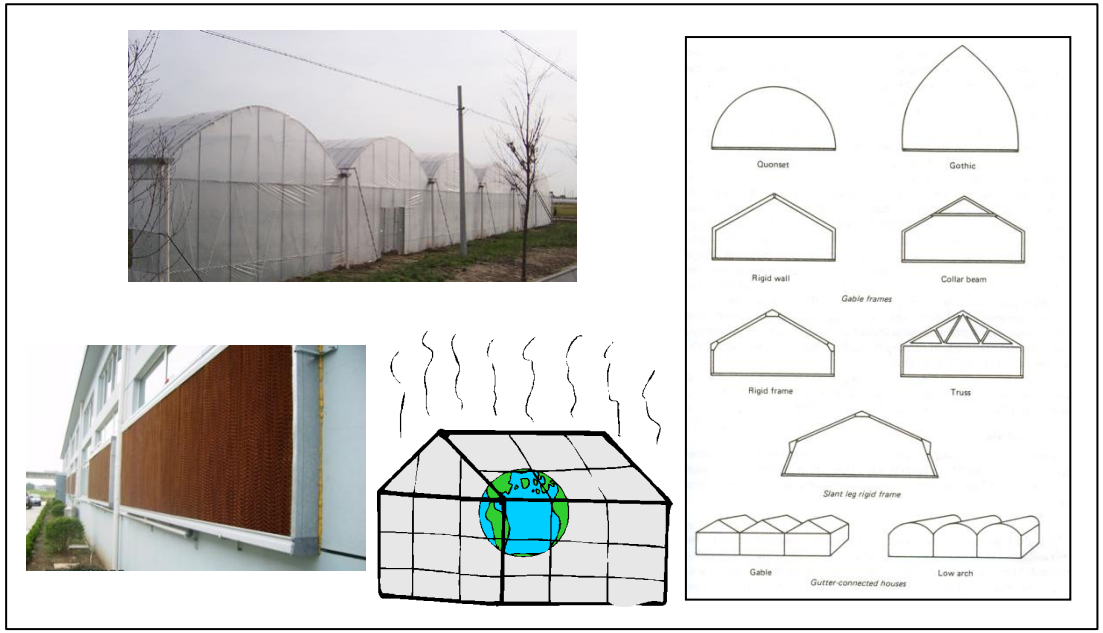
Engineering of Greenhouses

Lecture 4: Psychrometrics & Instruments



Psychrometrics

Station : Giza

Latitude: 30.03 Longitude: 31.13 Elevation: 19 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	5	5	1	0	0	0	0	0	0	0	2	6	19
Temp. average	12.2	13.5	16.3	19.8	23.2	26.5	27.0	26.7	25.2	22.7	18.5	14.0	20.5
Temp. mean max.	19.5	21.0	24.2	28.2	31.7	34.7	34.2	34.3	32.5	30.1	25.3	21.2	28.1
Temp. mean min.	6.3	6.6	10.1	12.0	15.2	18.8	20.1	20.3	18.5	16.0	12.2	8.2	13.7
Temp. mean day	15.3	16.4	19.7	23.1	26.4	29.6	29.6	29.7	27.9	25.4	21.0	16.9	23.4
Temp. mean night	11.0	11.8	15.1	17.6	20.6	23.9	24.4	24.4	22.5	19.8	15.7	11.6	18.2
Vapour pressure	10.3	10.5	11.5	13.1	15.0	19.0	22.0	23.1	21.1	18.2	15.5	11.3	15.9
Relative humidity %	77	75	66	64	60	61	67	70	71	71	79	74	70
Wind speed 2m	2.0	2.1	2.4	2.4	2.7	2.9	2.7	2.1	1.9	2.2	1.9	1.8	2.3
Sunshine %	68	72	73	75	80	86	85	85	85	82	78	70	78
Tot. radiation	280	354	441	519	585	627	613	577	512	417	326	268	459
ETo	2.1	2.7	4.0	5.1	6.4	7.3	6.8	6.1	5.2	4.2	2.8	2.2	4.6

Type of growing season: all year round dry
Dry days: 365
Interm. Days: 0
Wet days: 0

Precipitation mm/mo
Temp. ^{o}C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation $Cal/cm^2.day$
ETo mm/day

Psychrometrics

Station : Tahrir

Latitude: 30.39 Longitude: 30.42 Elevation: 20 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	10	7	1	1	1	0	0	0	0	2	5	8	35
Temp. average	13.1	13.7	16.5	19.2	22.6	26.3	26.7	27.0	24.8	22.2	18.5	14.5	20.4
Temp. mean max.	19.6	20.5	24.0	28.0	31.7	34.3	34.5	34.8	32.5	30.2	25.7	21.5	28.1
Temp. mean min.	7.8	8.0	10.1	12.5	15.1	18.8	20.3	20.8	18.7	16.5	13.2	9.5	14.3
Temp. mean day	15.9	16.6	19.6	23.1	26.4	29.3	29.9	30.2	28.0	25.7	21.6	17.5	23.6
Temp. mean night	12.1	12.5	15.0	17.8	20.6	23.8	24.6	24.9	22.6	20.2	16.5	12.6	18.6
Vapour pressure	11.5	11.7	13.2	14.2	16.5	21.0	23.5	24.5	22.2	19.0	16.0	12.6	17.2
Relative humidity %	80	79	76	68	66	68	71	72	74	73	77	78	74
Wind speed 2m	3.1	3.6	3.8	3.6	3.6	3.3	3.0	2.5	2.4	2.4	2.5	3.0	3.1
Sunshine %	68	72	73	75	80	86	85	85	85	82	78	70	78
Tot. radiation	275	350	438	518	585	628	614	576	509	413	321	262	457
ETo	2.3	2.9	4	5.5	6.7	7.2	6.9	6.3	5.3	4.2	3	2.5	4.7

Type of growing season: all year round dry.
Dry days: 365
Interm. Days: 0
Wet days: 0

Precipitation mm/mo
Temp. ^{o}C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation $Cal/cm^2.day$
ETo mm/day

Psychrometrics

Station : Sakha

Latitude: 31.07 Longitude: 30.57 Elevation: 20 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	14	13	7	3	3	0	0	2	0	4	7	14	67
Temp. average	12.7	13.3	14.8	17.3	20.1	23.1	25.0	25.5	24.3	21.7	18.1	14.3	19.2
Temp. mean max.	19.3	20.5	23.0	27.0	31.1	32.0	34.0	33.5	32.0	29.8	25.8	21.5	27.5
Temp. mean min.	6.0	6.2	7.8	10.3	14.1	17.0	19.0	18.3	17.6	15.5	12.5	8.2	12.7
Temp. mean day	15.1	16.0	18.2	21.7	25.7	27.2	29.2	28.6	27.3	25.1	21.4	17.1	22.7
Temp. mean night	10.8	11.4	13.2	16.1	19.7	21.8	23.6	22.7	21.7	19.3	16.0	11.7	17.3
Vapour pressure	10.8	11.1	11.7	12.6	14.1	17.8	21.1	22.5	21.3	18.5	15.3	12.3	15.8
Relative humidity %	82	82	76	68	59	65	68	75	75	75	76	81	74
Wind speed 2m	1.3	1.4	1.7	1.5	1.5	1.5	1.3	1.3	1.1	1.0	1.1	1.1	1.3
Sunshine %	69	71	73	78	78	85	84	86	85	83	77	66	77
Tot. radiation	273	344	435	517	576	625	610	579	507	412	315	250	453
ETo	1.8	2.3	3.3	4.4	5.5	5.9	5.9	5.5	4.5	3.4	2.4	1.7	3.9

Type of growing season: Intermediate season
Dry days: 359
Interm. Days: 6
Wet days: 0
Season NR: 1
Season begins on 24 Dec.

