INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SECOND AUTUMN WORKSHOP ON
CLOUD PHYSICS AND CLIMATE

(23 November - 18 December 1987)

ATMOSPHERIC CLOUD PHYSICS MEASUREMENTS

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ATMOSPHERIC CLOUD PHYSICS MEASUREMENTS

SECOND AUTUMN WORKSHOP ON CLOUD PHYSICS AND CLIMATE

LECTURES TO BE GIVEN IN WEEK THREE OF THE COURSE

C P R Saunders, Physics Department, UMIST, Manchester, UK.

1 Basic Techniques.

a) Temperature.

i) Liquid in glass thermometers (eg mercury, alcohol)

ii) Thermocouples (eg copper/constantan).

iii) Thermistors

iv) Platinum resistance thermometers.

See Data sheets from Electroplan, PO Box 19, Orchard Rd. Royston Hertfordshire SG8 5HH UK

and Radio Spares (RS)
PO Box 99
Birchington Road
Weldon, Corby, Northants,
NN17 9RS, UK

and Sensing Devices Ltd (SDL)
See list of World addresses.

and John Fluke Mfg. Co Inc
(See list of World addresses)

b) Pressure.

i) Fortin barometer.

ii) Pressure transducers.

See Electroplan data sheets.

c) Humidity.

i) Wet and dry bulb. Sling psychrometer
ii) Novel UMIST probe.

d) Dew / Frost Point (Hygrometer)

Mitchell Instruments, Unit 9, Nuffield Close, Nuffield Rd., Cambridge, CB4 1SS Uk
(Tel. 0223-312427)

e) Liquid Water Content

i) Psychrometric Method

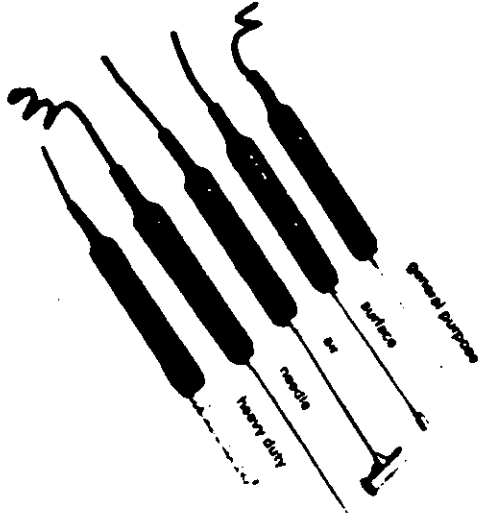
ii) Rotating target method.

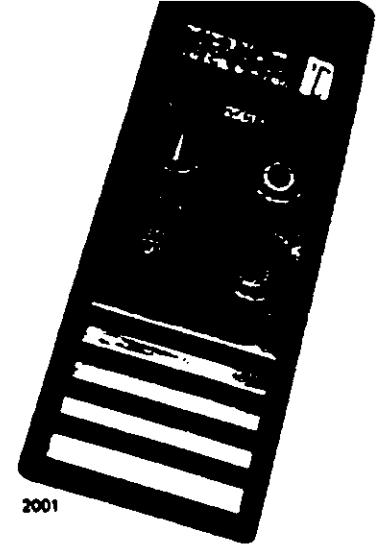
Papers: Impaction of Dust and Smoke Particles on Surface and Body Collectors.
Ranz W.E. and Wong J.B.
Ind. Eng. Chem. 44 pp 1371-1381; 1952.

An Instrument for measuring liquid water content of laboratory supercooled clouds.
Wishart E.R.
J. Rech. Atmos. II pp 191-196; 1977.

A hot-wire instrument to measure liquid water content for use in the laboratory.
Keith W D and Saunders C P R
J Phys E: Sci Instrum. 19; 1986.

f) Data handling.





Digital Thermometers and Probes

- Mineral insulated flexible probe
- Penetration and air/gas probes
- Surface temperature probes
- 2000 Series: water and dust resistant to IP65
- 2001: with backlight and temperature hold
- 3006: Intrinsically safe thermometer

Ordering Information

Description	*Order Code*	*Price*
General Purpose Probe	20-87-01	£23·00
Surface Probe	20-87-02	£26·00
Air Probe	20-87-03	£26·00
Needle Probe	20-87-04	£25·50
Heavy Duty Surface Probe	20-87-05	£32·00

Ordering Information

Description	*Order Code*	*Price*
2007 Thermometer	20-85-01	£86·00
2001 Thermometer	20-86-01	£127·00
3006 Thermometer (I.S.)	20-79-01	£160·00

TEMPERATURE PROBES

All the probes are type K and are fitted with a miniature plug and 1 metre of coiled lead.

ROBUST SEALED DIGITAL THERMOMETERS

The 2000 Series is a new generation of water and dust resistant thermometers, with a temperature range from −60 °C to +1372 °C at 1 °C resolution, or 0·1° from −60 °C to 199·9 °C. Operated from front panel sealed tactile switches, the 2001 also has a backlight facility and temperature hold feature. The 2007 is a general purpose instrument with a temperature range from −40 °C to +700 °C.

The 3006 is an **intrinsically safe** thermometer for use in hazardous areas where a risk of fire or explosion may exist.

Specification

General Purpose Mineral Insulated Probe
The assembly consists of a seamless stainless steel sheath in which the thermocouple is embedded in compressed mineral powder. The probes can be bent without adversely affecting their performance, are impervious to liquids and gases and can withstand high external pressures. The probe has a rapid response to temperature changes with a time constant of 0·2 second in water. Temperature limit 1100 °C. Probe diameter 1·5 mm. Length 100 mm.

Ribbon Surface Probe
The head diameter is only 7·8 mm, has a fast response time of 0·1 second (clean metal) and good accuracy in the low temperature range. Fitted with a grounded junction head. Temperature limit +250 °C. Probe length 100 mm.

Air/Gas Probe
Unique radiation shield design (30 mm long × 13 mm diameter) permits maximum air flow across the measuring junction. Response time 0·3 second (in air). Temperature limit +120 °C. Probe length 115 mm.

Needle Probe
The shaft is 3·3 mm diameter with a pencil point tip to keep the insertion force axially along the probe. Response time is 2 seconds (in water). Temperature limit +600 °C. Probe length 100 mm.

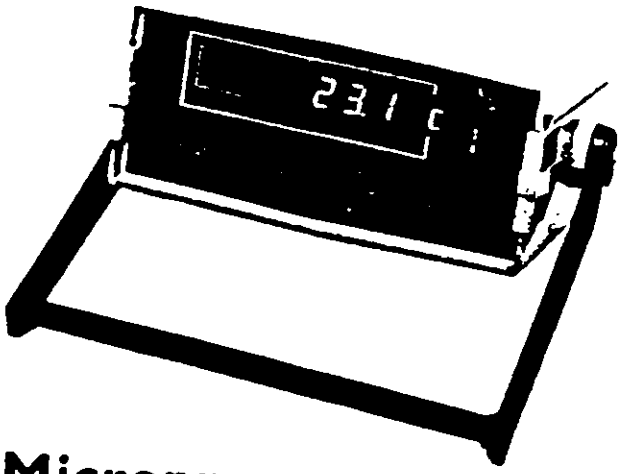
Heavy Duty Surface Probe
Has a spring-loaded tip with ceramic draught shield for good repeatability. Temperature limit +750 °C. Probe diameter 13 mm. Length 60 mm.

