is possible that such contamination could have affected the cavity channel components. It is also possible that a minute amount of outgassing could have occured in the early mission days. Indications from the engineering

FIG2. ERB N7 CH. 10C IRRAD AND STD. DEV.

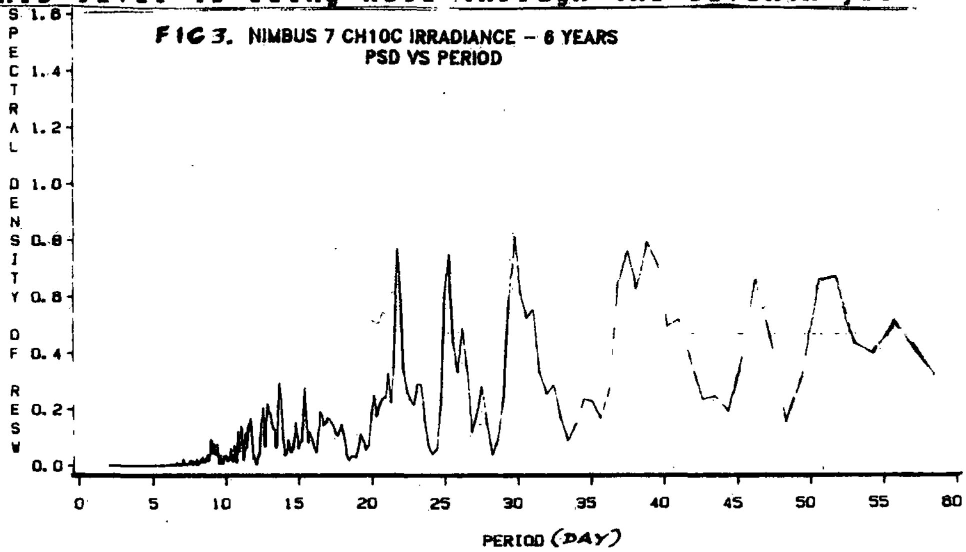


Nimbus 7 ERB Channel 10C Total Solar Irradiance Results by Year (6 years) ; Table 2

Mission Year	Mission Days	Number Daily Means	Yearly Mean W / m^2	change W/m^2	Std.Dev. W/m^2 (%)	Slope W/m^2-day	(%/year)
1	1 - 350	263	1371.24		0.84 (0.06)	-0.00253	(-0.067)
2	351 - 716	271	1371.06	-0.18	0.63 (0.05)	-0.00064	(-0.017)
3	717 - 1081	284	1370.75	-0.31	0.73 (0.05)	-0.00056	(-0.015)
4	1082 - 1446	275	1370.57	-0.18	0.69 (0.05)	+0.00017	(+0.005)
5	1447 - 1811	291	1370.53	-0.04	0.49 (0.04)	-0.00090	(-0.024)
6	1812 - 2146	305	1370.16	-0.37	0.59 (0.04)	+0.00048	(+0.013)
Period	1 - 2146	1689	1370.70	N/A	0.75 (0.05)	-0.00057	(-0.015)

Solar data started with door opening on November 16, 1978: 11 1/2 months in 1st year
Year 6 has more data points because of periods of full time operation
Change in yearly mean for six years = 1.08 W/m^2 or -0.079%

level data for the first 10 months of the seventh year indicate a small positive slope. If confirmed by the SEFDT level data, this may be an indication of a solar upward trend since there is no known mechanism for the sensor to increase in response. The calibration of channel 10c depends on the three factors of heater voltage, heater current and thermopile signal while viewing deep space during calibration. These had remained within the instrument resolution for the first 6 years at about 0.05% (Hickey, 1985). Calibration data through August 1985 show that this level is being held through the seventh year.



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COOLED RECEIVER RADIOMETERS

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In the USSR the design of higher accuracy radiometric instrumentation with receivers cooled down to ambient temperatures dates back about a decade. These studies have become particularly active during the recent years when it was proved both theoretically and experimentally that thermal stabilization of the receiver at level of the instrument housing makes it possible to lower the measurement error by approximately a factor of 3 in comparison to the case when a similar receiver is overheated by about 2...3 K.

The first prototypes of cooled receiver radiometers had flat receiving surfaces which were attached to the butt thermoelectric coolers (TEC). Later when it became clear that the measurement accuracy of such instruments is limited by the degree to which the absorption coefficient of the receiver surface is known, new radiometers with cooled cavity receivers were constructed. Simultaneously the calibrating installation which provided the needed degree of accuracy was built ($\alpha \simeq 1$, $\Delta\ \alpha$ up to $3 \cdot 10^{-5}$). This installation was primarily used for testing the conic cavities for which it is easier to diminish the edge effect. The quality of the cone (both with and without the diaphragm) and of its inner coating were determined from the zonal characteristic of the absorption coefficent which was retrieved by scanning the opening diameter with a thin ray. As a result copper golded conic cavities with mirror-black coating and cylindrical optical trap at the cone point were constructed. Variations of their zonal characteristic do not exceed the limit (0.99930...0.99997) ± 0.00003. Besides the termal fields of the receiver unit were studied using the IR imager of a sensitivity better than 0.1 K. It was found that the temperature profiles are adequately uniform during electrical heating (within ± 0.1 K) and recede in a similar manner towards both the cone point and its opening (where the TEC is mounted). Upon increasing the heating powers these recessions (i.e. the temperature gradients along the generating curve) become more steep and the overheating with respect to environments increases (to about 0.5 K mm^{-1} and 3.2 K, respectively at W = 20 mW). The radiative heating of the same power produces the temperature profiles identical to those above to ± 0.2 K. However their character, in particular the gradients and positions of the thermal extrema vary (thus the zonal effect shows itselfs). Upon turning the TEC on the cone temperature comes to that of the environment to within 0.1...0.2 K, the temperature gradients significantly diminish and the extrema do not exceed 0.2 K. Obtained data made it possible to adjust the theoretical estimates of the substitution equivalency, and were accounted for in designing the prototype radiometers of the second generation.

We constructed and tested the first prototypes of the cooled receiver cavity radiometers in 1980. The basic model used the cone having the absorption coefficient α_λ = 0.99981 ± 0.00003 (at λ = 500 nm), as averaged over the precision diaphragm area. Three microthermistors placed along the cone perimeter between the TEC and the substitution winding serveda as temperature sensors. The prototype had the sensitivity of $2 \cdot 10^{-6}$ V $m^2 W^{-1}$ and the non-excluded residual of the systematic error of about ± 0.1%. However the random component of the error reached ± 0.3%. Besides the complex measurement scheme along with the two-stage cooling of the receiver produced difficulties in maintaining of this instrument. These drawbacks were eliminated during the design and construction of the new prototype (the PP-2 type) in which the thermoelectric thermometers are used and the second (baseline) channel identical to the first is introduced so that both channels are interchangeable. This feature makes it possible to use the new instrument in both the differential (when the receivers' batteries oppose each other in the circuit) and in the monomode. For each measurements series the TEC current is chosen for both receivers so that their temperature at the moments of measurement are equivalent to ambient temperature.

Field tests and laboratory studies of the PP-2 prototypes are being carried out since 1982. It was found that the deviations from the WRR scale presented in the USSR by the Å 212 pyrheliometer do not exceed ± 0.2%. The prototypes' sensitivity is within (5...7) 10^{-6} V $m^2 W^{-1}$, the time constants are of the order of 15 s, rms deviation of the measurement results does not exceed ± 0.1%. Correction factors are as following: 1. Absorption coefficient - 1.00000 ± $3 \cdot 10^{-5}$; 2. Precision diaphragm area - 1.00000 ± $4 \cdot 10^{-5}$; 3. Substitution power - 1.0000 ± $2 \cdot 10^{-4}$; 4. Thermal resistance effect* - 1.00012 ± $2 \cdot 10^{-5}$; 5. Edge effect* - 1.0004 ± $3 \cdot 10^{-4}$; 6. Zonal effect - 1.00002 ± $1 \cdot 10^{-5}$; 7. Lead heating* - 1.00040 ± $4 \cdot 10^{-5}$; 8. Diffraction losses - 1.0013 ± $2 \cdot 10^{-4}$; 9. Heat exchange with diaphragm* - 0.99980 ± $1 \cdot 10^{-5}$; 10. Backward radiation reflected by the trap and scattered in the tube - 0.9996 ± $2 \cdot 10^{-4}$; 11. Radiation from the blind* - 1.00025 ± $1 \cdot 10^{-5}$; Total correction factor - 1.00194 ± $6 \cdot 10^{-4}$.

Asterisks denote those five of the total error components which are eliminated by introducing the cooled receiver. Note, finally, that at present the accuracy of pyrheliometric measurements is limited by the quality of the precision diaphragm and the mode of account for the edge effect. These problems must take the central place in perfecting the design of absolute radiometers and the technique of their metrologic certification.

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Spectral measurements on pyranometers at NTI in September 1985

The intention for our study was to measure the responsivity for irradiance (calibration factor) of pyranometers at several equally spaced wavelengths in the wavelength range 300-2500 nm. However, this was not possible because the pyranometers are not very sensitive detectors and the radiant flux coming out from our monochromators is rather small even with the largest bandwidth settings. We also want to have a very uniform irradiance distribution over the detector surface which further stresses the demand for high available flux.