Precipitation mm/mo
Temp. °C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation Cal/cm^2.day
ETo mm/day

Psychrometrics

Station : Ismailia

Latitude: 30.35 Longitude: 30.26 Elevation: 20 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	7	2	7	1	5	0	0	0	0	3	10	3	38
Temp. average	12.6	13.5	16.3	20.2	23.1	26.8	27.3	27.5	25.3	22.5	18.5	14.3	20.7
Temp. mean max.	19.8	21.0	23.8	28.6	31.1	35.0	35.0	35.0	32.7	30.2	25.6	21.5	28.3
Temp. mean min.	7.0	7.6	9.8	13.0	16.0	19.5	20.8	21.1	19.1	16.3	12.7	8.8	14.3
Temp. mean day	15.8	16.8	19.4	23.7	26.3	30.0	30.4	30.5	28.3	25.6	21.3	17.3	23.8
Temp. mean night	11.6	12.4	14.7	18.4	21.0	24.5	25.1	25.1	23.0	20.1	16.1	12.1	18.7
Vapour pressure	8.8	9.7	8.3	9.0	11.5	15.1	19.2	20.0	16.7	15.7	13.0	10.0	13.1
Relative humidity %	63	66	48	42	44	47	56	58	55	61	64	64	56
Wind speed 2m	1.6	1.8	2.1	1.9	1.7	1.4	1.7	1.6	1.4	1.4	1.2	1.4	1.6
Sunshine %	69	71	71	74	77	85	84	85	85	82	77	68	77
Tot. radiation	278	349	431	514	572	624	609	576	509	413	319	259	454
ETo	2.2	2.7	4.2	5.3	5.9	6.4	6.6	6.1	5.1	3.9	2.6	2.1	4.4

Type of growing season: all year round dry.

Precipitation mm/mo
Temp. °C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation Cal/cm^2.day
ETo mm/day

Psychrometrics

Station : Gemmeiza

Latitude: 30.43 Longitude: 31.07 Elevation: 20 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	8	6	4	2	3	0	0	0	0	3	7	18	51
Temp. average	12.3	13.1	15.3	19.0	23.0	25.6	27.0	27.0	25.0	22.7	19.3	15.1	20.4
Temp. mean max.	19.5	20.6	23.2	27.7	32.0	34.0	34.5	34.6	32.7	30.5	25.6	21.7	28.1
Temp. mean min.	5.2	5.6	7.3	10.0	14.1	17.2	19.2	19.1	17.1	15.0	13.1	8.5	12.6
Temp. mean day	15.0	15.9	18.2	22.1	26.3	28.6	29.6	29.6	27.6	25.4	21.5	17.3	23.1
Temp. mean night	10.4	11.0	12.9	16.1	20.0	22.6	23.8	23.6	21.5	19.2	16.4	12.0	17.5
Vapour pressure	11.0	11.2	12.3	14.0	16.8	20.0	23.7	24.5	22.5	19.6	16.8	13.2	17.1
Relative humidity %	86	85	82	76	70	70	75	78	80	80	81	85	79
Wind speed 2m	0.8	1.2	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.8	0.7	0.8	0.8
Sunshine %	69	71	73	75	78	85	84	86	85	83	77	66	77
Tot. radiation	276	347	437	518	576	624	610	580	509	415	318	254	455
ETo	1.6	2.2	3	4	4.9	5.6	5.6	5.3	4.4	3.3	2.2	1.6	3.6

Type of growing season: Intermediate season
Dry days: 338
Interm. Days: 27
Wet days: 0
Season NR: 1
Season begins on 5 Dec.
End of season on 1 Jan.
Total length of season is 28 days.

Precipitation mm/mo
Temp. °C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation Cal/cm^2.day
ETo mm/day

Psychrometrics

Station : Al Fayyum

Latitude: 29.04 Longitude: 31.06 Elevation: 28 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	0	2	1	1	0	0	0	0	0	0	0	4	8
Temp. average	12.8	14.1	17.0	21.0	25.1	27.2	28.3	28.5	26.3	23.7	19.1	14.8	21.5
Temp. mean max.	20.7	22.5	25.5	30.0	34.2	36.0	36.7	36.5	34.3	31.7	26.7	22.1	29.7
Temp. mean min.	5.0	5.8	8.5	12.0	16.1	18.5	20.0	20.2	18.3	15.7	11.5	7.5	13.3
Temp. mean day	15.7	17.2	20.1	24.3	28.4	30.4	31.3	31.2	29.1	26.4	21.7	17.3	24.4
Temp. mean night	10.6	11.8	14.5	18.2	22.1	24.1	25.1	25.0	22.9	20.1	15.6	11.4	18.4
Vapour pressure	8.5	8.3	8.8	9.8	11.5	13.6	17.0	17.5	17.5	15.2	12.1	10.5	12.5
Relative humidity %	66	60	53	47	42	43	50	51	58	59	62	70	55
Wind speed 2m	1.0	1.2	1.2	1.8	1.5	1.6	1.2	1.2	1.9	1.9	1.2	1.3	1.4
Sunshine %	74	78	77	81	80	90	89	90	88	85	81	72	82
Tot. radiation	301	378	459	545	584	643	630	598	526	432	342	280	476
ETo	2.0	2.8	3.7	5.5	6.1	6.9	6.5	6.1	5.8	4.6	2.9	2.2	4.6

Type of growing season: all year round dry.
Dry days: 365
Interm. Days: 0
Wet days: 0

Precipitation mm/mo
Temp. °C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation Cal/cm^2.day
ETo mm/day

Psychrometrics

Station : Asyut

Latitude: 27.03 Longitude: 31.01 Elevation: 70 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. average	13.5	15.0	18.5	23.7	27.5	30.0	29.7	30.3	27.5	24.3	19.3	15.1	22.9
Temp. mean max.	20.7	22.5	26.5	31.7	36.0	37.6	31.7	36.8	34.8	31.0	26.5	22.2	29.8
Temp. mean min.	6.7	7.5	10.5	14.8	19.5	21.5	22.2	22.3	20.0	18.0	12.7	8.7	15.4
Temp. mean day	16.3	17.8	21.4	26.3	30.7	32.4	28.6	32.1	30.0	26.7	22.0	17.7	25.2
Temp. mean night	11.7	12.8	16.1	20.6	24.9	26.7	25.1	26.6	24.3	21.6	16.5	12.4	19.9
Vapour pressure	7.0	7.0	6.7	7.0	8.0	11.0	14.1	15.0	14.2	14.0	10.7	8.3	10.3
Relative humidity %	50	47	36	28	24	30	41	40	43	50	52	52	41
Wind speed 2m	1.6	2.0	2.2	2.3	2.9	2.8	2.5	2.4	3.0	2.4	2.0	1.7	2.3
Sunshine %	85	88	83	81	85	90	90	92	89	88	87	87	87
Tot. radiation	344	421	490	549	604	639	631	608	538	454	373	330	498
ETo	2.8	3.7	5.1	6.6	8.6	8.9	7.5	7.7	7.4	5.3	3.8	2.9	5.9

Type of growing season: all year round dry
Dry days: 365
Interm. Days: 0
Wet days: 0

Precipitation mm/mo
Temp. °C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation Cal/cm^2.day
ETo mm/day