Specification

2000 SERIES
Input NiCr/NiAl Type K thermocouple calibrated to B.S. 4937 using standard miniature thermocouple connectors.
2001 (2 ranges) 1 °C resolution: −60 °C to +1372 °C.
0·1 °C resolution: −60 °C to 199·9 °C.
Accuracy ±0·5% reading ±0·5 °C.
Backlight and temperature hold feature.
2007 1 °C resolution: −40 °C to +700 °C.
Accuracy ±0·5% reading ±1 °C to 400 °C.
Degree of Protection (B.S. 5490) to IP65.
Display 12·5 mm LCD with error indicators.
Battery PP3 type.
Dimensions 190×82×28 mm (H×W×D).

3006 INTRINSICALLY SAFE (I.S.) THERMOMETER
Accuracy and range as for 2007 above.
Certification: meets requirements of category EEXia IIC T5 of B.S. 5501: pt 7: 1977 EN 50020 I.S. safety standard.

All prices are subject to confirmation and exclude carriage, insurance and VAT



Microprocessor Thermometer

Up to 10 inputs. K, T or J options

High accuracy: 0·1 °C resolution up to 700 °C

Analogue output. Panel mounting option

Ordering Information

Description	*Order Code*	*Price*
6110 (Type K)	20-88-02	£480·00
6120 (Type J)	20-88-01	£480·00
6130 (Type T)	20-88-03	£480·00
Panel Mounting Kit	20-98-01	£16·00

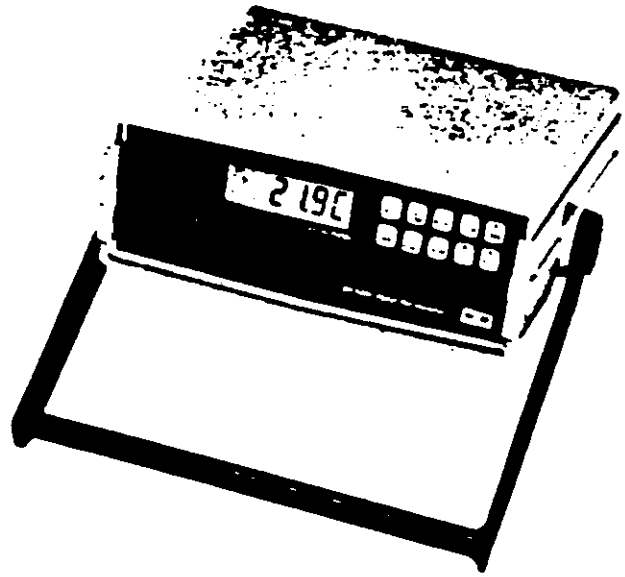
Please see page 190 for details of thermocouple accessories.

ADVANCED MICROPROCESSOR THERMOMETERS

The three models accept up to 10 inputs selected by a front panel switch. Full range analogue output is fitted as standard. The instruments cover a temperature range from −200 °C to +1372 °C and feature a unique auto calibrating/zeroing measurement system to give high measurement accuracy, and exceptional stability within a few minutes of switch on.

Specification

Sensor Type NiCr/NiAl (K), Fe/Con (J) or Cu/Con (T).
Resolution 0·1 °C up to 700 °C. 1 °C above.
Display 14 mm high brightness LED.
Inputs 10, miniature connectors on isothermal block.
ACCURACIES – add together for worst case error
Thermocouple type ranges and accuracy:
6110 −200 °C to +1372 °C. Worst case error <0·15 °C.
6120 −200 °C to +1200 °C. Worst case error <0·15 °C.
6130 −200 °C to +400 °C. Worst case error <0·14 °C.
CJC Negligible error from 20 °C to 25 °C.
<0·05 °C per °C ambient (−5 °C to +40 °C).
Measurement Typical ±3 μV ±0·025% of reading.
Temperature Coefficient ±35 p.p.m./°C maximum.
Digitising Error ±½ least significant digit.
Series Mode Rejection and Voltage
60 dB (50/60 Hz). 100 V DC.
Common Mode Rejection and Voltage
120 dB (50/60 Hz). 300 V DC. (1 kΩ unbalance.)
Analogue Output 1 V=100 °C, 500 °C or 1000 °C.
Operating Temperature −5 °C to +40 °C.
Supply 110/120 V. 220/240 V. ±10%. 50/60 Hz.
Dimensions 99×216×236 mm.



Storage Thermometer

Mains battery temperature indicator

640 reading storage facility

5 operating modes

Ordering Information

Description	*Order*	*Price*
6020 Storage Thermometer	20-79-00	£600·00

Please see page 190 for details of thermocouple accessories.

6020 THERMOMETER WITH READING MEMORY

The 6020 is a portable temperature measuring instrument with internal storage for up to 650 readings, which can be subsequently recalled. Current temperature, deviation from a set point or over a programmable time scale, and maximum/minimum modes of operation can be selected. Readings can be taken manually or at a set time interval. A step feature also allows external triggering.

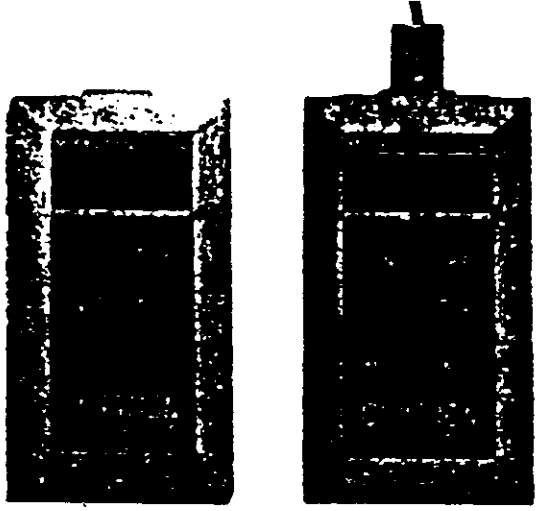
Specification

Inputs 10 (switchable – type K).
Rear Panel Isothermal block.
Scales °C, °F, °A (Kelvin).
Range −200 °C to +1372 °C all scales.
Resolution 0·1° from −50 °C to +1000 °C.
External Read Trigger input 3–30 V DC.
Display LCD. Reading rate 4 per second.
Response Time 1 second.
Measurement Accuracy 0·2% of reading ±0·5 °C.

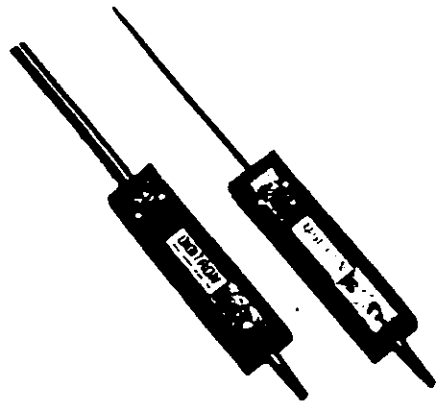
OPERATING MODES
Continuous display of current temperature. Continuous display of deviation of current temperature from a set point, or change in temperature over a time interval. Display of maximum or minimum temperature reached.
Internal Store Up to 640 readings which can be retrieved in the same order.
Serial Output ±5 V RS232C compatible. 600 baud.
Working Ambient Range −10 °C to +50 °C.
Power 110/240 V 50/60 Hz plus external DC.
Internal Rechargeable Pack 8 hours typical
Dimensions 73×216×235 mm (H×W×D). **Weight** 2·7 kg.