Instead we decided to use glass filters to select different wavelengths distributions. The set up for the measurement is very simple. Figure 1. We use a 24 V, 250 W tungsten halogen lamp with condensing mirror and lenses within an ordinary slide projector Kodak, Carousel. A removable infrared (IR) cut-off filter is placed between the lenses. In the slide position we put in the different spectral filters. Long wave IR radiation is blocked by a combined filter of 8 mm thick plexiglass and 2 mm thick ordinary glass with the plexiglass facing the source. The cut-off wavelength of this filter is 2000 nm. The filter is cooled to ambient temperature by a fan in order to reduce long wave IR radiation emission from the filter itself.

A diaphragm tube reduces the influence from stray radiation and from changes in the long wave IR radiation level from the surroundings.

Each pyranometer is vertically positioned (with cable connection upwards) about one meter from the condensor. At this distance the uniformity of the irradiance is very good. The variation is less than ±0.2 % over a surface corresponding to that of the Kipp&Zonen CM10 detector surface and less than ±0.5 % over the detector surface of the Schenk Star pyranometer.

As reference for the measurements we use a Laser Precision Rs 3940 absolute radiometer which has a pyroelectric detector with gold black coated black surface. Its area is 0.5 cm^2. The pyranometer and the reference detector (including its chopper) are placed on a rotational stage and they can be positioned into the optical path fast and conveniently with less than ±1 mm unaccuracy in distance and translational position. The reference detector has no window and is therefore very sensitive to long wave IR radiation. The temperature of the surroundings seen by the detector must be kept constant during the measurement.

We used eight different spectras (see figure 2) of which one is used as reference for the measurements with the other ones. From the source we used two basic spectras: One with 24V on the lamp and with the IR cut-off filter in position and the other one with 8V on the lamp and with the IR cutoff filter removed. The first spectrum is used as the reference spectrum. From this spectrum four other spectras are selected using the following Schott filters: BG 28 (1 mm), BG 38 (2 mm), VG 9 (1 mm) and RG 665 (1 mm). The other basic spectrum is used itself and also filtered by a Schott filter RG 1000 (2 mm). The eighth spectrum is formed with 24 V on the lamp without the IR cut-off filter and with an interference filter having 1500 nm center wavelength and 60 nm half power bandwidth. This filter is placed outside the projector but in front (nearer the source) of the long wave IR blocking filter. The effective wavelengths, i.e. half integrated irradiance below and half above, are for the spectras in the mentioned order 595, 491, 548, 549, 699, 1210, 1317 and 1501 nm.

Nine pyranometers were measured with this method. Seven of these are one of the sets of pyranometer circulating for measurements by different countries within the IEA TASK IX project. The other two are EKO MS-801 (double dome type) pyranometers owned by EKO.

Table 1 shows the result of the measurements. Most striking is that both the Kipp&Zonen pyranometers have flat response for all spectras while the other ones have a decreasing responsivity for IR radiation. All pyranometers has flat response in the visible wavelength range except the Schenk Star in the blue and the CSIRO in the red region.

The reproducabilty of the measurements are typically ±0.5 % in the visible range, ±1 % for the broadband IR spectras and ±2 % for the narrowband IR spectrum (1500 nm). The irradiance levels on the pyranometers are ranging from 1.5-22 W/m^2 for the different spectras (see table 1). At these low levels it was necessary to use a symmetrical procedure for the measurements at each specific spectrum as there was, in spite of the precautions, a remaining change in the radiance of the surrounds seen by the reference detector. Also the pyranometer output voltage is a changing somewhat during the measurement. Each pyranometer is left for stabilization for at least a few hours after handling them before the measurement. The procedure was: RD, RDZ, RD, P, PZ, P, RD, RDZ, RD.
RD=reference detector reading. RDZ=reference detector zero reading. P=pyranometer reading. PZ=pyranometer zero reading.

A 10 nV resolution nV-meter, Keithley 180, was used to measure the pyranometer output. The waiting time for the pyranometer readings was 1-2 minutes depending on the pyranometer type.

The result of the measurements conserning the PSP and CM10 relation in the IR response confirmed similar measurement at Kipp&Zonen preliminary reported in a letter from Mr. van Wely in April 1985. He also repeated the measurements 1) with changing the domes to CM10 domes on the PSP and also 2) without domes and got the same low response in IR for PSP and he concluded that the mean absorptivity of the PSP black paint must be considerably lower in the 1100-2700 nm range than in the 300-1100 nm range.

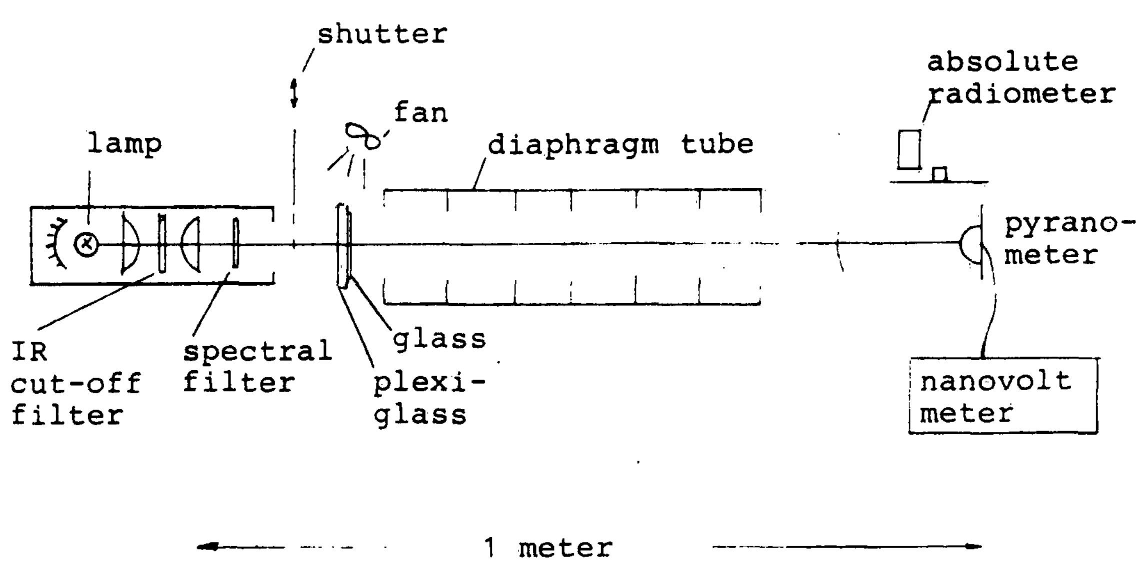

Fig 1. - Instrumental set up for spectral measurements of pyranometers.

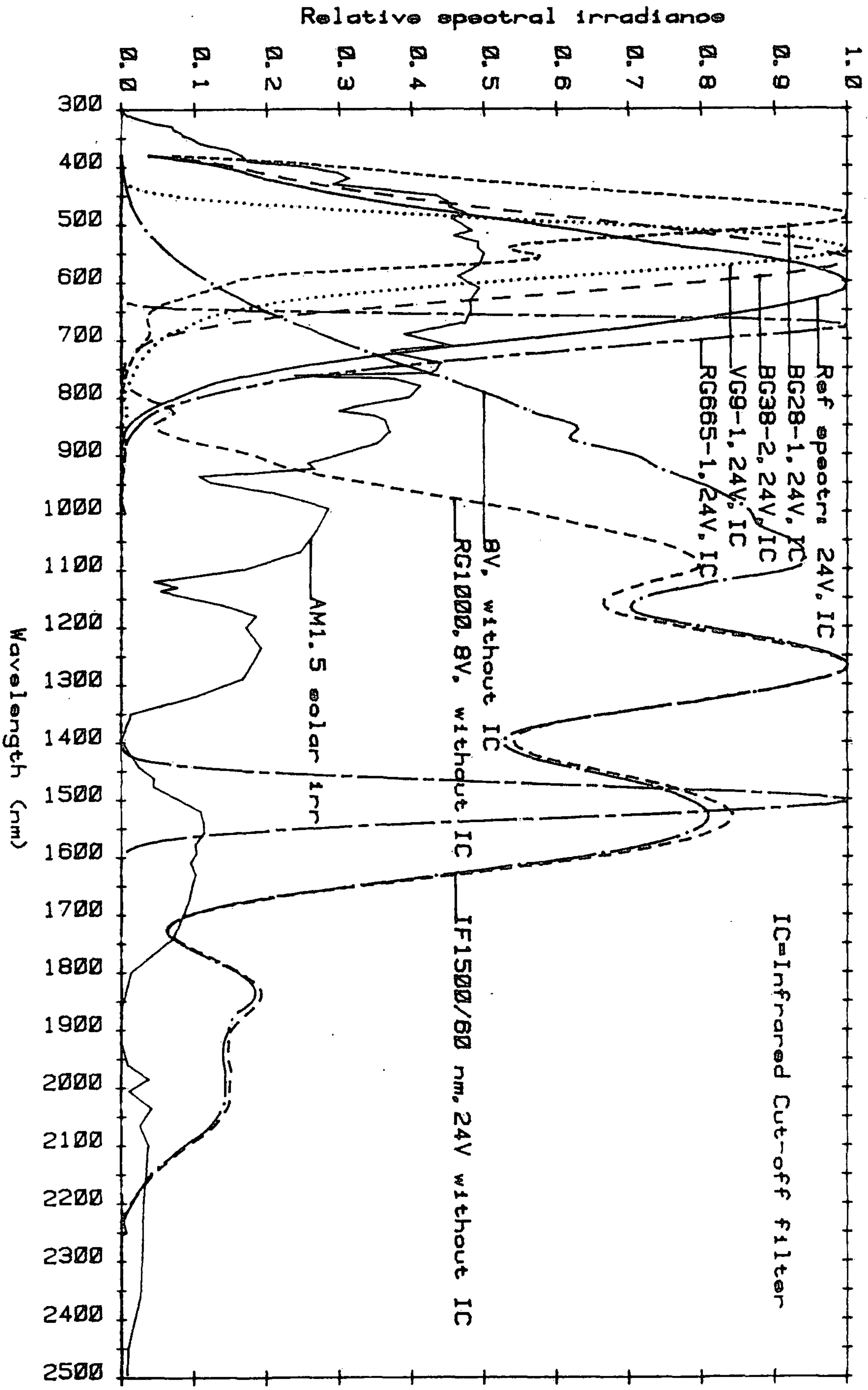

Fig 2. - Relative spectral irradiance of the different spectral distribution used in the test.