Psychrometrics

Station : Aswan

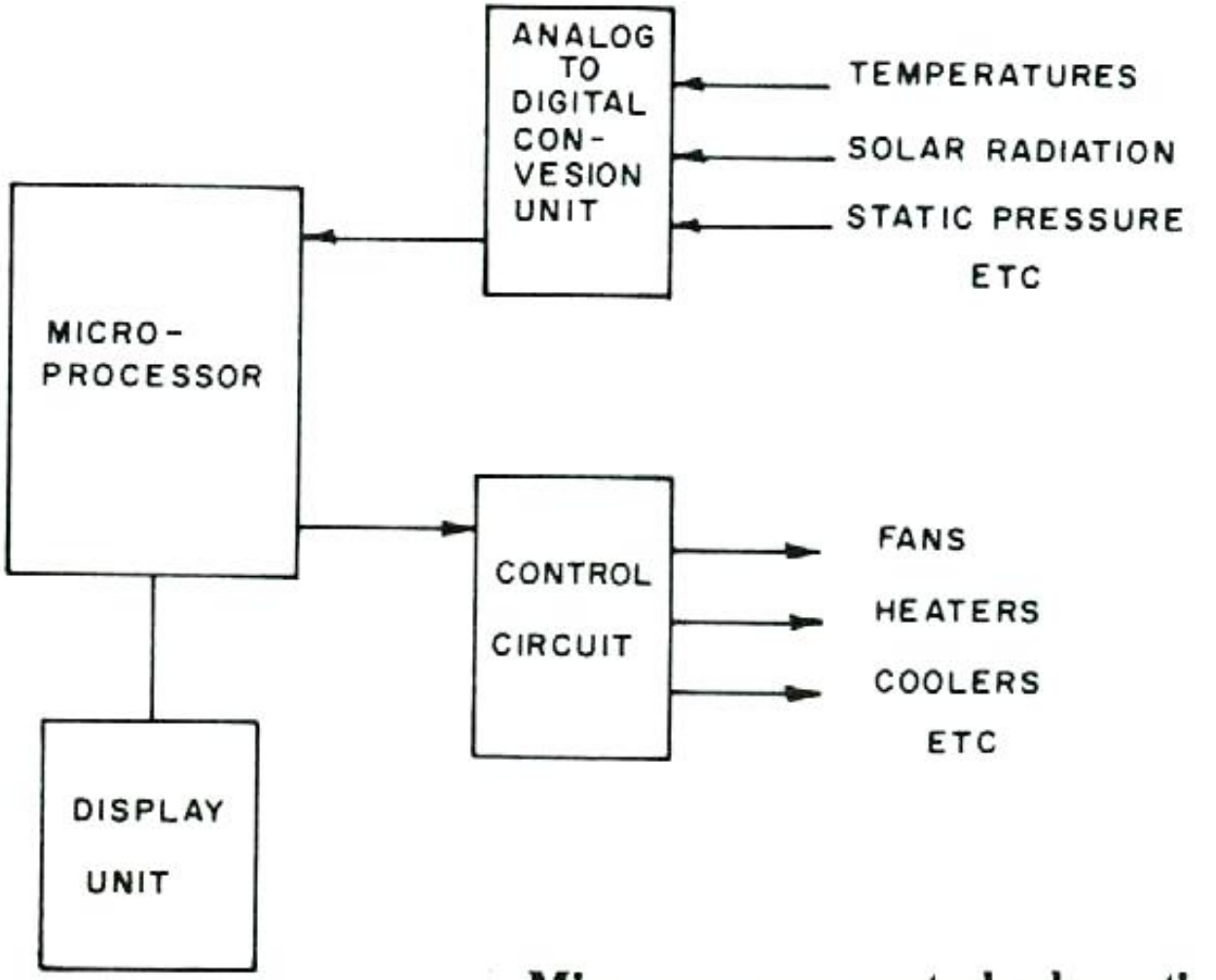
Latitude: 24.02 Longitude: 32.53 Elevation: 200 met.

Month / Characters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Precipitation	0	0	0	0	1	0	0	0	0	0	0	0	1
Temp. average	16.7	18.5	22.3	27.1	31.7	33.5	34.0	34.1	32.0	29.5	24.0	19.7	26.9
Temp. mean max.	24.1	26.5	30.6	35.6	40.2	42.0	41.8	42.0	40.0	37.5	32.6	26.5	35.0
Temp. mean min.	9.5	10.5	14.1	18.5	23.5	25.0	26.0	26.3	24.0	21.6	16.5	13.1	19.1
Temp. mean day	19.5	21.4	25.4	30.2	34.9	36.6	36.7	36.9	34.8	32.3	27.3	22.1	29.8
Temp. mean night	14.6	16.1	19.8	24.3	29.0	30.4	30.9	31.0	28.7	26.1	21.0	16.8	24.1
Vapour pressure	6.7	6.5	6.5	7.1	8.3	9.7	11.0	12.2	12.2	12.0	10.6	9.3	9.3
Relative humidity %	39	35	28	23	20	21	23	25	29	33	39	44	30
Wind speed 2m	1.5	1.9	2.2	2.3	2.5	2.0	1.6	1.8	1.8	1.9	1.3	1.6	1.9
Sunshine %	91	91	85	84	86	89	89	90	89	91	92	92	89
Tot. radiation	387	454	512	566	606	627	621	601	549	484	413	371	515
ETo	3.4	4.5	5.9	7.4	8.7	8.4	7.7	7.9	7.1	6.2	4.2	3.6	6.3

Type of growing season: all year round dry
Dry days: 365
Interm. Days: 0
Wet days: 0

Precipitation mm/mo
Temp. °C
Vapor pressure mbar
Wind speed m/sec
Tot. radiation Cal/cm^2.day
ETo mm/day

Control Unit



Microprocessor control schematic

Instruments

- Instruments for internal measurements, i.e. inside the greenhouse:

1. Data Logger, Thermocouples, Humidity Sensors, and Air Velocity Sensor
2. Lux Meter (Radiometer)
3. Barometer
4. Leaf Area Meter
5. Infrared Thermometer
6. Infra-Red Gas analyzer (IRGA)
7. Spectrophotometer
8. SPAD Chlorophyll Meter

Instruments

➢ Data Logger, Thermocouples, Humidity Sensors, and Air Velocity Sensors: they form a package which is used for measuring the microclimate conditions (internal dry-bulb temperature, relative humidity, and air velocity) inside the greenhouses, these conditions are the main criteria that determine the effectiveness of the ventilation, cooling, and/or heating systems.

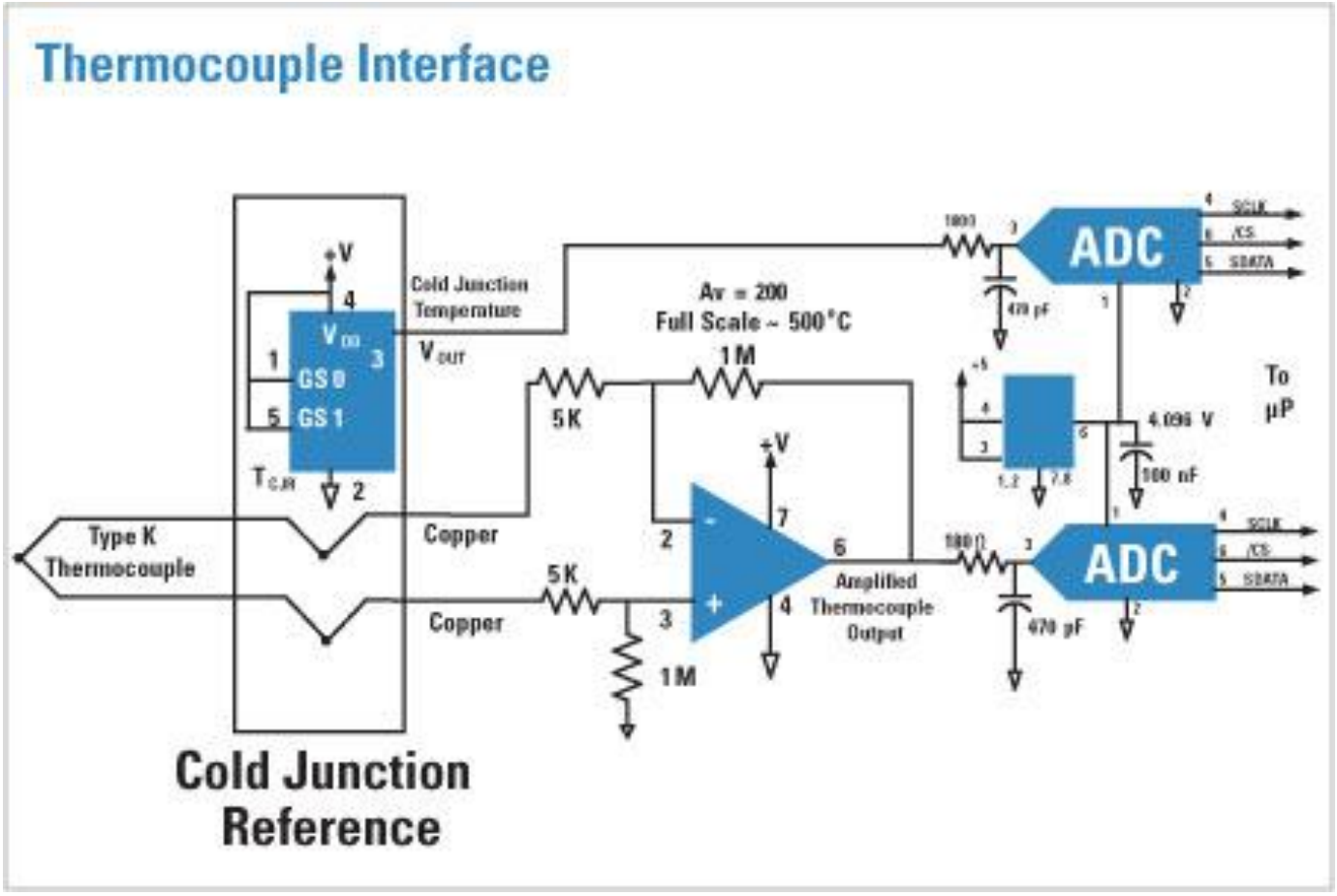
➢ Leaf Area Meter is important for determining the leaves' area of the plants which is a strong indicator of plant health. Infrared thermometer is used for measuring the temperature of plant leaves and covering material.