Please see page 232 for Conditions of Sale

see page 103



1802 1808



D/4R/4B D/2/R2

Digital Thermometers

Temperature measurement from −150 °C to +1200 °C

Thermocouple input (K) or Pt 100 sensor (1804)

Recorder output and max./min. hold facility (1804/8)

Ordering Information

Description	*Order Code*	*Price*
1802 Thermometer	21–42–00	£95·00
1804 Thermometer	21–43–00	£120·00
1808 Thermometer	21–44–00	£120·00

Please see page 190 for details of accessories.

The 1804 and 1808 have a max./min. reading hold feature together with an analogue output. The Pt 100 sensor 1804 can be used where higher accuracy readings or lower temperatures down to −150 °C need to be measured.

Specification

Specification applies to all models unless stated.
Sensor Type 1802/8 (K) thermocouple to B.S. 4937.
1804 Pt 100 platinum resistor to B.S. 1904 (4-wire).

Range	**1·0 °C resolution**	**0·1 °C resolution**
1802	−50 °C to +950 °C	−50 °C to +199·9 °C
1804	−150 °C to +800 °C	−150 °C to +199·9 °C
1808	−50 °C to +1200 °C	−50 °C to +199·9 °C

Accuracy (10 °C to 25 °C ambient). Sensor not included.
1802/1808 ±0·2% of reading ±0·5 °C.
1804 0·1° resolution: ± 0·2% of reading ±0·1 °C.
1° resolution: ±0·2% of reading ±0·5 °C.
Input Impedance 10 MΩ, not applicable on 1804.
Cable Length Compensation 4-wire system on 1804 compensates for loop resistance up to 100 Ω.
Operating Range 0 °C to 55 °C.
Cold Junction Compensation 1802/8 precision thermistor.
Probe Input 1802/8 – standard miniature thermocouple plug.
1804 – Digitron connector.
Display 12·7 mm LCD with backlight.
Battery MN1604 (PP3 type 9 V)
Battery Check Automatic 'battery low' indication.
Overrange, or sensor open circuit indication.
Recorder Output (1804/8) 1 mV/°C linearised.
Hold facility (1804/8) For maximum or minimum readings.
Dimensions 122×70×37 mm (H×W×D).
Weight 235 g.

Temperature Probes

Choice of probes for digital thermometers

Temperatures to 1100 °C (T/C), 800 °C (PRT)

Thermocouple and platinum resistance sensors

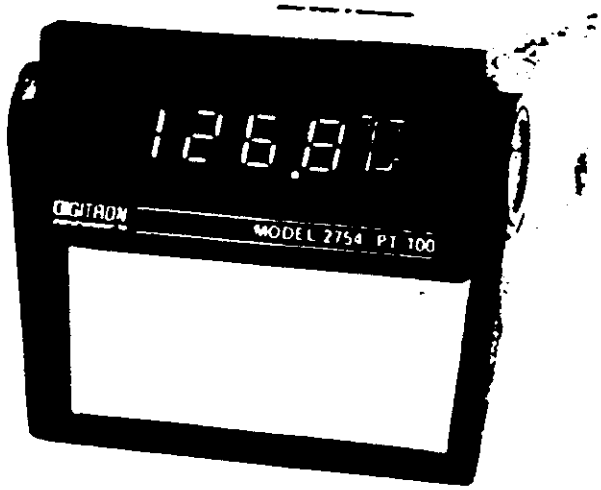
Ordering Information

Description	*Order Code*	*Price*
Probes for 1802/1808 series		
D2 General Purpose Probe	20–71–10	£21·60
D/4B Surface/Air Band Probe	20–73–10	£28·85
D/4R Heavy Duty Surface Probe	20–72–12	£23·50
Probes for 2750/1750 series		
D2 General Purpose Probe	20–71–00	£23·60
D/4B Surface/Air Band Probe	20–73–00	£25·85
D/4R Heavy Duty Surface Probe	20–72–02	£25·50
Probe for 1804 (Pt 100)		
DR2 Resistance Probe	21–20–00	£32·45
Accessories		
Surface Resistance Film (pk of 2)	20–78–02	£49·50
Coupling Unit (Pt 100 sensors)	21–23–00	£9·65
Coupling Unit (1750/2750 T/C's)	20–74–00	£12·00
Cold Junction Plugs (pk of 3)	20–97–00	£20·25

Please see page 190 for details on extension cables, etc.

Specification

D/2 General Purpose Probe Extremely rugged with a fast response of 1 s and a maximum tip temperature of 1100 °C. Probe dimensions 125×3·2 mm.
D/4B Band Probe Provides a rapid response for air and surface temperature measurements. Response time 0·25 s. Maximum temperature 250 °C. Dimensions 100×8 mm.
D/4R Heavy Duty Surface Probe Specially designed to withstand rigorous use. Maximum temperature 1100 °C. Dimensions 110×11 mm. Response time 1 s.
DR/2 Resistance Probe (for model 1804) A general purpose platinum resistance probe suitable for measurements up to 800 °C. Dimensions 125×3·2 mm. Response time 5 s.
Surface Resistance Film Used in conjunction with the Pt 100 coupling unit (21–23–00). These films are designed for fixing to surfaces up to 250 °C.
Coupling Units Digitron sprung hook connectors for monitoring *in situ* sensors.
Cold Junction Compensating Plugs Pack of three plugs to terminate any type K thermocouple for use with the 1750/2750 series.



Bench or Panel Digital Thermometers

Bench or DIN size panel thermometers for Type K thermocouples or Pt 100 sensors

Auto-ranging: 0·1 °C resolution below 185 °C, 1 °C above 185 °C

Analogue recorder output: 1 mV/°C

Cold junction compensated

Ordering Information

Description	*Order Code*	*Price*
2751-K Bench Thermometer	21-14-00	£137·50
2754-PT Bench Thermometer	21-30-00	£137·50
12-way Bench Mounting Selector Unit for Type K Thermocouples	21-31-00	£47·60
6-way Bench Mounting Selector for Platinum Resistance Sensors	21-32-00	£47·60
3750-K Panel Thermometer	21-15-00	£110·00
3754-PT Panel Thermometer	21-33-00	£110·00
12-way Panel Mounting Selector Unit for Type K Thermocouples	21-24-00	£43·75
6-way Panel Mounting Selector for Platinum Resistance Sensors	21-34-00	£43·75

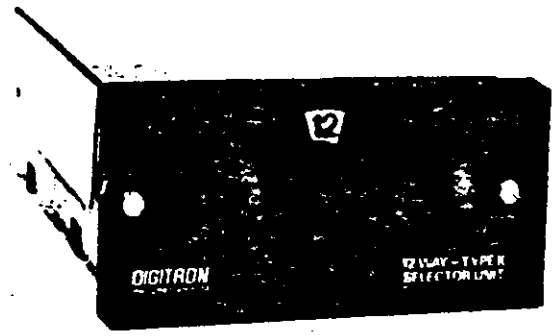
Please see pages 188, 190 and 191 for details of suitable probes and extension cables.