Table 1 - Result of the measurements: Relative responsivity of pyranometers for irradiance in different wavelength bands.

Pyranometer	Ref Spectr 24V no IR	BG 28 24V no IR	BG 38 24V no IR	VG9 24V no IR	RG 665 24V no IR	WG9 8V IR	RG 1000 8V IR	IF 1500 24V IR	Responsivity $\mu V W^{-1} m^2$
K&Z CM5-773656	1.00	0.99	1.00	1.00	1.01	1.02	1.02	1.02	11.7
K&Z CM10-810121	1.00	0.99	1.00	1.00	1.00	1.01	1.01	1.01	4.59
Eppley PSP20524	1.00	0.99	1.00	1.00	1.00	0.93	0.92	0.90	10.2
Schenk Star2209	1.00	0.97	1.00	1.00	1.02	0.94	0.93	0.94	15.4
EKO Star 81908	1.00	1.00	1.00	1.00	0.99	0.86	0.83	0.80	10.1
EKO MS-80185022	1.00	0.99	1.00	1.00	1.00	0.92	0.89	0.85	6.83
EKO MS-80185023	1.00	0.99	1.00	1.00	1.00	0.92	0.89	0.84	6.63
Swissteco 114	1.00	0.99	1.00	1.00	1.00	0.95	0.94	0.90	15.9
CSIRO MK2 115	1.00	1.01	1.01	1.00	0.97	0.82	0.79	0.74	4.24
Irradiance (W/m^2):	21.5	4.0	11.2	5.4	4.4	16.6	11.4	1.5	
Effective wave-length (nm):	595	491	548	549	699	1210	1317	1501	

SOME EXPERIENCES WITH AN EPPLEY SELF-CHECKING PYRANOMETER

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1. INTRODUCTION

The Eppley Laboratory has developed a self-checking pyranometer (model SCP). This instrument has the same glass hemispheric domes as the model PSP, but the sensor unit is similar to that of the model H - F pyrheliometer, that is the receiving "surface" is the aperture of the upper cavity.

The pyranometer No. 23205 was specially fabricated for the Hungarian Meteorological Service to use the same control and readout box built for our model H - F pyrheliometer.

2. THE CALIBRATION

Exposing the SCP pyranometer to G global radiation its thermopile output

$$U = G \; T_r \; K_r,$$

here T_r is the transmission of glass domes,

K_r is the sensitivity to radiant heat.

Covering the glass domes with a metallic hemisphere, the same thermopile output could be produced by W electric heating power

$$U = W \; K_e,$$

here K_e is the sensitivity to electric heating.

$$G = W \frac{1}{T_r} \frac{K_e}{K_r} = W \frac{F}{T_r} = \frac{U \; F}{T_r \; K_e}$$

F is called as non-equivalence factor between radiant and electric heating. The K_e sensitivity should be determined for the actual conditions of the measurements. The glass transmission and the non-equivalence factor are supposed to be long-term constant. The full calibration of the model SCP requires the knowledge of both of them or at least the product of them.

3. TRANSMISSION OF GLASS DOMES

The Hungarian Meteorological Service purchased a model PSP pyranometer several years ago but it has been exposed to solar radiation for 2 days only. The transmission of the two glass domes of this pyranometer has been determined separately and altogether in both overcast and clear conditions. The results are shown in Table 1. Each measured value is a mean of approximately 30 pairs of reading.

Table 1

Transmission of glass domes

		Overcast conditions	Clear conditions
Small hemisphere	T_1	0.985 ± 0.003	0.963 ± 0.003
Large hemisphere	T_2	0.927 ± 0.003	0.936 ± 0.002
$T_1 \times T_2$		0.913	0.902
Both hemispheres	T_r	0.918 ± 0.003	0.913 ± 0.004
U S E D		0.915	0.907

4. COMPARISON TO PYRANOMETER

A Kipp and Zonen CM-5 pyranometer serves as national reference pyranometer. The two instruments were compared in both overcast and clear weather conditions.

Overcast case: $T_r \times K_r = 0.011587 \pm 0.00027$

$K_r = 0.0127 \text{ mV/(W/m}^2)$

Clear case: $T_r \times K_r = 0.011438 \pm 0.00012$

$K_r = 0.127 \text{ mV/(W/m}^2)$

The sensitivity for electric heating during the comparison varied between 0.01368 and 0.01377 $\text{mV/(W/m}^2)$, the mean was 0.01372. Therefore the non-equivalence factor:

$$F = K_e/K_r = 1.080$$

5. COMPARISON TO PYRHELIOMETER

At the factory, in Newport, the SCP pyranometer was calibrated using the sun-shadow method. The data on the plot attached to the instrument show an increasing sensitivity with increasing solar elevation.

Similar calibration were made in Budapest too, the results are shown on Figure 1. The 90 degrees solar elevation measurements were made with tilted pyranometer. (The electric calibration results do not depend on the position of the pyranometer according to the experiments made indoor.) Against the scattering of the measurements the solar e-levation dependence is obvious.

6. CONCLUSIONS

- -- The transmission of glass domes is different in clear and in overcast weather conditions, the value varies between 0.90 and 0.92.
- -- The non-equivalence factor between electric and radiative heating is about 8 percents.
- -- The sensitivity determined by sun-shadow calibration shows a continuous increase with solar elevation from 25 to 90 degrees.

Note: Since it was realized only during the comparison in Davos that the voltmeter built in the control box was not quite correct, therefore the value of the non-equivalence should be taken as 6 percents instead of 8 percents given in the text, supposing the value of glass transmission to be valid.

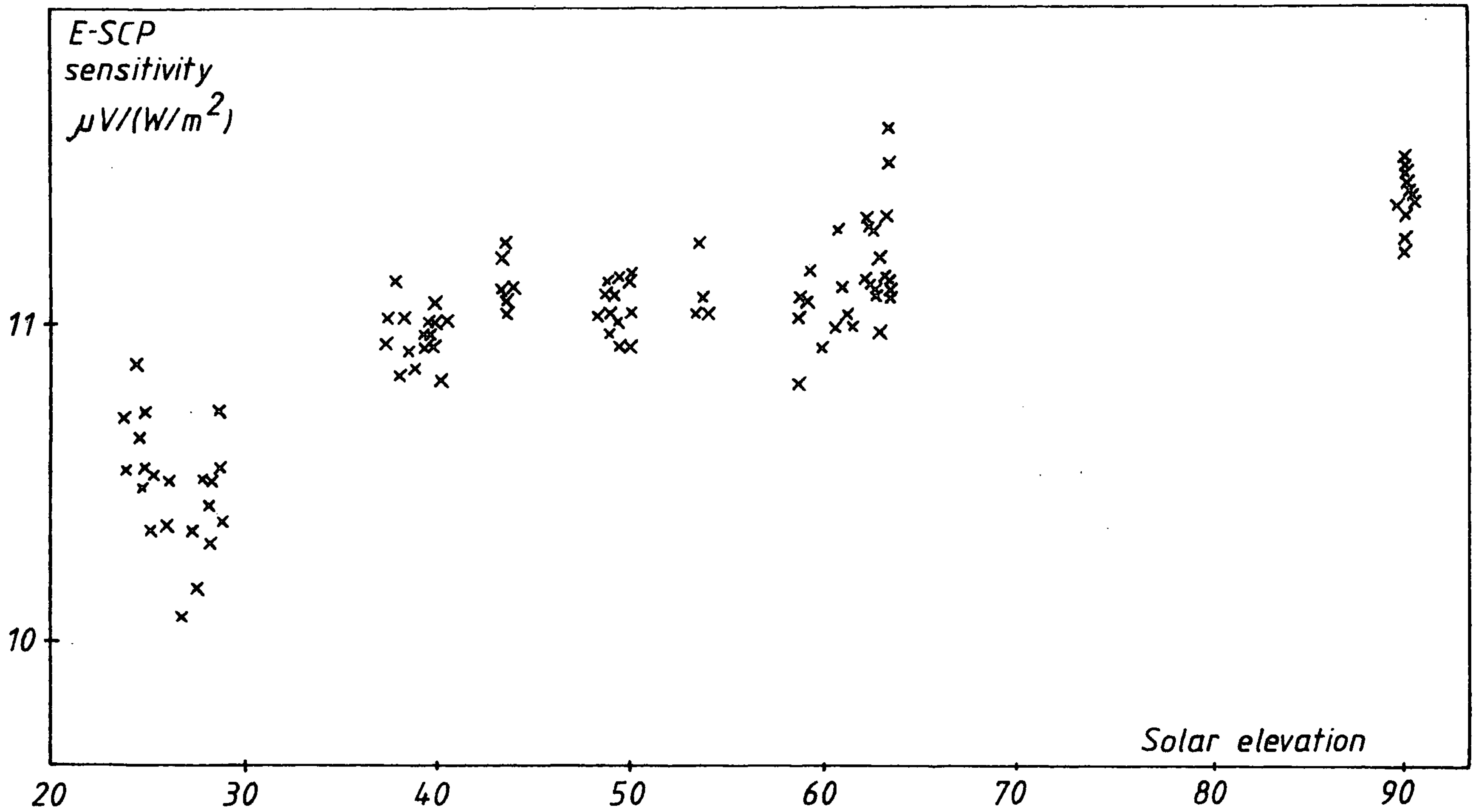

Figure 1. The sensitivity of the model SCP pyranometer as a function of the solar elevation.