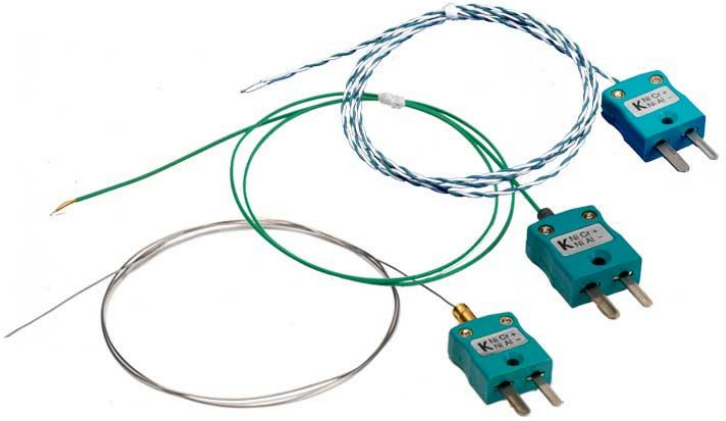
➢ IRGA (Infra-Red Gas Analyzer) measures CO_2 (respiration rate of the plants). Moreover, it is able to monitor the concentration of other gases, such as: NH_3, CH_4, N_2O, H_2O and O_2 which are important for animal housing.

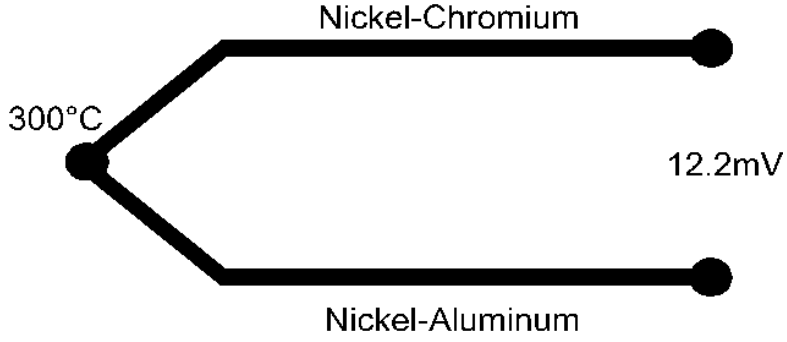
➢ Spectrophotometer estimates pigments, total carbohydrates & enzyme activity.

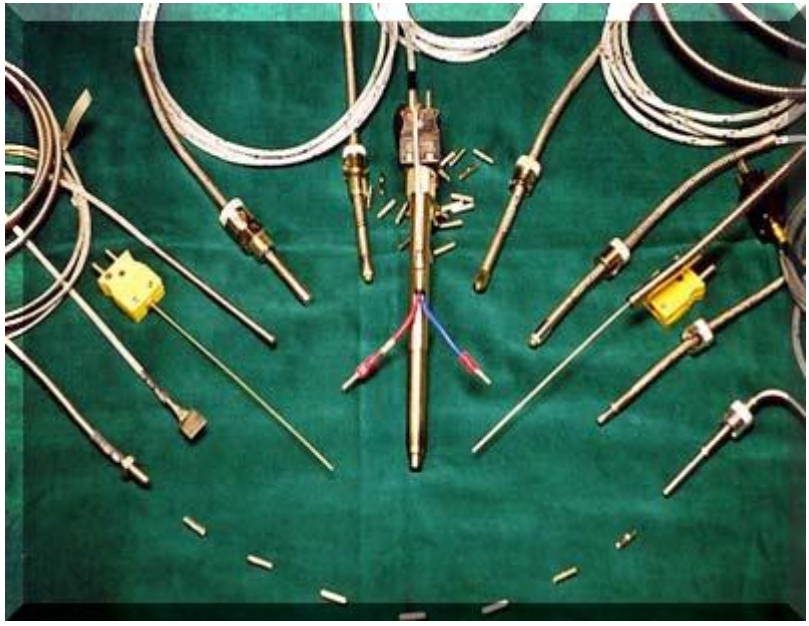
➢ SPAD Chlorophyll Meter estimates the chlorophylls content of leaves.