AUTO-RANGING WITH ANALOGUE OUTPUT

The thermometers have automatic range selection enabling resolutions of 0·1 °C to be obtained below 185 °C and 1 °C above 185 °C. The instruments have an analogue output of 1 mV/°C for connection to chart recorders or control equipment.

The 2751 is a bench thermometer and the probes shown on page 188 may be used with the instrument. Additionally, any type K thermocouple can be connected by using the grab lead (code 20-74-00) or input connectors (code 20-97-00) which are supplied complete with cold junction thermistors. Any type K thermocouple can be connected to the panel mounted 3750 via the rear panel terminal strip. The 2754 bench thermometer and 3754 panel thermometer use a 4-wire measuring technique to eliminate the effect of lead resistance, and are suitable for use with Pt 100 sensors with a fundamental interval of 38·5 Ω to B.S. 1904.

MULTIWAY SWITCH SELECTOR UNITS



Bench or panel mounting selector units enable readings to be taken from a number of sensors. Housed in the same case as the corresponding thermometers they are available as 6-way units for platinum resistance sensors, or 12-way units for thermocouples.

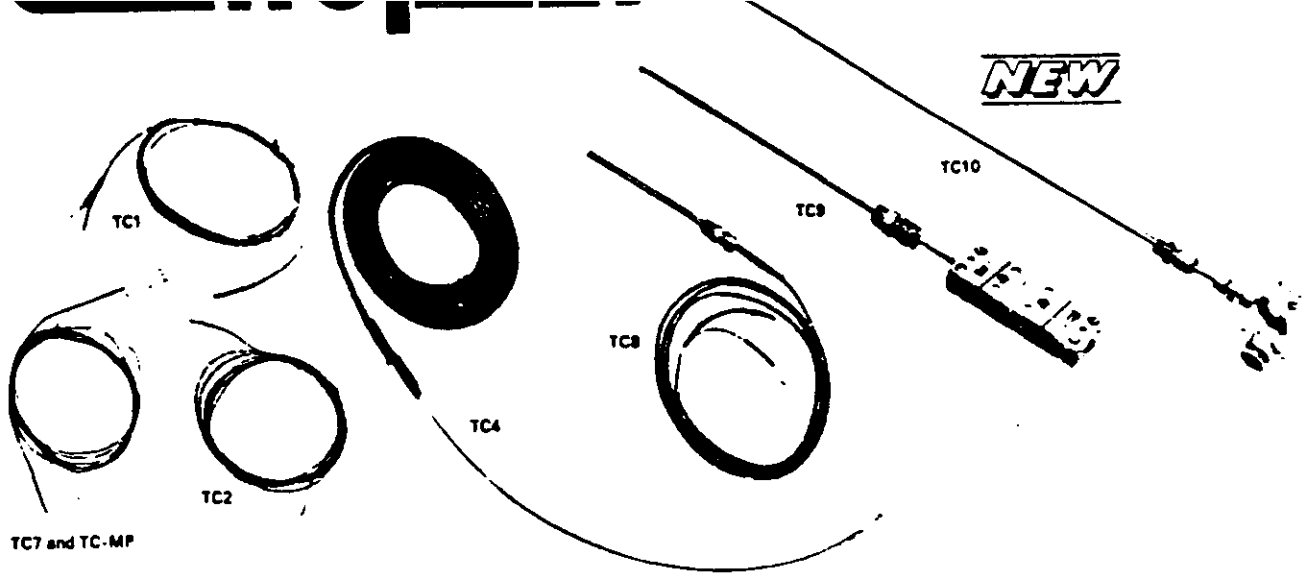
Specification

MODEL 2751 (bench) and MODEL 3750 (panel mounted)
Thermocouple Type K to B.S. 4937 or DIN 43710.
Range −50 °C to +1200 °C.
Accuracy ±0·2% of reading, ±0·5 °C.
Input Impedance 1·5 MΩ typical.
Cold Junction Automatic by precision thermistor.
Note: Maximum error includes B.S. conformity, calibration, span, zero, reference junction, noise and stability, but does not include sensor errors.

MODEL 2754 (bench) and MODEL 3754 (panel mounted)
Sensor Pt 100 platinum resistor to B.S. 1904.
Range −150 °C to +800 °C.
Accuracy ±0·2% of reading ±1 digit.

COMMON SPECIFICATION
Resolution 0·1 °C below 185 °C. 1 °C above 185 °C.
Auto-ranging Range change at 185 °C ±5 °C.
Display 3½ digit (11·2 mm) LED.
Recorder Output 1 mV/°C (2 kΩ source).
Sensor Inputs 2751/2754 Digitron connector.
Sensor Inputs 3750/3754 Terminal strip.
Power Supply 220 V 50/60 Hz 10 VA.
Dimensions 48 × 96 × 165 (bench) or 152 (panel) mm.
Panel Cut-out (3750/4) 42 × 90 mm.
Weight 600 g (2751/4). 350 g (3750/4).

Please see page 232 for Conditions of Sale



TC7 and TC-MP

Thermocouples and Probes

- K, T, and J thermocouples
- Exposed junction thermocouples
- Magnetic and self adhesive surface sensors
- Industrial probes to 1100 °C
- Waterproof patch thermocouples
- Flexible metal sheath probes

Ordering Information

Description	*Order Code*	*Price*
Pack of 5 TC1 NiCr/NiAl (K)	20-61-01	£16·00
Pack of 5 TC1 Cu/Con (T)	20-61-02	£16·00
Pack of 5 TC1 Fe/Con (J)	20-61-03	£16·00
Pack of 5 TC2 NiCr/NiAl (K)	20-62-01	£17·00
Pack of 5 TC2 Cu/Con (T)	20-62-02	£17·00
Pack of 5 TC2 Fe/Con (J)	20-62-03	£17·00
Pack of 10 TC7 NiCr/NiAl (K)	20-68-01	£39·00
Pack of 10 TC7 Cu/Con (T)	20-68-02	£39·00
Pack of 2 TC-SRS NiCr/NiAl (K)	20-66-01	£33·00
Pack of 3 TC-MP NiCr/NiAl (K)	20-68-11	£15·00
Pack of 2 TC-HT NiCr/NiAl (K)	20-70-01	£38·00
TC4 Probe NiCr/NiAl (K)	20-64-01	£19·50
TC4 Probe Cu/Con (T)	20-64-02	£19·50
TC4 Probe Fe/Con (J)	20-64-03	£19·50
TC8 Industrial Probe NiCr/NiAl (K)	20-75-01	£16·95
TC8 Industrial Probe Cu/Con (T)	20-75-02	£16·95
TC9 Industrial Probe NiCr/NiAl (K)	20-60-01	£24·00
TC10 Heavy Duty Probe NiCr/NiAl (K)	20-80-01	£34·00

GLASS FIBRE INSULATED THERMOCOUPLE (TC1) – K, T, or J types
0·2 mm varnished fibreglass insulated wire 1·5 m long with exposed fast response bead tip. **Range −100 °C +350 °C.**

PTFE INSULATED THERMOCOUPLE (TC2) – K, T or J types
Similar to the TC1 but made of close tolerance (ANSI C96·1) wire, PTFE covered. **Maximum temperature 250 °C.**