SOME RESULTS OF THE BUDAPEST PYRANOMETER COMPARISON

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1. INTRODUCTION

The data collected from the existing world pyranometer network and published by the WMO Radiation Data Center in Leningrad are not used extensively. One of the reasons of this situation is the unknown reliability of the measurements. To obtain some idea about the comparibility of the global radiation data measured in Europe, the RA-VI organised an international comparison of pyranometers operated in different countries. The comparison took place in Budapest, between July and December of 1984.

2. THE PARTICIPATING INSTRUMENTS

Table 1 contains the pyranometers participated on the comparison. Moreover 3 electronic sunshine recorders were compared to each other and to a pyrheliometer.

TABLE 1

Participating pyranometers

Type	Temperature correction	Directional correction	Country
CM-5			Norway
CM-5			United Kingdom
CM-5	0.15 per cent per centigrade		Switzerland
CM-5			Poland 1
CM-5	0.2 per cent per centigrade		Hungary
Sonntag			Poland 2
Sonntag			G D R
CM-10	Compensated		F R G
E-PSP	Compensated		Turkey
Stern		Azimuth and elevation chart	Austria

2. DATA COLLECTION AND EVALUATION

All pyranometers were placed on a roof and oriented according to the owners' descriptions. They were switched to a data collector which measured the electromotive force. The on-line calculator printed the instant value of global radiation in W/m^2 for each instrument using the calibration factor sent by the owner and applying the temperature and solar direction corrections as indicated in Table 1.

No reference instrument had been chosen since the purpose of the comparison was to look for the possible and expectable deviations between the pyranometers operated in different countries.

Altogether 544 readings were collected during the half-year period within different temperature, solar elevation and cloudiness conditions. The data are to be published by the WMO as INSTRUMENTS AND OBSERVING METHODS REPORT No 16.

3. SOME RESULTS

Well calibrated pyranometers placed near to each other at the same moment ought to give the same value for the global radiation. In reality however there are always differences between the measurements of the 10 pyranometers. The difference for each reading has been characterized by the relative standard deviation expressed in per cents. In Table 2 the average relative standard deviations are shown for all readings and for samples characteristic for the 3 seasons.

Table 2

Average relative standard deviations for different data samples

Sample	Using original calibration factors (per cent)	Calibrated to the sample mean (per cent)
All data	5.1	4.9
Summer	2.0	0.8
Fall	4.1	1.9
Winter	9.5	6.6

As it seems from Table 2 on the yearly basis the expected difference as much as 5 per cents even after calibration the pyranometers to each other. In the 3 seasons the unified calibration has significant increase in the comparability of the global radiation values. The summer results are the best mainly because the pyranometers are calibrated to pyrheliometers usually in summer conditions. As the temperature, solar elevation and irradiance level go farther and farther from the values usual at calibration weather conditions, the comparability becomes worse and worse.

Regarding only the identical type pyranometers, that is the 5 CM-5 pyranometers and the 2 SONNTAG pyranometers, the improvement is not significant. It seems therefore that the pyranometers need individual corrections to achieve better comparability of global radiation measurements

4. CONCLUSIONS

- The unification of the methods of calibration of pyranometers to pyrheliometers would increase the comparability of the global radiation data.
- The pyranometers need combined corrections for the effects of temperature, solar direction and irradiance level. Maybe, the solution could be the introduction of a "pyranometric scale" which would be valid in all possible weather conditions and the pyranometer correction function could be determined by outdoor measurements similarly to those described by Ambrosetti et al (1984).

5. REFERENCE

Ambrosetti, P., Andersson, H.E.B., Liedquist, L., Fröhlich, C., Wehrli, Ch. and Talarek, H.D. 1984: Results of an Outdoor and Indoor Pyranometer Comparison, International Energy Agency Document No. III.A.3.

THE STRUCTURE FUNCTIONS OF GLOBAL RADIATION AND THE OPTIMAL NETWORK DENSITY

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1. INTRODUCTION

The structure function of global radiation is defined as follows:

$$F = \overline{(G(1) - G(2))^2}$$

where G(1) and G(2) are the daily amount of global radiation measured at places 1 and 2, the bar means averaging in time. The quantity F has been calculated for each possible pairs of stations situated along different latitudes (see Figure 1). The time period is 1965 - 1980.

2. THE STRUCTURE FUNCTIONS

The functions are shown on Figures 2, 3, 4 and 5 for March, June, September and December. Generally the "saturation distance" (for larger distances the measurements are quite independent) is larger for lower latitudes. At zero distance the values are very different latitudes. The F value at zero expresses the combined effect of local or small scale atmospheric processes, the horizon obstruction and the instrumental non-equivalence.

3. THE NETWORK DENSITY

If areal mean values of extended areas are expected from the global radiation network, then the difference between point measurements and areal means should be estimated. For this end Czelnai (1970) used the structure functions in his formula. On Figure 6 some examples are shown for circular areas. For latitudes 47 and 60 degrees the significant increase of the error with circle radius begins at 200 km, while in the case of other latitudes it begins at 400 km or so.

4. REFERENCE

Czelnai, R. 1970: On the accuracy of estimation of areal mean values (in Russian) Proceedings of Main Geophys. Obs. Leningrad, Booklet No. 267.

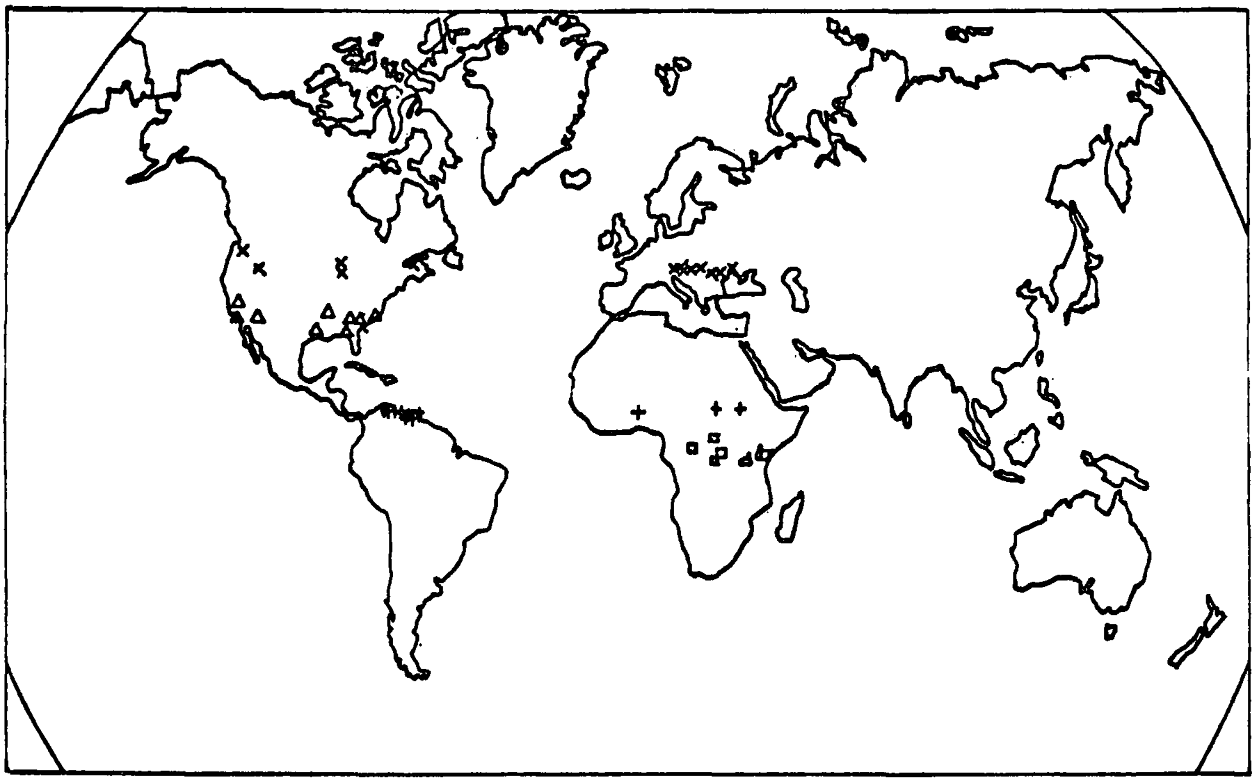

Figure 1. Locations of the global radiation stations involved in the structure function calculations.