Thermocouples

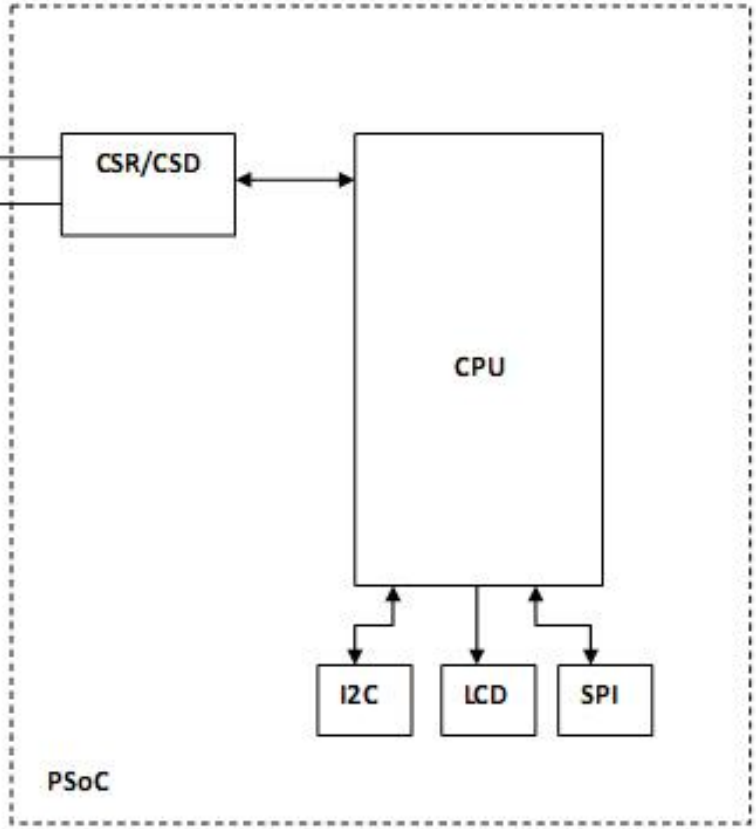








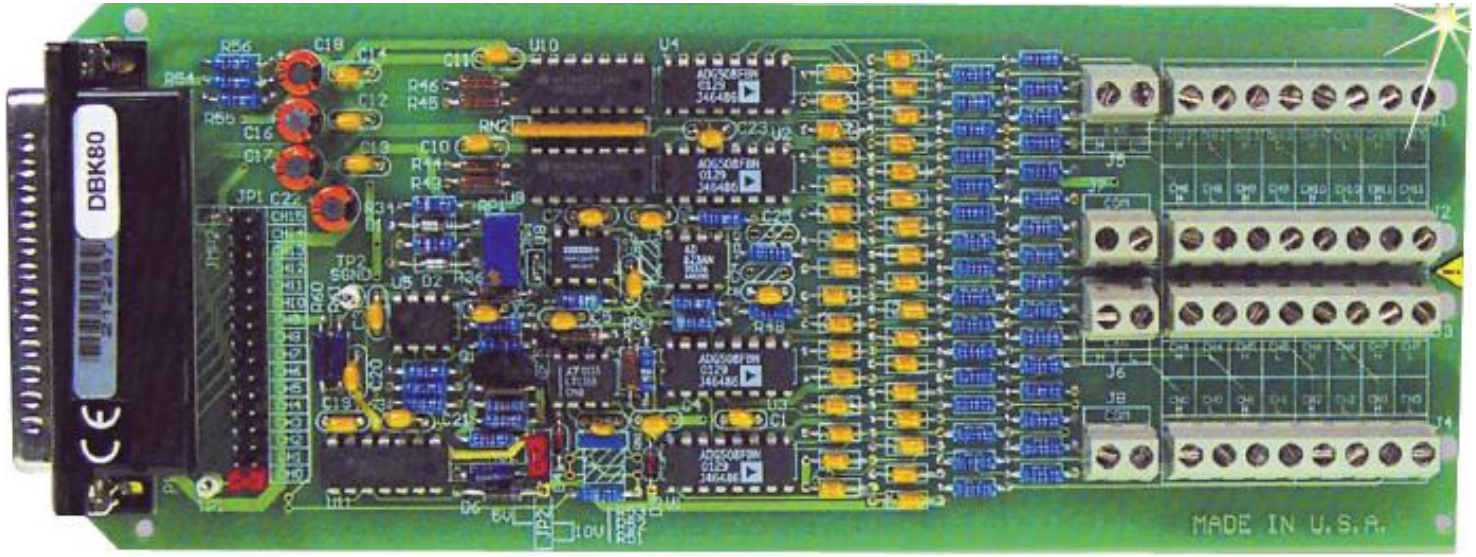
Humidity Sensors



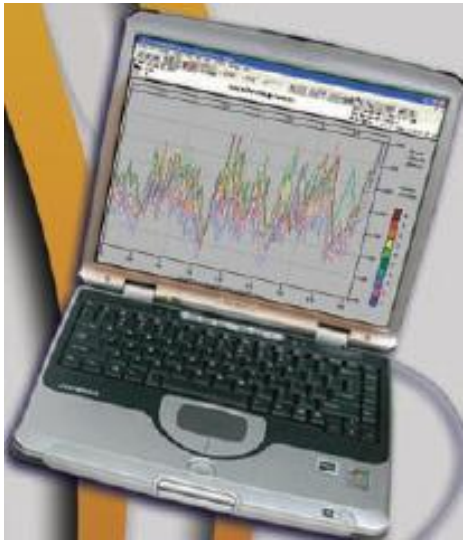
Air Velocity Sensors

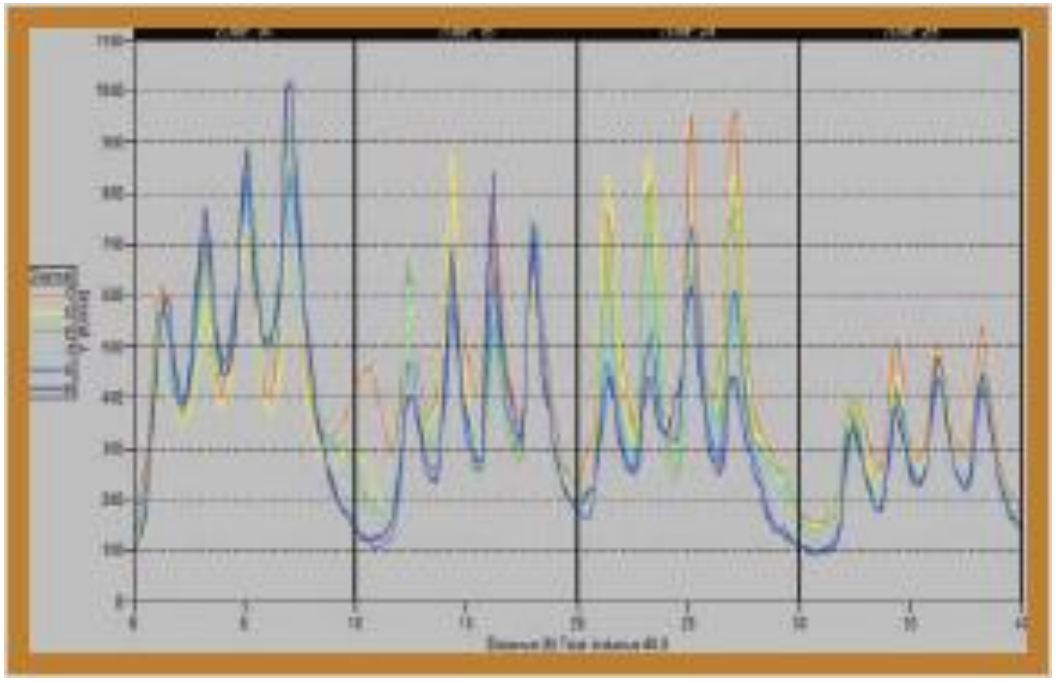
Data Logger

16-Channel Differential Input Voltage Card

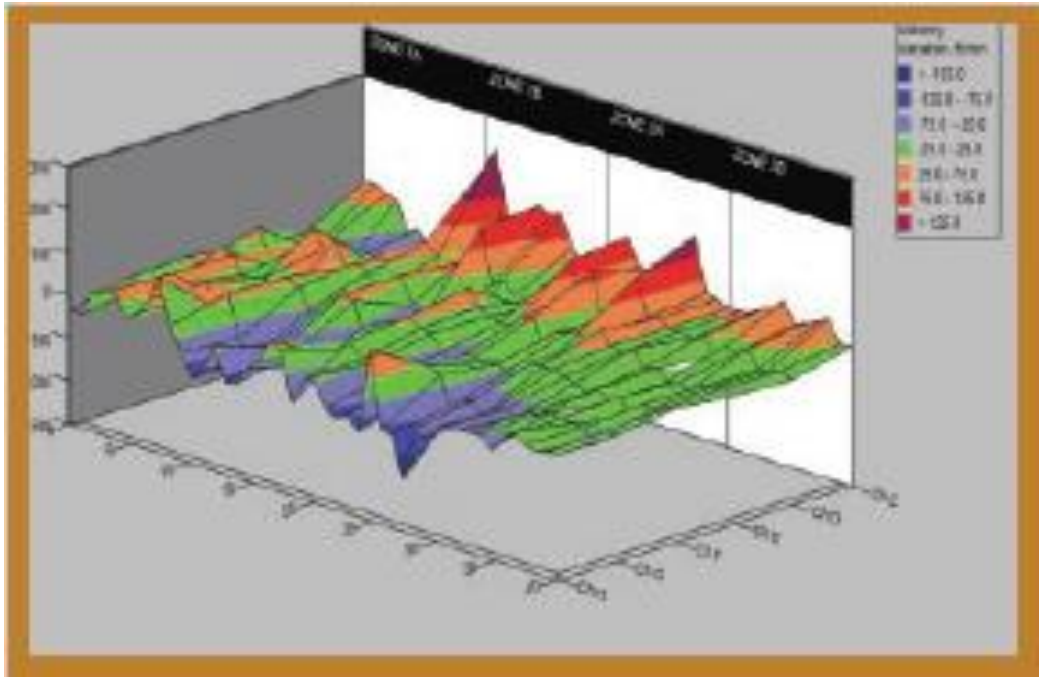


Results Analysis





2D Line Graph



3D Mesh Graph

Proforma Invoice

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QUOTATION
09/09019
Account No. CAI05

SOLD TO	SHIP TO
CAIRO UNIVERSITY	CAIRO UNIVERSITY
AGRICULTURAL ENGINEERING DEPT	AGRICULTURAL ENGINEERING DEPT
FACULTY OF AGRICULTURE	FACULTY OF AGRICULTURE
GAMMAA STREET	GAMMAA STREET
GIZA	GIZA
12613	12613
EGYPT	EGYPT

Cust PO No.	RFQ	Ship Via Carrier	U P S
Order Date	08 July 2009	Carrier Account No.	-
Despatch Date	10 August 2009	Shipping Terms	SHIPPING POINT
Buyer	DR M SAMER	VAT No.	EG
Sales Person	CHRIS MELIA	Terms	PRO-FORMA

	Part Number	Description	Qty Ord	Qty Rem	Unit Price US$	Disc %	Ext US$
1	HX93AV	TEMP/HUMIDITY TX VOLTAGE	8	8	224.99	5	1,709.95
2	FMA-905-I	AIR VELOCITY TRANSDUCER	8	8	881.98	10	6,350.24
3	OMB-LOGBOOK-300	PC BASED DAS SYS-REQ 1 MEMCARD	1	1	3,998.90	0	3,998.90
4	OMB-DBK80	16CH DIFFERNT INPT VOLT CARD	2	2	548.99	0	1,097.97
5	OMB-MEMCARD-10	1GB HARD DRIVE FOR OMB-LOGBOOK	1	1	494.99	0	494.99
6	OMB-DBK10	3 SLOT EXPANSION CARD ENCLOSURE	1	1	209.00	0	209.00
7	OMB-CA-37-2	CABLE	1	1	61.00	0	61.00
8	*CARRIAGE	SHIPPING CHARGES	1	1	255.00	0	255.00

Delivery: Approx. 6 week(s) from placement or order.
Quotation valid for a period of 60 days.