HIGH TEMPERATURE THERMOCOUPLE (TC-HT) – K type
Exposed junction. Ceramic fibre insulated with 1·5 m lead length. **Temperature 800 °C continuous.**

SELF-ADHESIVE PATCH (TC7) – K and T types
Flexible fibreglass self-adhesive patch with 1 m PTFE lead. Patch size 24×10 mm. **Temperature range −50 °C to +250 °C.**

MAGNETIC SURFACE PATCH (TC-MP) – K type
Re-usable on magnetic surfaces. Fast response bead cemented to 25×50 mm flexible magnetic patch with 1 m PTFE lead. **Maximum temperature 120 °C.**

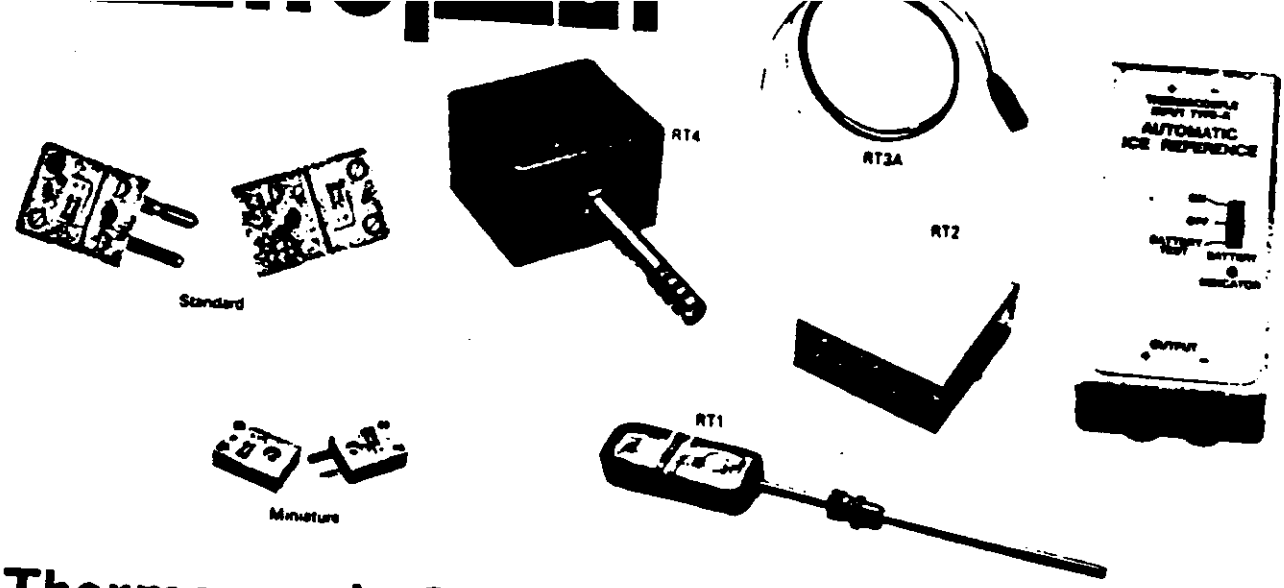
WATERPROOF SURFACE PATCH (TC-SRS) – K type
Self adhesive silicone rubber patch (35×13×2 mm thick) with 2 m PTFE insulated cable. Good resistance to oils and chemicals. **Temperature range −60 °C to +250 °C.**

FLEXIBLE METAL SHEATH (TC4) – K, T and J types
250×1·5 mm diameter flexible stainless steel sheath (Inconel on type K) with mineral insulated junction. 1·5 m. **Temperature range (K) −100 °C to +1100 °C. (T) −100 °C to +400 °C. (J) −100 °C to +870 °C.**

INDUSTRIAL PROBE (TC8) – K and T types
The TC8 has a stainless steel sheath 150×4·8 mm diameter with a stainless steel braided lead 1·5 m long. A ⅛ inch BSP brass compression fitting is supplied.
Maximum temperature: (K) 500 °C. (T) 400 °C.

INDUSTRIAL PROBE (TC9) – K type
Mineral insulated junction thermocouple in 3 mm diameter stainless steel sheath. Length 250 mm below standard thermocouple plug and mating socket. Complete with ⅛ inch BSPT male stainless steel compression gland for mounting. **Maximum tip temperature 1100 °C.**

HEAVY DUTY PROBE TC10 – K type
Mineral insulated junction thermocouple in a 6 mm diameter stainless steel sheath. Length 400 mm below aluminium miniature terminal head complete with ⅛ inch BSPT male stainless steel gland for mounting.
Maximum tip temperature 1100 °C.



Thermocouple Cable and Connectors

- Miniature and standard thermocouple connectors
- Thermocouple extension cables
- PRT probes, air and surface sensors
- Pt 100 elements to B.S. 1904 grade B
- Electronic cold junction reference for K and T type thermocouples

Ordering Information

Description		*Order Code*	*Price*
TC Connectors 5 plugs (miniature)	NiCr/NiAl(K)	20-40-01	£8·50
	Cu/Con(T)	20-40-02	£8·50
	Fe/Con(J)	20-40-03	£8·50
TC Connectors 5 sockets (miniature)	NiCr/NiAl(K)	20-41-01	£8·50
	Cu/Con(T)	20-41-02	£8·50
	Fe/Con(J)	20-41-03	£8·50
TC Connectors 5 pairs (Standard	NiCr/NiAl(K)	20-69-01	£30·00
	Cu/Con(T)	20-69-02	£30·00
	Fe/Con(J)	20-69-03	£30·00
Extension Cable (per 10 m) 100 °C	NiCr/NiAl(K)	20-26-01	£7·50
	Cu/Con(T)	20-26-02	£7·00
	Fe/Con(J)	20-26-03	£7·00
Extension Cable (per 10 m) 300 °C	NiCr/NiAl(K)	20-38-01	£8·50
	Cu/Con(T)	20-38-02	£8·00
	Fe/Con(J)	20-38-03	£8·00
RT1 General Purpose Sensor		20-76-00	£37·50
RT2 Internal Air Temp. Sensor		20-77-00	£23·50
RT3A Pack of 2 surface patches		20-78-02	£49·50
RT4 outside air temp. sensor		20-39-01	£49·50
Type K Electronic cold junction		20-84-00	£39·00
Type T Electronic cold junction		20-84-01	£39·00

THERMOCOUPLE CONNECTORS

The colour-coded glass-filled polyester will withstand 220 °C. Contacts are made from thermocouple materials, and the connectors can be bolted together. Available in miniature or standard sizes.

THERMOCOUPLE EXTENSION LEAD WIRE

PVC insulated cable withstands temperatures up to 100 °C. Silicon varnish glass-fibre cable can be used up to 300 °C. Resistance: (K) 5·25 Ω per combined metre. (T) 2·42 Ω per combined metre. (J) 3·13 Ω per combined metre.

PRT (Pt 100) Sensors Cold Junctions

PLATINUM RESISTANCE SENSORS

These sensors have a resistance of 100 Ω at 0 °C with a fundamental interval of 38·5 Ω and comply with B.S. 1904 grade B accuracy.