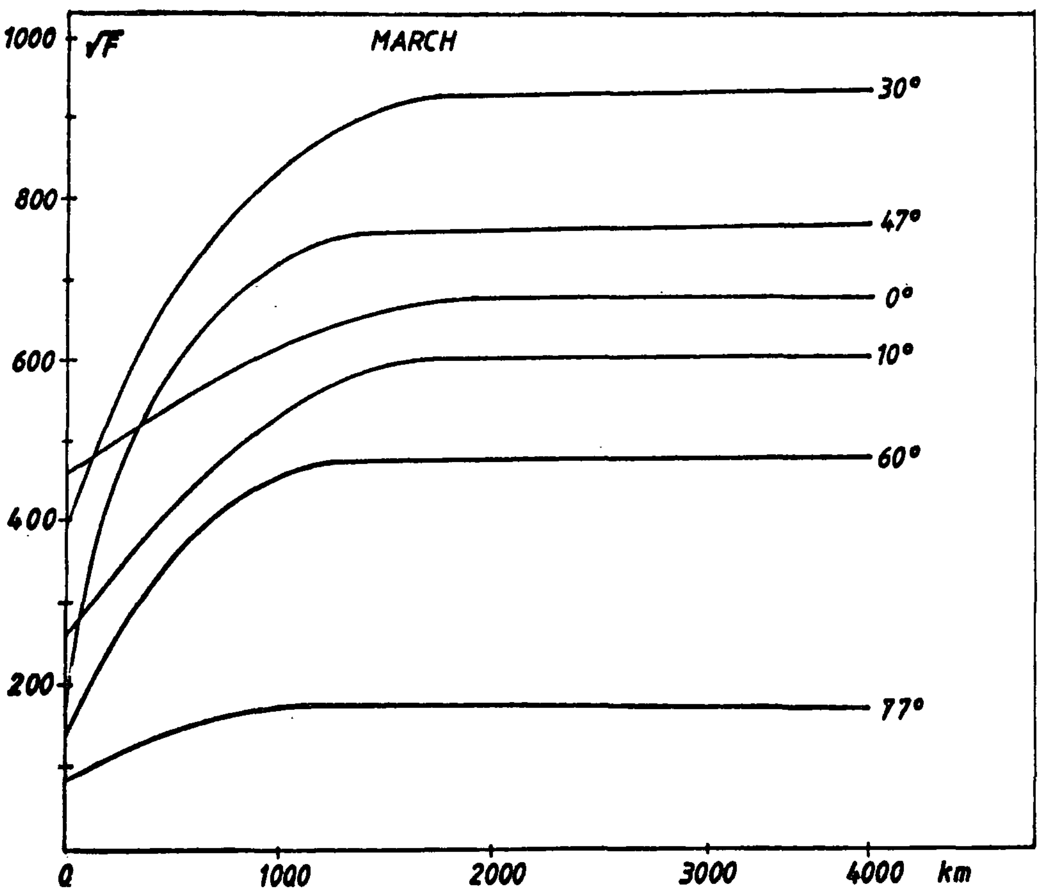

Figure 2. SQR of structure functions of daily global radiation from 15 years data.

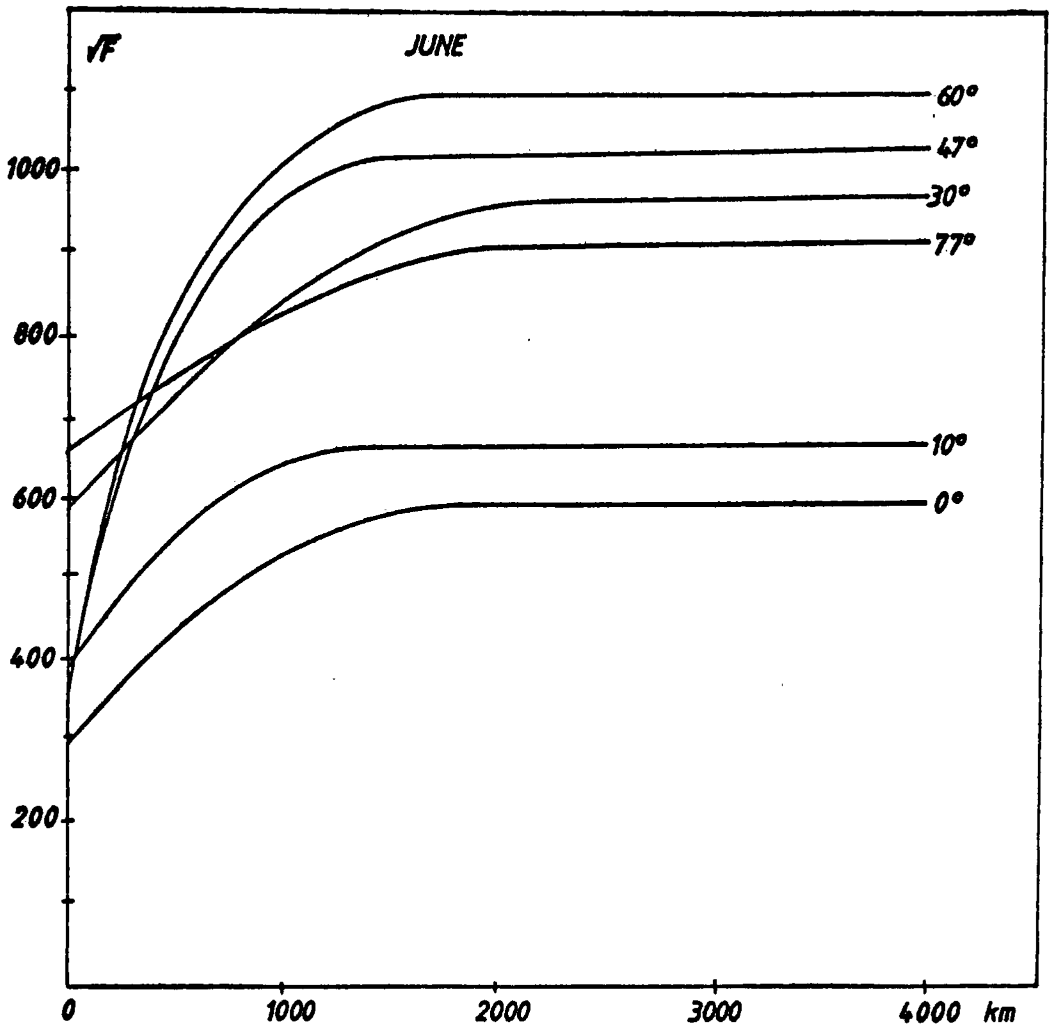

Figure 3. Same as Figure 2.

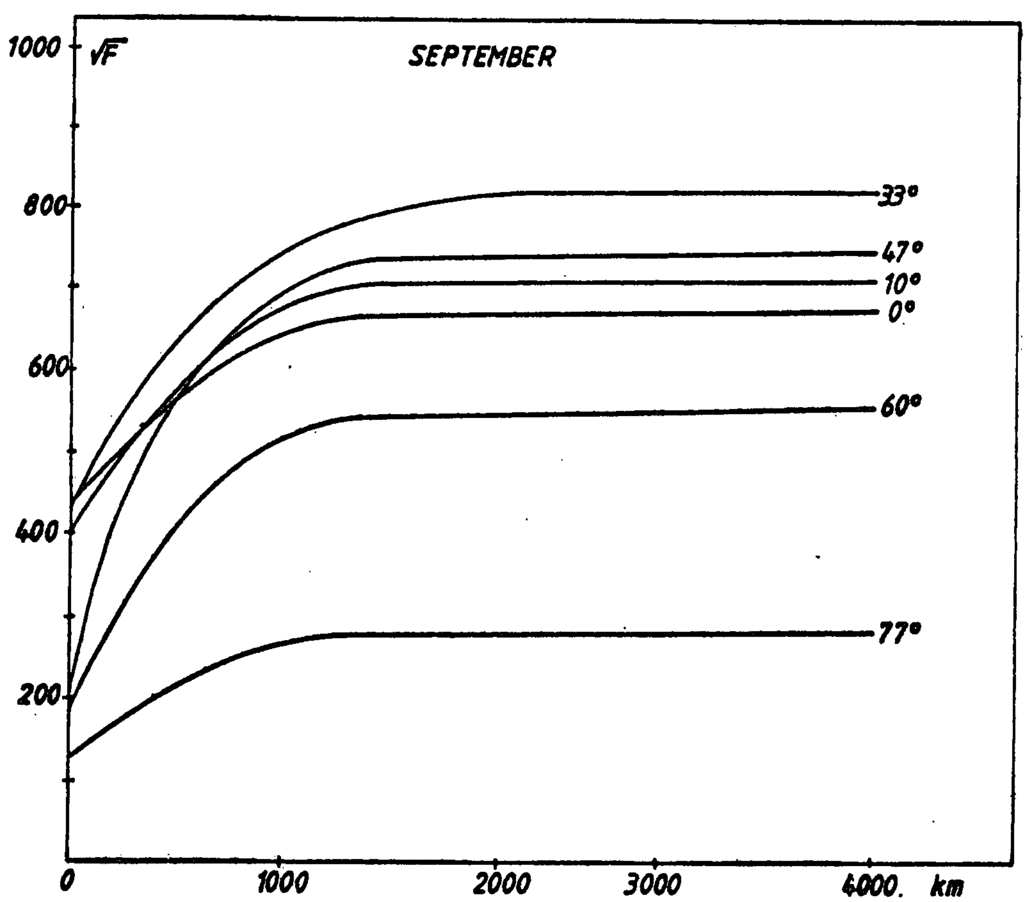

Figure 4. Same as Figure 2.