Total Goods Value	US$ 14,972.63
Less Discount	US$ -795.58
TOTAL	US$ 14,177.05

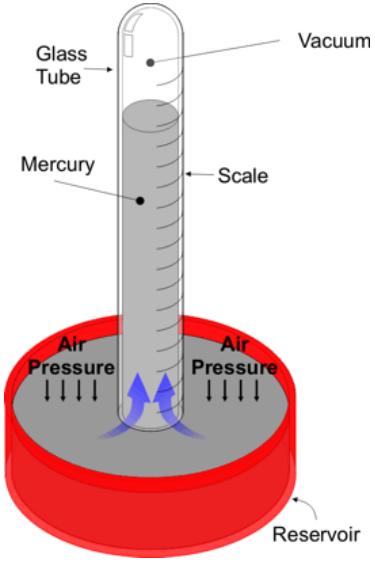
Lux Meter

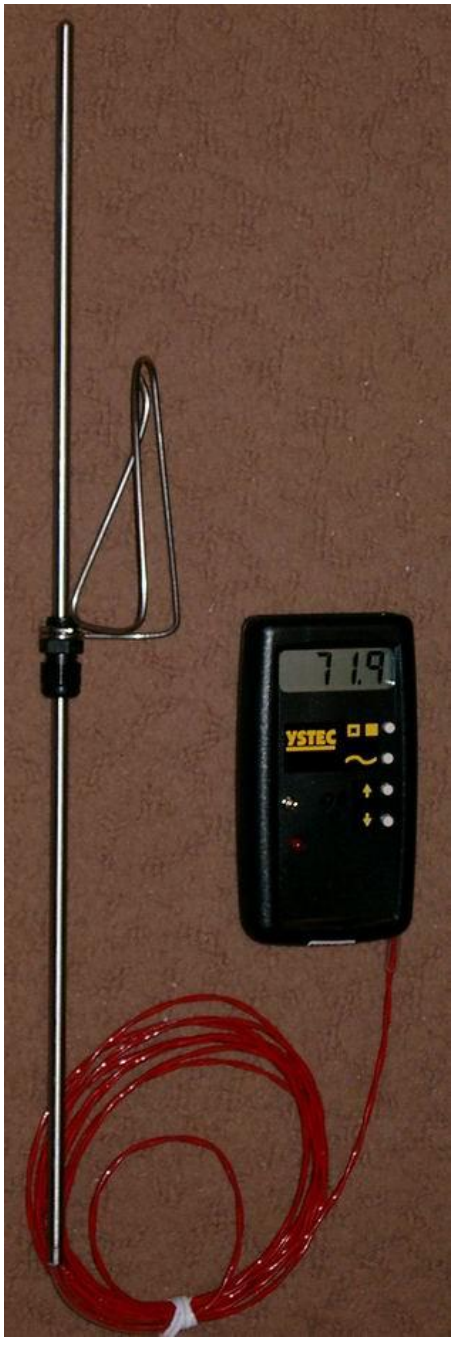
Portable Lux Meter

Lux Meter

Barometer

Traditional Barometer

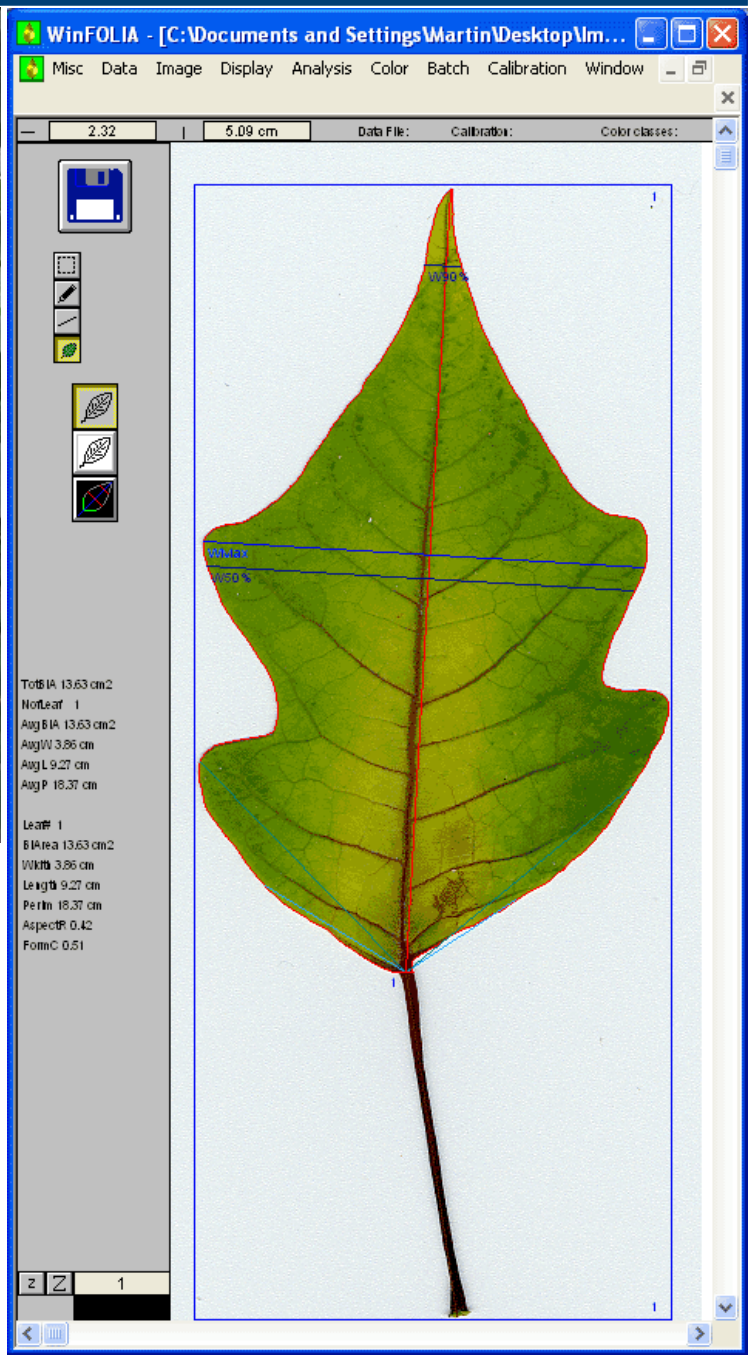




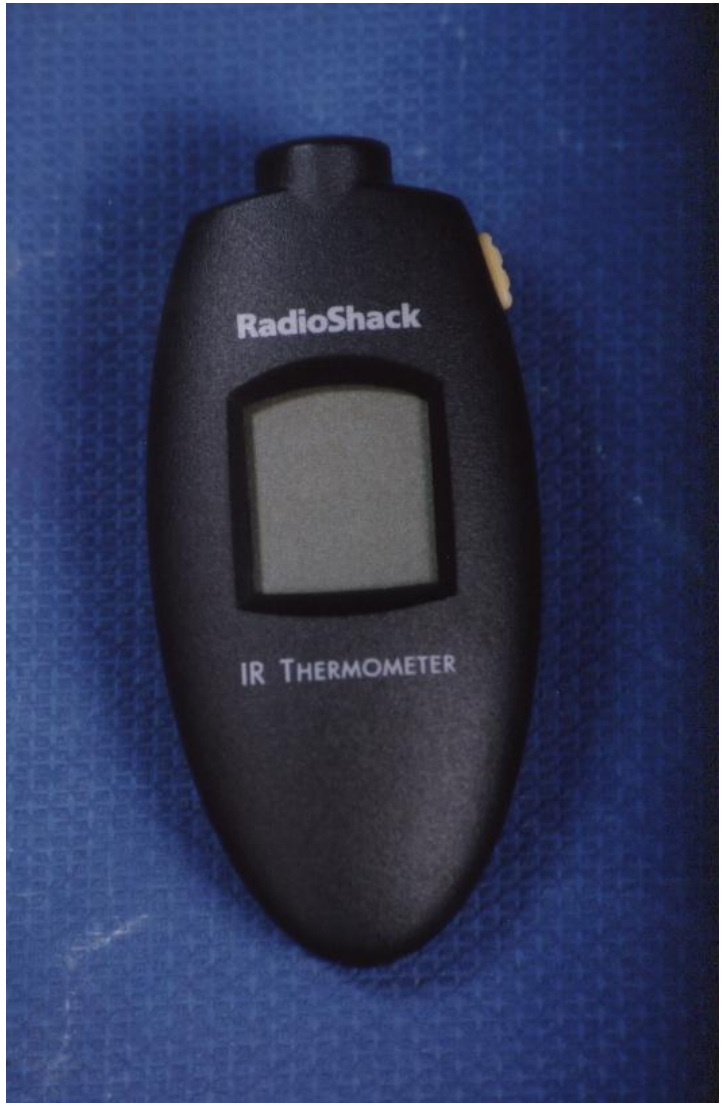
Digital Barometer

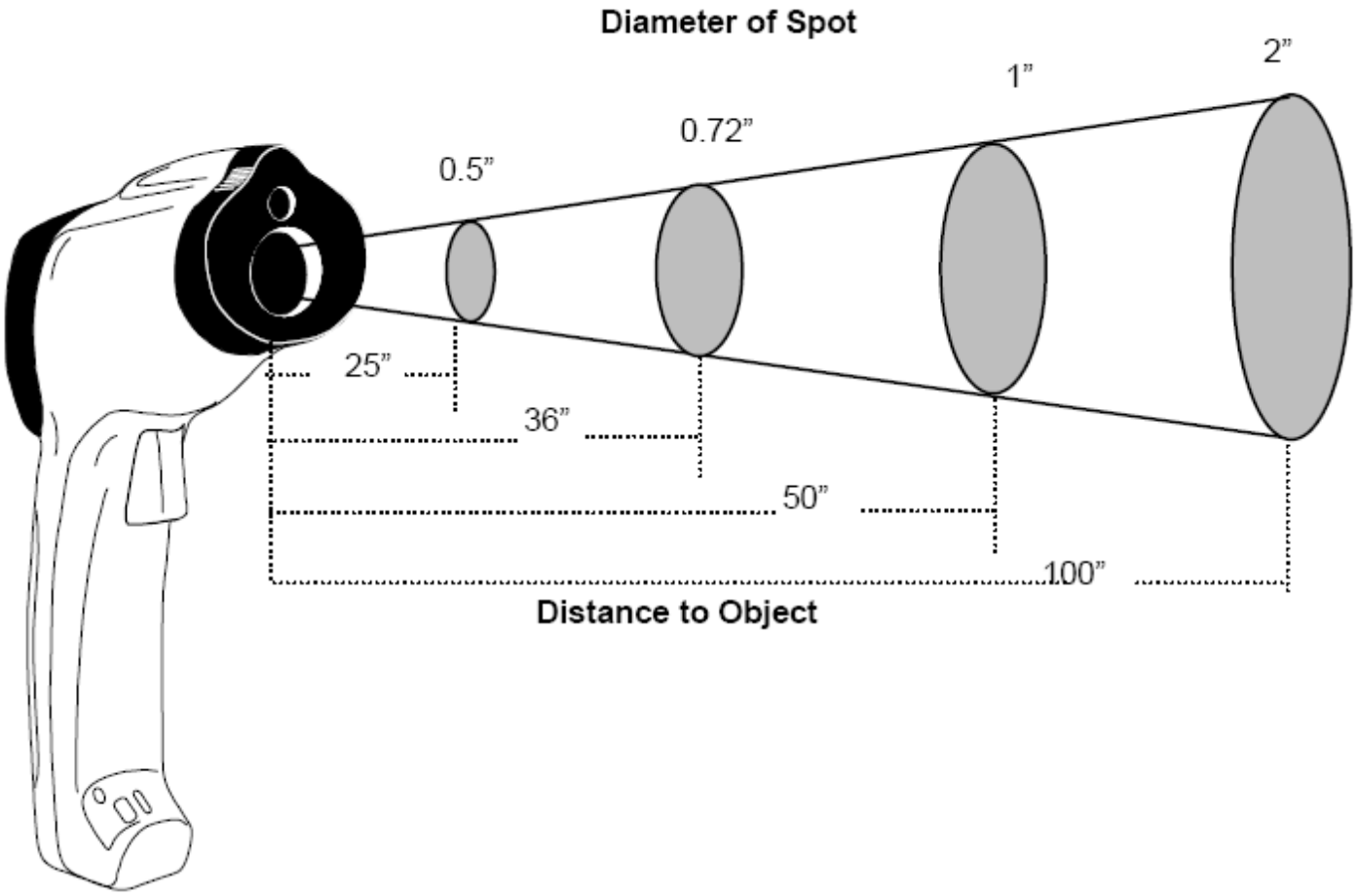
Portable Digital Barometer

Leaf Area Meter



Infrared Thermometer



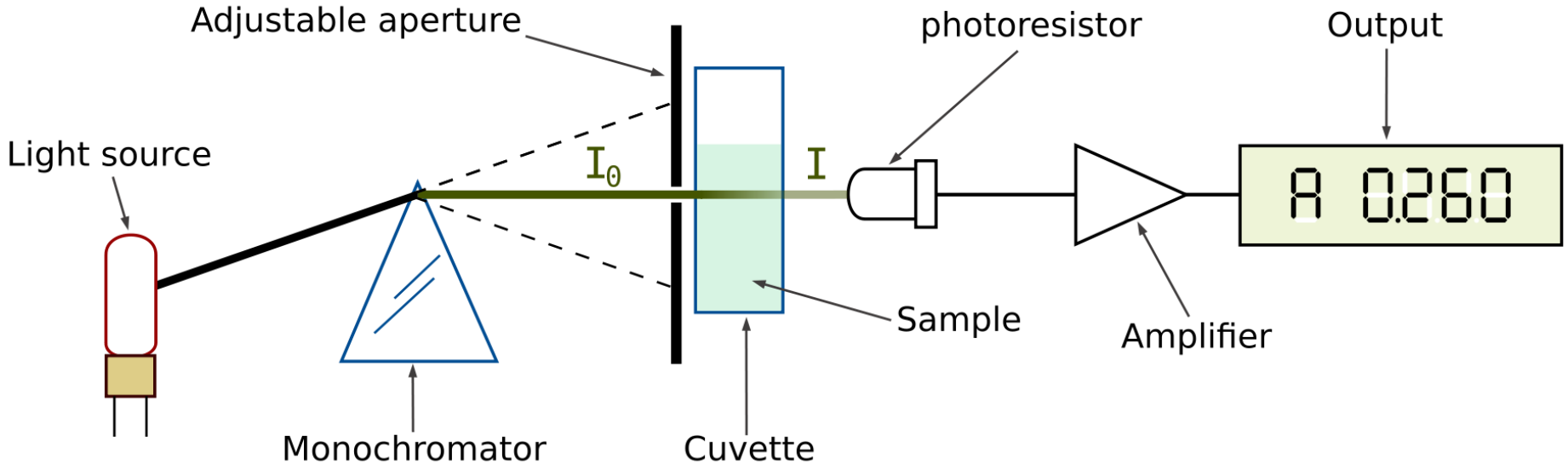


IRGA

Gas to be measured	Formula	LDL (ppm)