GENERAL PURPOSE PROBE (RT1)

The RT1 probe has a ceramic base platinum resistance element mounted inside a 4·76 diameter by 152 mm long stainless steel sheath, terminating in a 2-pin socket. A mating plug and a ⅛ inch BSP brass compression fitting for mounting are supplied. **Temperature range −60 °C to +350 °C.**

AIR TEMPERATURE SENSOR (RT2) – INDOOR

The RT2 has a fast response platinum sensor mounted in an enamelled box 70 mm square with a depth of 24 mm. Holes are provided for mounting and to provide air flow. Suitable for indoor use only. **Temperature range +5 °C to +80 °C.**

AIR TEMPERATURE SENSOR (RT4) – OUTDOOR

The RT4 has a precision sensor mounted inside a sheath shielded by a perforated stainless steel tube 12·5 mm diameter by 75 mm long. Dimensions of waterproofed connector box 80×74×54 mm. **Temperature range −50 °C to +80 °C.**

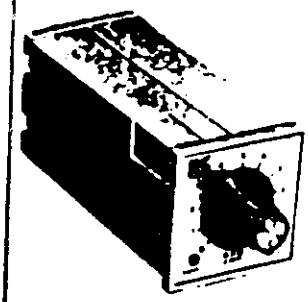
FLEXIBLE SENSOR (RT3A) – WATERPROOF

Suitable for use on flat or curved surfaces. The sensor is mounted on a self adhesive silicone rubber patch 35×13×2 mm thick with 2 metres of 4 wire PTFE insulated lead. Good resistance to oils and chemicals. **Temperature range −60 °C to +250 °C.**

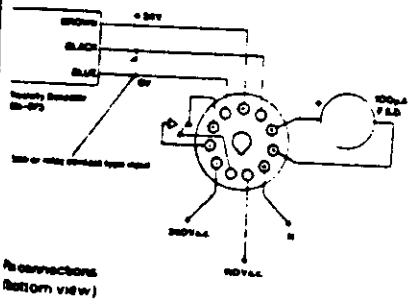
REFERENCE FOR K OR T THERMOCOUPLES

Designed as a low-cost alternative to the ice flask method, these electronic cold junctions simulate a cold junction reference temperature of 0 °C, with a deviation of less than ±0·5 °C over an operating range of 0–45 °C. The unit can be run for 1000 hours with an alkaline battery. The measuring junction plugs in using a standard thermocouple connector, and the output is directly referred to a 0 °C cold junction. Dimensions 28×49×115 mm. Weight 150 g.

Please see page 232 for Conditions of Sale



H (incl knob) 120
W 48
D 48
Panel cut-out 45 × 45



Pin connections (bottom view)

An electronic unit which is able to monitor the speed of various types of machinery via inputs from an RS inductive proximity detector (stock no. 305-973), open collector transistor or relay contact type inputs, etc. The unit counts the rate of incoming pulses. If the rate of pulses exceeds a value which has been previously set, using a potentiometer with graduated scale mounted on the face of the unit, an internal S.P.D.T. relay changes over. Also mounted on the face of the unit are two L.E.D.'s which indicate supply and relay status. Other outputs provided by the unit are a 24 V d.c. supply required by the proximity detector, and an output suitable to drive RS 100 μA F.S.D. moving coil meters to give an indication of actual r.p.m. of the device being monitored. A preset potentiometer is accessible via an aperture in the side of the case to calibrate the meter. The unit is ideally suited for use as a general-purpose, overspeed or underspeed alarm/protection device for many types of rotating machinery. The internal circuitry is housed in a 48 × 48 mm DIN standard case, which may be front-panel or chassis mounted with connections being made to the unit via an 11-pin relay base, such as compact base RS 402-361. Instruction leaflet and front-panel fixing brackets supplied with product.

technical specification	
Supply voltage	110 V a.c. or 240 V a.c.
Frequency	50 Hz ± 10%
Power consumption	Less than 4 VA
Scale range	200 to 10,000 r.p.m.
Scale calibration	-0+5% F.S.D.
Meter output	Suitable to drive a 100 μA F.S.D. moving coil meter
Meter calibration	A preset potentiometer is accessible via aperture in the side of the unit
Input impedance	15 kΩ pull-up to 24 V
Ambient temperature range	-10 °C to +50 °C
Output relay contact (S.P.D.T.) rated	240 V a.c. 5 A resistive

Suitable hole punch for panel mounting stock no. 180-048 (see Tools/Production Aids section).

stock no.	price each 1–4	5+
348-158	£34.88	£31.32

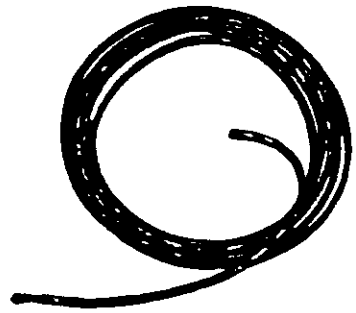
temperature sensors

thermocouples (type K)

Nickel-chromium/nickel-aluminium thermocouple components are also known as type K. The usual temperature range for type K thermocouples is 0 °C to +1100 °C (modified by the construction). Particularly suited for use in oxidising atmospheres.
The colour coding on these components is in accordance with B.S. 1843: 1952. The coding for type K thermocouples is:

Overall sleeve	Red	
Inner sleeves	Brown (positive)	Blue (negative)

thermocouple wire – with welded tip (type K)



Two metres of nickel-chrome/nickel-aluminium type K thermocouple wire insulated with varnish-impregnated glass fibre sleeving. The hot junction tip is welded in an argon atmosphere to eliminate any oxidising of the junction. Suitable for temperature measurement in confined places, i.e. electronic components, etc. -

technical specification	
Wire diameter	1/0.315 mm
Overall diameter	1.5 mm
Operating temperature range	-50 °C to +400 °C
Thermocouple calibration	Type K to B.S. 4937
Wire identification	To B.S. 1843

Data sheet 3043 November 85 available on request.

stock no.	price each 1–19	20+
151-182	£4.75	£4.28

thermocouple probe (type K)

L. (probe) 152
L. (overall) 242
Lead L. 2 m

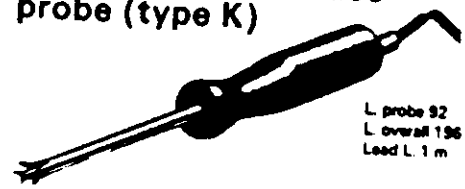
A nickel-chrome/nickel-aluminium thermocouple housed in a 3 mm dia. stainless steel probe. The tip, attached to a P.V.C. covered hardwood handle, has a ground finish to provide good thermal response. The thermocouple is electrically isolated from the probe. Recommended for measurement of oven temperatures and immersion in liquids, etc.

technical specification	
Operating temperature range	-200 °C to +250 °C
Thermocouple calibration	Type K to B.S. 4937
Insulation resistance (between thermocouple and probe)	10^{10} Ω at 500 V d.c.
Proof voltage	1000 V d.c.
Lead identification	To B.S. 1843

Data sheet 3043 November 85 available on request.

stock no.	price each 1–9	10+
151-186	£11.87	£10.68

thermocouple surface probe (type K)



L. probe 92
L. overall 196
Lead L. 1 m

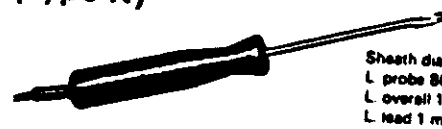
A nickel-chrome/nickel-aluminium type K thermocouple surface probe, with a low mass fast response sprung tip. The tip comprises a thin metallic disc approximately 4 mm diameter, which has attached to it the thermocouple junction. This makes the probe ideal for use on low thermal mass devices, where minimum heat sink effect is required. The thermocouple is protected by a 5 mm dia. stainless steel sheath with a splayed tripod end and the probe handle is moulded in Nylon 66.

technical specification	
Temperature range of tip	-100 °C to +750 °C.
Thermocouple calibration	Type K to B.S. 4937.
Lead identification	To B.S. 1843.