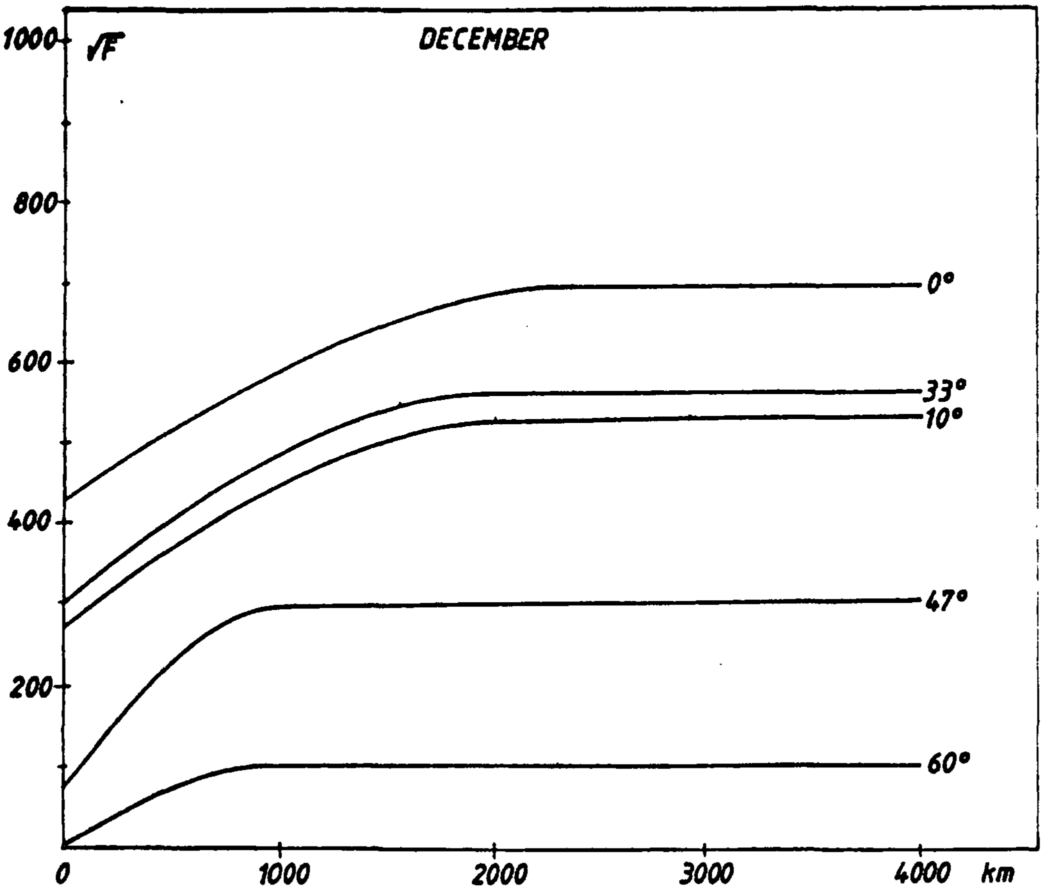

Figure 5. Same as Figure 2.

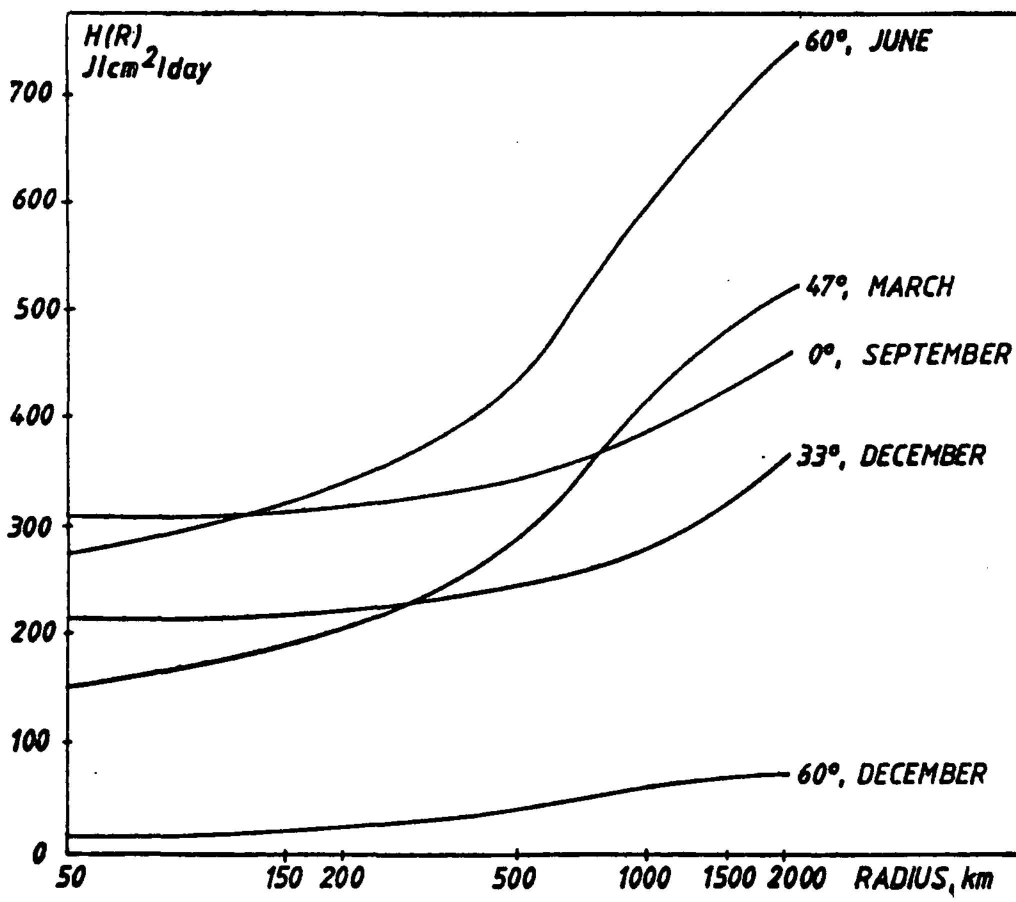

Figure 6. Statistically expected difference (as a function of the radius) between the global radiation measured at a point and the areal mean for circles around that point. Some example. The other curves are between the extreme ones.

THE NEW RIVER INTERCOMPARISONS OF ABSOLUTE CAVITY * PYRHELIOMETERS (NRIP I - VI)

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ABSTRACT

The genesis of the New River Intercomparisons and their operation are discussed in detail. NRIP I (November 1978) came about as a result of a need to establish a basis for transfer of calibration from primary standard pyrheliometers to field pyranometers (and field pyrheliometers) for use in solar device testing. NRIP VI, with 15 cavities participating, as held in late November, 1983. The six intercomparisons held to date have involved a total of 31 different absolute cavities from five countries. Dates of the intercomparisons are selected to insure the greatest probability of cloud- and haze-free conditions in the northern Sonoran desert of Arizona. Simultaneous instantaneous readings are organized into ten-minute sequences of 21 readings in 30-second intervals. Between 30 and 40 runs are obtained in each intercomparison, requiring no more than four days at the site selected. The advantages and disadvantages of the procedures employed in the NRIP's, which require that the normal readout electronics associated with a given instrument are a part of the intercomparison, are discussed in terms of procedures employed in the International Pyrheliometric Conferences. Results of the comparisons are presented in aggregate. Agreement for the more than 40,000 instantaneous measurements is within .25% for the 31 cavities intercompared.

INTRODUCTION

Largely as a result of our early assessment of the disparate results of the first U.S. National Bureau of Standards-sponsored Round Robin tests of the thermal performance of solar hot water collectors[1], and our own independent observations of pyranometer-to-pyranometer difference among a large group of so-called WMO Class I instruments, DSET Laboratories purchased an Eppley Model H-F absolute cavity pyrheliometer in January 1977. This particular instrument was the first terrestrial version of the Hickey-Frieden absolute cavity radiometer that was developed for the Nimbus satellite series, In early 1979 we obtained a second Model H-F cavity radiometer, SN 17142.

In the summer of 1977 we began periodic shading disk calibrations of our family of Eppley Model PSP pyranometers at test angles of interest, but predominantly at normal incidence employing at altazimuth tracking mount. Altazimuth tracking is the most widely used altitude employed in the U.S. to test solar collectors for thermal performance. Calibration transfers are made directly from the H-F cavity radiometers.