Ammonia	NH_3	1.0
Carbon Dioxide	CO_2	0.3
Carbon Monoxide	CO	1.0
CFCs/Freons		2.0
Dichloromethane	CH_2Cl_2	2.5
Methane	CH_4	2.0
Nitric Oxide	NO	5.0
Nitrogen Trifluoride	NF_3	0.5
Nitrous Oxide	N_2O	0.5
Sulphur Dioxide	SO_2	2.0
Sulphur Hexafluoride	SF_6	1.0
Toluene	$C_6H_5CH_3$	5.0
Water Vapour	H_2O	5.0

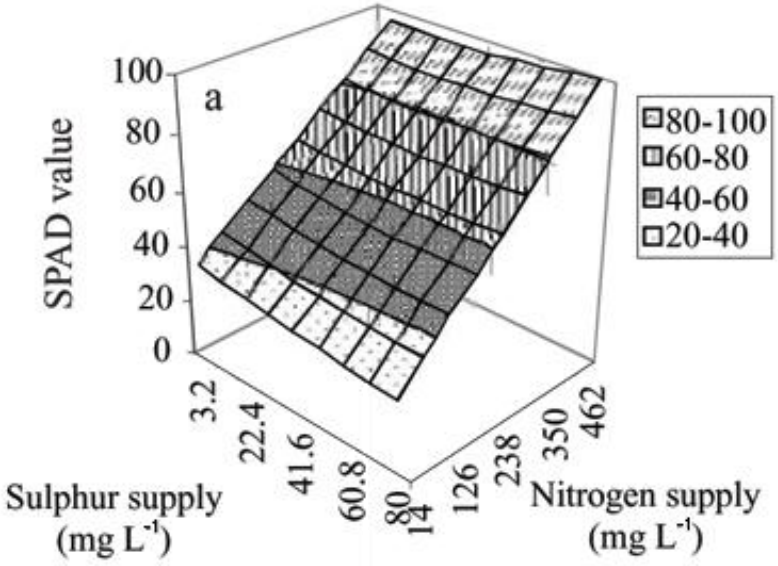
Spectrophotometer

A spectrophotometer is a photometer (a device for measuring light intensity) that can measure intensity as a function of the color (or more specifically the wavelength) of light.