Note: Tip is not isolated from the thermocouple junction.
Data sheet 3043 November 85 available on request.

stock no.	price each 1–9	10+
158-395	£14.70	£13.23

air temperature probe (type K)



Sheath dia. 5
L. probe 86
L. overall 186
L. lead 1 m

An exposed low mass nickel-chrome/nickel-aluminium thermocouple. Protected from damage by a stainless steel sheath which is perforated to allow the free passage of gases across the thermocouple junction. The handle is made from Nylon 66. The thermocouple junction is isolated from the sheath. Supplied with connection plug fitted.

technical specification	
Temperature range	-100 °C to +750 °C
Thermocouple calibration	Type K to B.S. 4937
Lead identification	To B.S. 1843

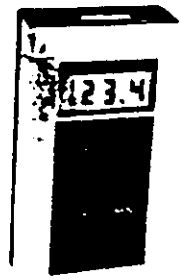
Data sheet 3043 November 85 available on request.

stock no.	price each 1–9	10+
158-525	£13.88	£12.49

continued

peak hold digital thermometer

+calibration



L 122
W. 70
D. 37
Wt 235 g

A hand-held, high accuracy temperature indicator with a membrane switch front panel specifically designed to be water and dust resistant. This temperature indicator features a liquid crystal display with backlight and the option of a reading being displayed with 1 °C or 0·1 °C resolution. Additional features include maximum or minimum hold facility and a linearised output of 1 mV/°C for a chart recorder. This instrument will measure temperature over the range −50 °C to +1200 °C when used in conjunction with a suitable RS type K thermocouple (see Sensors section) or any other Nickel-Chrome/Nickel-Aluminium type K thermocouple to B.S. 4937.
Note: Temperature indicator is *not* supplied with thermocouple. For compatible probes refer to the Sensors section.

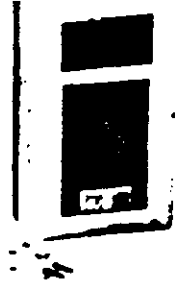
- Hold facility. Maximum or minimum readings can be held, indicated by ∧ or ∨ signs respectively on the display.
- Recorder output of 1 mV/°C linearised, source resistance of 10 kΩ, connection by two 2 mm plugs.
- Switchable resolution: 0·1 °C over the temperature range −50 °C to +199·9 °C, or 1 °C over the temperature range −50 °C to +1200 °C.
- Automatic cold junction compensation.
- Automatic low battery indication.
- Rugged, water and dust resistant construction.
- Supplied complete with 9 V battery (PP3 size) and miniature thermocouple plug.

technical specification	
Accuracy (10 °C to 25 °C ambient)	± (0·2% of reading +0·5 °C)
Operating temperature range	0 °C to +55 °C
Input impedance	10 MΩ

	stock no.	price each 1–9	10+
+calibration	◆ Ⓡ 611-234	£129·00	£114·00
	611-717	£145·00	£139·00

Ⓡ repair/exchange charge code H
◆ calibration/recalibration charge code C1

+calibration



L 122 W. 70 D. 37

A hand-held L.C.D. temperature indicator with wide input temperature range. The large L.C.D. display will indicate temperatures in the range −50 °C to +950 °C when used in conjunction with a suitable RS thermocouple, or any other Nickel-Chrome/Nickel-Aluminium type K thermocouple to B.S. 4937.
Note: Temperature indicator is *not* supplied with thermocouple. For compatible probes refer to the Sensors section.
Features are as follows:

- Switchable resolution: 0·1 °C (temperature range −50 °C to +199·9 °C) or 1·0 °C (temperature range −50 °C to +950 °C).
- Input is compatible with any NiCr/NiAl type K thermocouple to B.S. 4937.
- Automatic cold junction compensation.
- Automatic battery low indication.
- Very rugged construction.
- Supplied complete with PP3 battery and miniature thermocouple plug to mate with input socket.

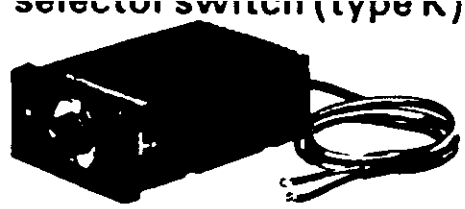
Sensor type	NiCr/NiAl type K thermocouple to B.S. 4937
Accuracy	0·1° resolution ±0·3%, ±0·5 °C 1·0° resolution, ±0·3%, ±1 digit
Operating temperature range	0 °C to +50 °C
Input impedance	30 MΩ typical

	stock no.	price each 1–9	10+
+calibration	◆ Ⓡ 610-867	£75·50	£71·75
	611-701	£100·50	£96·75

Ⓡ repair/exchange charge code E
◆ calibration/recalibration charge code C1

◆ A calibration service is available for all products bearing this symbol against the stock number.
+calibration Shows that this product may be purchased with a certificate of calibration. Use the separate stock number and price information.
See Conditions of Sale on page 525 of this catalogue for full conditions.

selector switch (type K)

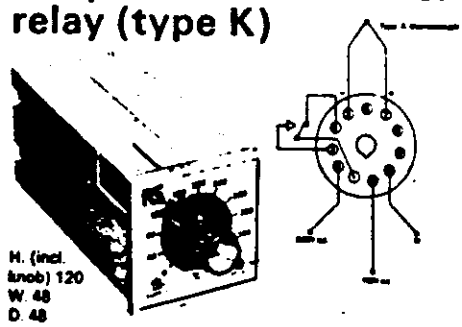


overall dims W 96 H 48 D 152 Panel cut out 90 × 42
Depth behind panel 140 Max panel thickness 6

A panel mounting selector switch unit in a standard DIN size case enabling one out of 12 type K thermocouple inputs to be selected. The front panel change switch gives clear indication of the thermocouple selected. When used in conjunction with the RS panel mounting digital temperature indicators (258-108 or 258-186) it enables readings to be taken from a number of sensors. The switch contacts are gold plated. Connections via a screw terminal strip on rear. Supplied complete with 1 m of thermocouple cable fitted with compensating terminals: red, +ve, black −ve.
Data sheet 3043 November 85 available on request.

stock no.	price each 1–4	5+
332-969	£43·75	£41·56

temperature controller relay (type K)



H. (incl. knob) 120
W. 48
D. 48
Panel cut-out 45 × 45

connections (bottom view)