Because of the need for a U.S. reference base to provide material continuity and traceability for legal purposes (in terms of product certification testing), we proposed hosting the first regional intercomparison of absolute cavity radiometers at DSET's New River, Arizona site. The facilities and generally superior environmental conditions that prevail in the

* Reprinted from IEA TASK IX (Draft), *Recent Advances in Pyranometry*, Symp. Proc., January 1984, S.M.H.I. Norrköping, Sweden.

northern Great Sonoran Desert north of Phoenix resulted in a consensus agreement among participants to hold subsequent intercomparisons in New River. These three-to-five day intercomparisons, known as the New River Intercomparisons of Absolute Cavity Pyrheliometers (NRIPs), have been co-sponsored by DSET Laboratories, the National Weather Service's Solar Radiation Laboratory (NOAA), and the Solar Energy Research Institute (DOE). In May 1982, in conjunction with NRIP V, the New River intercomparisons became partially self-supporting on a participating fee basis. NRIP VI was held in November 1983 and future intercomparisons are planned for November 1985, and thereafter on a biannual basis.

The success of the NRIPs has been largely due to the helpful support and enthusiasm of Mr. Edwin Flowers of NWS/SRL/NOAA, Mr. John Hickey of The Eppley Laboratory, Mr. James Kendall of the Jet Propulsion Laboratory, and Mr. Chester Wells of the Solar Energy Research Institute.

OPERATION OF THE NRIPs

More than 40,000 individual instantaneous irradiance readings have been accumulated by five different absolute cavity radiometers in NRIP I through VI, as shown in Table 1. Five different cavity designs from the United States, Canada, Switzerland, Italy and the People's Republic of China have contributed to this data base.

TABLE 1
NRIP Instrument Breakdown

Intercomparison	Date	New	Total	Solar Observations
NRIP I	Nov. 1-5, 1978	14	14	315
NRIP II	May 2-5, 1979	4	12	441
NRIP III	Nov. 5-9, 1979	4	17	550
NRIP IV	Nov. 17-19, 1980	4	15	465
NRIP V	May 3-5, 1982	2	7	798
NRIP VI	Nov. 14-18, 1983	3	16	525

Dates for the intercomparisons are selected to ensure the greatest probability of cloud- and haze-free conditions. The site at New River, Arizona is distinguished by a combination of moderate temperatures, low average humidity, clear sky conditions, and high average daily sunshine for the times of year chosen.

Outdoor laboratory facilities were constructed specially for the NRIP experiments. They consist of three permanent double-tiered instrument benches, with the upper table serving as the cavity mounting deck, which in turn shades a lower electronic shelf that also doubles as working desk space. Each table accommodates eight experimenters, making it possible to intercompare 24 cavity radiometers at a time.

Instantaneous readings are organized into 10-minute sequences of 21 readings at 30-second intervals (some ACR-type instruments obtained 11 readings at 1-minute intervals). Readings for all instruments are sensed within less than 1 second of each other to minimize scatter between instruments due to rapidly changing sky conditions. Calibrations are usually performed both before and after each experimental sequence with the apertures shuttered. A complete description of the NRIP comparisons has been published by Estey and Seaman[2], and a summary by Zerlaut[3].

Direct beam spectral measurements were obtained during NRIP V (May 1982) and NRIP VI (November 1983) employing DSET's Scanning Solar Spectroradiometer. The spectroradiometer design has been described previously[4]; it is based on a Leiss dual-prism quartz monochromator with source optics consisting of a pyrheliometer comparison tube/integrating sphere receiver. Complete solar spectral measurements were obtained in the 300 to 2500 nm region in a 4-minute period. The field of view and slope angle of the occulting tube match exactly those of the Eppley Model NIP Pyrheliometer. Data obtained represented a band pass resolution of from 4 nm in the middle ultraviolet to 50 nm in the 2300 nm wavelength region.

SUMMARY OF NRIP I THROUGH NRIP VI

Summary results of NRIP I through V have been compiled by the author[3]. These data have been updated by adding results of the recently completed NRIP VI and are presented in Table 2. The standard deviation (S.D.) shown is the statistical average of the S.D. computed for each intercomparison in which the instrument was involved. The standard deviation of all readings (weighted average of the individual S.D.'s) is 0.0011.

The excellent agreement obtained between all absolute cavity instruments (with the agreement being to within 0.25% for more than 40,000 instantaneous measurements) is attributed principally to (1) the excellent quality of currently available absolute cavity instruments, (2) the quality of the environmental conditions obtained at New River for the times of the year chosen for the intercomparisons, and (3) the improved techniques with which the experimenters themselves operate their respective instruments as a result of the experience gained.

COMPARISON OF NRIP INSTRUMENTS TO SN 67502

Data for each intercomparison are also obtained by ratioing the irradiance of each instrument to that of the agreed upon reference instrument — NOAA/SRL's SN 67502. The set values are given in Table 3 for these instruments that have participated in most of the NRIP's. Also, the ratios to SN 67502 are given for the results of IPC V (Davos, 1980) for those instruments that have participated in both. This was done by normalizing IPC V data[4] to SN 67502 results for those instruments.

TABLE 2

Results of NRIP I through NRIP VI with Ratio of Each Instrument to Group Mean

Model	SN	Participant	NRIPs	N	Weighted Mean Ratio	S.D.x
EPAC	11399	AES, Canada	1,3	40	0.9997	±0.0021
*EPAC	11402	The Eppley Lab.	1	15	1.0008	0.0018
*EPAC	12843	NOAA	3,4	50	0.9968	0.0042
,H-F	14915	The Eppley Lab.	1 thru 6	140	1.0010	0.0009
H-F	14917	NASA-Lewis	2	22	0.9995	0.0004
*H-F	15745	NOAA (SRL)	1,2,3,4,6	122	0.9973	0.0007
,H-F	17142	DSET Labs	2 thru 6	137	1.0006	0.0013
,H-F	18747	AES, Canada	3	25	0.9990	0.0007
H-F	18748	The Eppley Lab.	3,4	44	1.0026	0.0009
H-F	19743	Peop. Rep. China Met.	6	22	0.9973	0.0008
H-F	20294	Peop. Rep. China Met.	6	25	0.9992	0.0010
ACR	501	Boeing Aerospace	1,5,6	59	0.9966	0.0027
ACR	601	NOAA	3	24	1.0067	0.0028
ACR	904	Battelle Mem. Inst.	5	23	1.0027	0.0018
ACR	1104	Lawrence Berkeley Lab.	4	31	1.0079	0.0028
,*PMO	PMO2	PMOD/Davos, Switz.	3	29	1.0008	0.0007
MK VI	001	Jet Propulsion Lab.	2,3,4	74	1.0027	0.0017
,MK VI	67401	Tech. Measurements	1,2,3,4,6	117	0.9997	0.0010
,*MK VI	67502	NOAA (SRL)	1 thru 6	160	1.0005	0.0010
MK VI	67603	Sandia Natl. Lab.	1,2,3,6	84	0.9999	0.0011
,MK VI	67702	Jet Propulsion Lab.	1,2,3,4,6	116	1.0011	0.0009
MK VI	67706	So. Cal. Edison	1,2,3,4,6	118	1.0004	0.0010
MK VI	67707	Utah State Univ.	1	15	1.0000	0.0011
MK VI	67811	Sandia Natl. Lab.	2	11	0.9997	0.0006
MK VI	67812	Ga. Institute of Tech.	1,3	40	0.9980	0.0007
,MK VI	67814	SERI	1 thru 6	162	0.9990	0.0006
MK VI	68017	SERI	4	27	0.9989	0.0006
MK VI	68018	SERI	4,5,6	94	1.0017	0.0009
MK VI	68020	Martin Marietta	4	31	0.9990	0.0006
MK VI	68021	Stazione Astron. Italy	6	24	0.9978	0.0009
MK VI	68022	Sandia Natl. Lab.	6	13	1.0012	0.0005

N = Number of 21-reading sets (runs) in which each instrument has participated

* = Also compared in IPC IV, Davos, November 1975

, = Also compared in IPC V, Davos, November 1980

These data are plotted in Figure 1 and 2 to show instrument trends. All instruments show a general trend to greater sensitivity compared to SN 67502. The marked similarities in data for NRIPs I, II and III leads to speculation that the reference instrument SN 67502 exhibited a decrease in sensitivity of about 0.15% in the period since May 1979. Also, one of the most important attributes of the frequency and procedures employed in the NRIPs is manifest in the behaviour of SN 17142 (the author's instrument). As a result of the nearly 0.5% apparent decrease in sensitivity of this instrument in NRIP V, the cavity was examined and several large dust particles were observed. After removal by blowing with an optics bulb, the apparent sensitivity increased and the instrument again essentially assumed its historical position among its peer group.