SPAD Chlorophyll Meter

SPAD: Single-Photon Avalanche Diode, a solid-state electronic photodetector.



$Y=35.4373 + 0.1307N - 0.0002N^2 - 0.2341S - 0.0012S^2 + 0.0004NS$ ($R^2=0.85$)

SPAD value is on a scale of 0 to 100

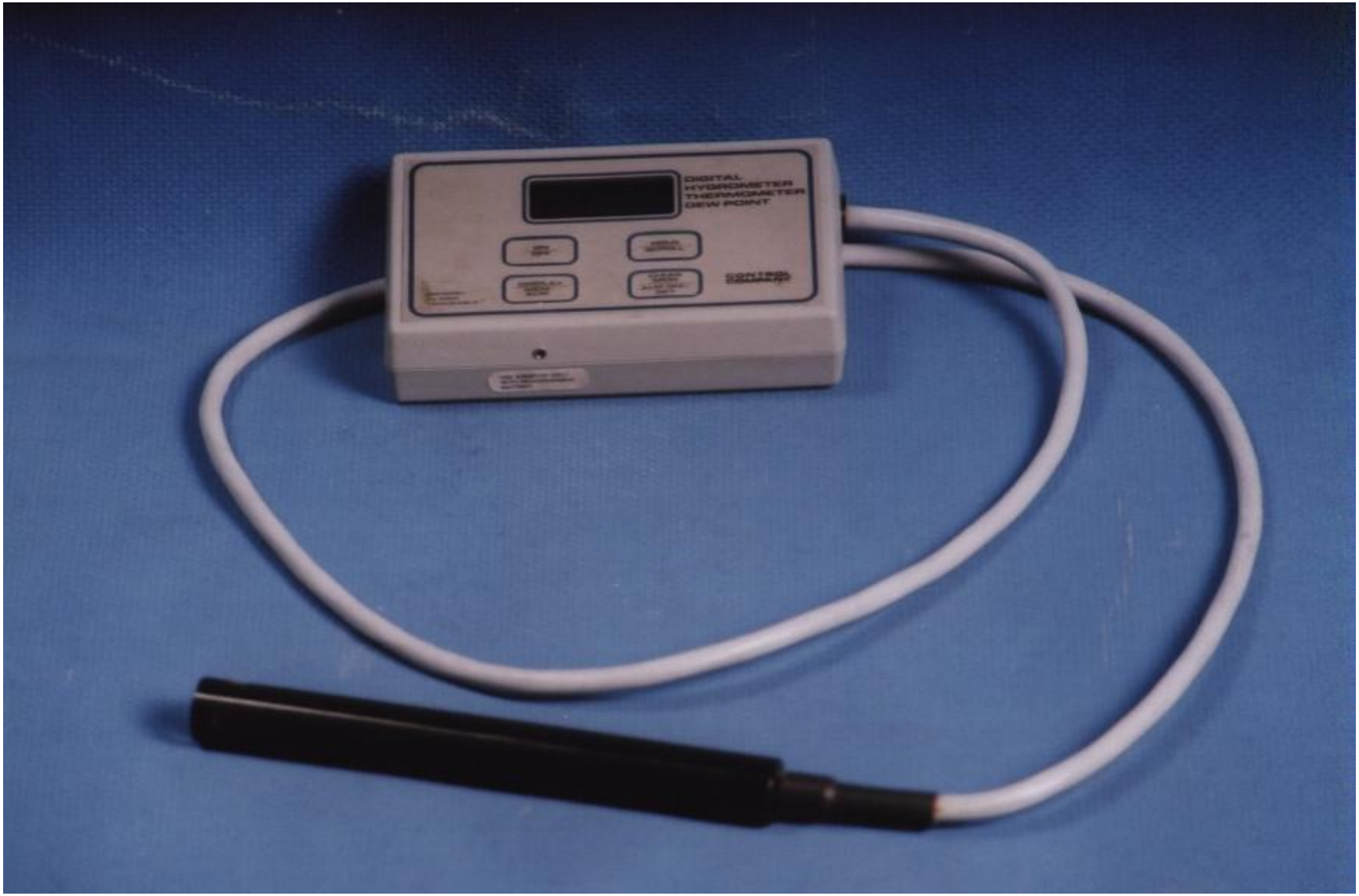
Instruments

- For on-site measurements of the external weather conditions:

1. Digital Hygrometer-Thermometer-Dew Point device

2. Vane Anemometer

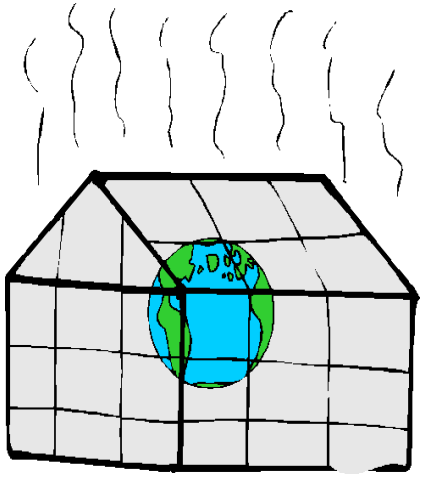
Digital Hygrometer-Thermometer

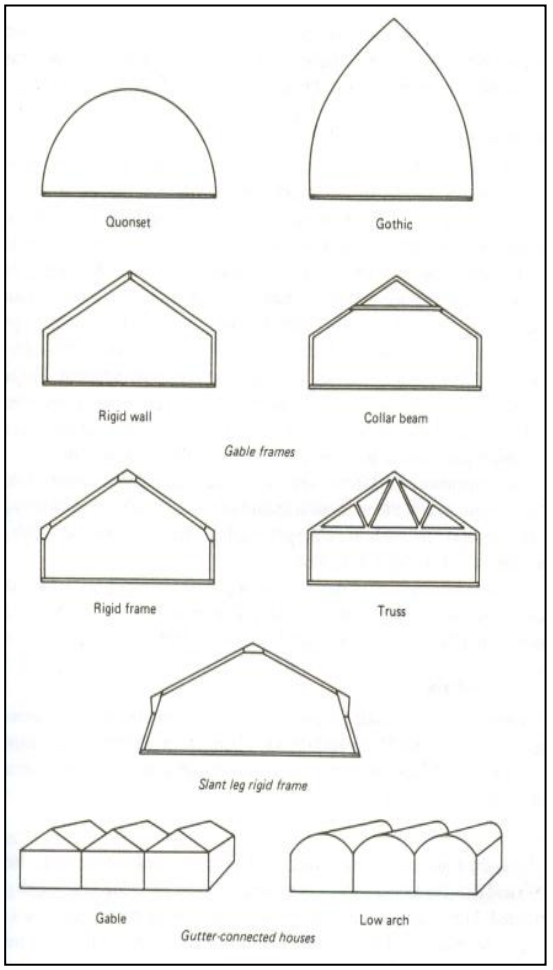


Vane Anemometer

Revision

Thank You




Quonset
Gothic
Rigid wall
Collar beam
Gable frames
Rigid frame
Truss
Slant leg rigid frame
Gable
Low arch
Gutter-connected houses