TABLE 3
Ratio of Each Instrument to the NOAA/SRL
Reference Cavity, SN 67502

	NRIP			Davos IPC	NRIP		
Inst.SN	**1**	**2**	**3**	**V**	**4**	**5**	**6**
14915	0.9984	0.9984	1.0013	1.0005	1.0011	1.0016	1.0006
15745	0.9963	0.9955	0.9971	—	0.9971	—	0.9975
17142	—	1.0008	1.0012	1.0005	1.0019	0.9971	1.0009
67401	0.9968	0.9956	1.0019	1.0004	0.9996	—	1.0006
67502	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
67603	0.9966	0.9980	0.9999	—	—	—	0.9998
67702	0.9940	0.9996	1.0023	1.0005	1.0019	—	1.0020
67706	0.9992	0.9983	1.0003	—	1.0002	—	1.0010
67814	9.9978	0.9968	0.9989	0.9974	0.9988	0.9989	0.9986
68018	—	—	—	—	1.0021	1.0013	1.0014

COMPARISON OF THE NRIPs WITH IPC IV AND V

Unlike the WMO-sanctioned intercomparisons held every five years at Davos where only the cavity is compared, the New River intercomparisons compare the cavity and its associated electronic data logging and readout equipment. The advantages of the NRIP-type comparisons are that the actual equipment compared is the same as employed by the participants when they use absolute cavity radiometers as primary reference instruments in their own laboratories. Hence, the performance of individual instruments compare in NRIPs has greater reference significance, if not greater credibility, than the same instruments compared at Davos.

The advantages of the NRIP intercomparisons relate to the de facto maintenance of the SI Radiometric Scale (WRR) in the U.S. by this peer group of instruments. To the reference quality of the intercomparisons for citation and traceability purposes, and to the availability of representatives of the peer grouping for the calibration and quality controlpurposes of any given organization.

ACKNOWLEDGEMENTS

The author wishes to thank Ms. Claudene Fliegel for data entry and computer analyses that made this report possible.

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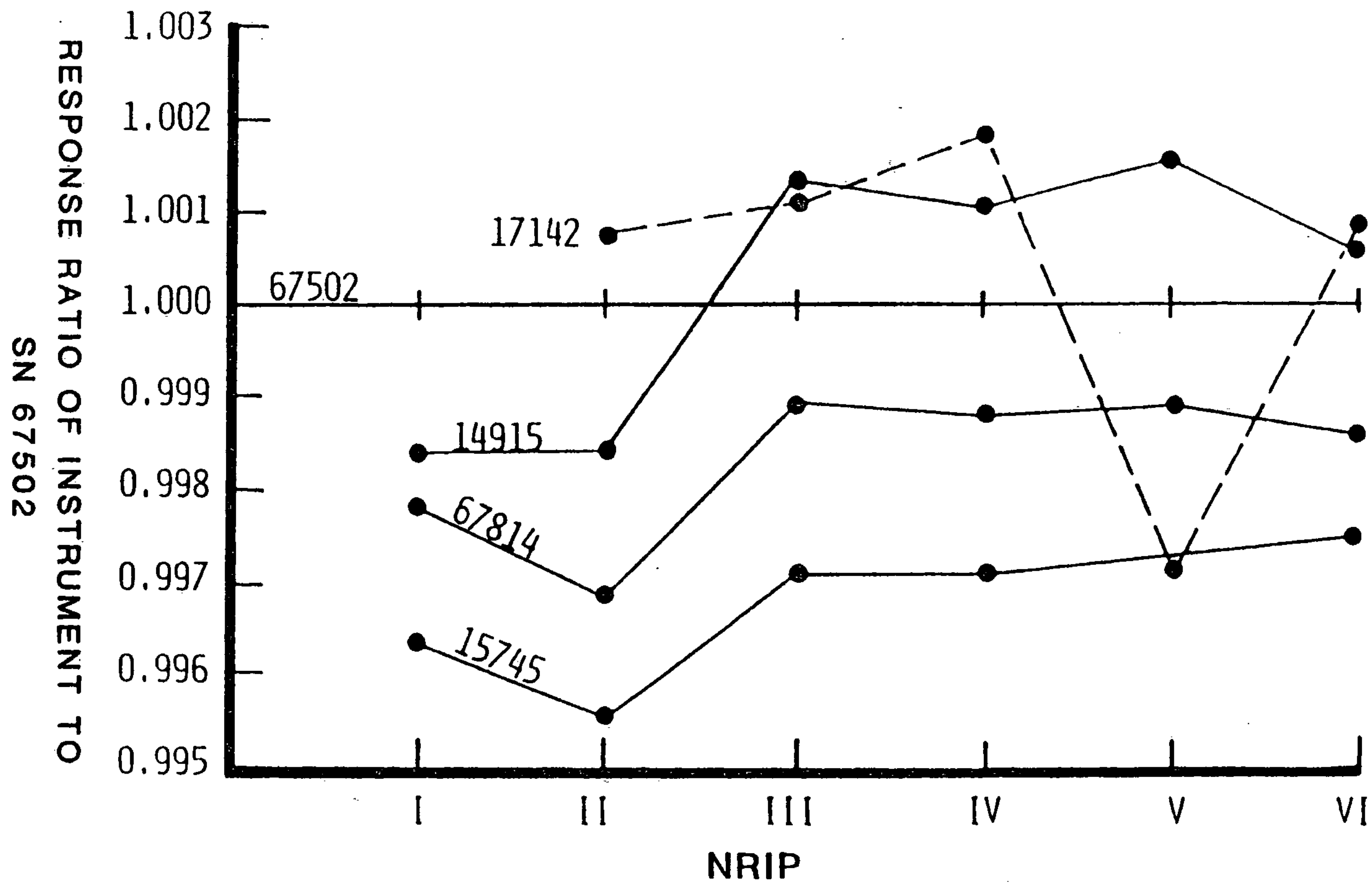

Figure 1. Comparison of several NRIP cavities to the NOAA reference, SN 67502

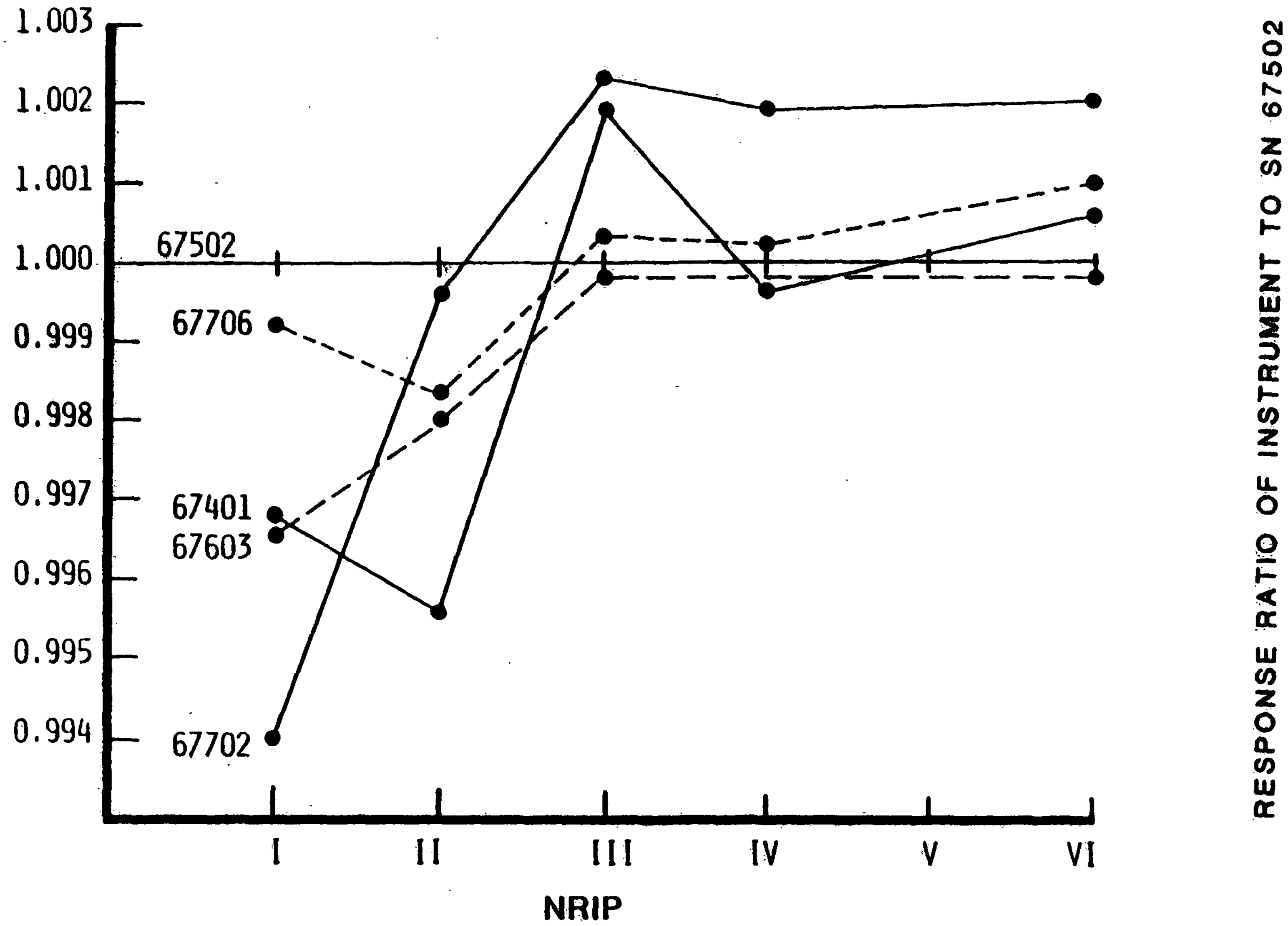

Figure 2. Comparison of several NRIP cavities to the NOAA reference, SN 67502