An electronic ON-OFF temperature controller, mounted in a 48 × 48 DIN standard case, which may be front-panel or chassis mounted via an 11-pin relay base, such as compact base RS 402-361. Ideal for use as an over/under temperature alarm, or a general-purpose temperature control module. The unit is designed to be used with nickel-chrome/nickel-aluminium type K thermocouples, to monitor temperature. A relay changeover contact within the unit operates at a predetermined temperature previously set by a potentiometer knob mounted on the face of the unit. A graduated scale marked 0–400 °C indicates set point temperature. Included on the unit are two L.E.D.'s, indicating supply and relay status. The unit is failsafe protected against thermocouple breaks, i.e. if the thermocouple goes open circuit, the relay will automatically return to the off condition. Front-panel mounting hardware and instruction leaflet supplied. For suitable type K thermocouples refer to this section. Suitable hole punch for panel mounting stock no. 600-048 (see Tools/Production Aids section)

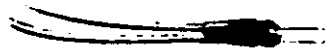
Supply voltage	110 V a.c. or 240 V a.c. 50 Hz ± 10%
Power consumption	Less than 4 VA
Scale range	0 °C to 400 °C
Scale calibration	1% of F.S.D. at 25 °C Amb
Repeatability of set point	0·5% of F.S.D. at 25 °C Amb
Set point hysteresis	± 2% of F.S.D.
Cold junction compensation	+0·2 °C/°C
Ambient temperature range	−10 °C to +50 °C
Output relay contact (S.P.D.T.) rated	240 V a.c. 5 A resistive
Input sensor	NiCr/NiAl (B.S. 4937-K)
Case material	Noryl
Case colour	Beige

stock no.	price each 1–4	5+
348-144	£34·64	£31·18

21

continued

over-temperature protection (p.t.c.)



disc	stud
Sleeved disc	Thread M4
L 14	L 5·5
W 4·5 max	Across flats 10

A range of positive temperature coefficient thermistors ideal for use in warning and trip circuits detecting excessive temperatures inside industrial equipments. Advantages include connecting thermistors in series (an open circuit being fail-safe) such that several monitoring points may be applied to an equipment using one detector circuit only, thus saving costs.
Each device essentially acts as a low resistance (typically 100 Ω) at low temperature and will rapidly increase in resistance by a factor of approx. 100 times when passing through the specified reference temperature T_r. Offered in two constructions, one comprises a small p.t.c. disc resin coated and protected by an irradiated polyolefin insulating sleeve. Its small size will find use where detection space is limited, i.e. encapsulations, motor windings, etc. The second construction features a p.t.c. disc embedded in an anodised aluminium stud, which may be readily mounted to heat sinks and equipment chassis offering high thermal conduction. All versions are supplied with 200 mm (nominal) colour-coded P.T.F.E. insulated silver clad copper wire.
White/White T_r = 80 °C Grey/Grey T_r = 120 °C.
Resistance at T_r is 1000 Ω. Test voltage (for insulation) disc 2·5 kV d.c. stud 500 V d.c. Working voltage 40 V d.c. max. at 25 °C. Dissipation constant in free air (25 °C) 5·5 mW per °C typ.

Data sheet 1867 November 84 available on request.

type T_r	temp. range	stock no.	price each 1–24	25+
disc 80 °C	−55 to +180 °C	150–272	£3·12	£2·81
disc 120 °C	−55 to +220 °C	150–286	£3·12	£2·81
stud 80 °C	−20 to +155 °C	150–250	£3·12	£2·81

R–T curve matched thermistors (n.t.c.) ●

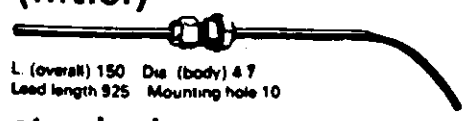
Bead dia 2·4 max
Lead length 76
Lead dia 0·2

The RS R–T curve (Resistance–Temperature) matched thermistors are small, high quality, epoxy encapsulated, precision devices. They offer true interchangeability over wide temperature ranges. This permits the circuit designer to standardise on circuitry, eliminating the need to individually adjust circuits and allowing the thermistors to be easily replaced without the need for re-calibration. Four types are available with resistances at 25 °C of 3 K, 5 K, 10 K and 100 K. Temperature range: −80 °C to +150 °C. Tolerance over temperature range 0 °C to +70 °C; ±0·2 °C.

Data sheet 1867 November 84 available on request.

type	stock no.	price each 1–24	25+
3 K	151–215	£3·78	£3·48
5 K	151–221	£3·78	£3·48
10 K	151–237	£3·78	£3·48
100 K	151–243	£3·78	£3·48

thermistor probes (n.t.c.)



L (overall) 150 Dia (body) 4·7
Lead length 925 Mounting hole 10

standard

A close tolerance thermistor housed in a stainless-steel body for immediate fitting into a tank, duct, oven, etc. Recommended for temperature measurement and control between −10 °C and +70 °C. The probe is fitted with an ¼ in B.S.P. tapped brass bush with sealing gland which allows adjustment of thermistor insertion distance.
Resistance 2 kΩ +2% at 50 °C. Ambient temperature range: −30 °C to +100 °C.

Data sheet 1867 November 84 available on request.

stock no.	price each 1–19	20+
151–128	£13·29	£11·83

high temperature

A high-temperature version of the above product. Recommended temperature range −10 °C to +200 °C, resistance 2 kΩ ±2% at 200 °C.
Ambient temperature range: −30 °C +250 °C.

Data sheet 1867 November 84 available on request.

stock no.	price each 1–9	10+
151–178	£13·29	£11·83

rod thermistors (n.t.c.)

TH-3

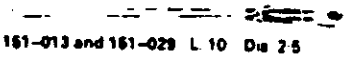
TH-7

General-purpose current-limiting types for circuit protection.

Type	Equivalent	Typ Res at 25 °C	Typ Res Hot	Dimensions
TH-3	VA1026 CZ13	380 Ω	28 Ω at 0·3 A	L 22 Dia 12
TH-7	VA1104 OD10	25 Ω (15 Ω min.)	1 Ω (max.) at 2·2 A	H 10 Dia 16

type	pk qty	stock no.	price per pk 1–24	25+
TH-3	3	151–875	£2·16	£1·94
TH-7	3	151–188	£2·74	£2·47

bead thermistors (n.t.c.)
bead type



151–013 and 151–029 L 10 Dia 2·5

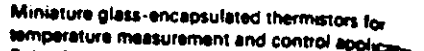
151–114 L 25 Dia 4

Glass-encapsulated thermistors for amplitude control and timing purposes (151–114) or temperature measurement (Types 151–013, 151–029).
Selection tolerance ±20% at 20 °C.

Data sheet 1867 November 84 available on request.

type	res. at 25 °C	min. res.	stock no.	price each 1–24	25+
GL16	1 MΩ	170 Ω	151–813	£3·45	£3·10
GL23	2 kΩ	116 Ω	151–829	£3·45	£3·10
GA53	5 kΩ	80 Ω	151–114	£3·87	£3·48

miniature bead type

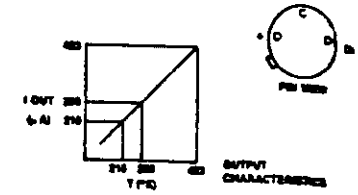


L 5 Dia 1·5

Miniature glass-encapsulated thermistors for temperature measurement and control applications. Selection tolerance ±20% at 20 °C. Recommended temperature range gives a bead resistance variation from 20 kΩ to 1 kΩ.

Res. at 25 °C	temp. range	equivalent to	stock no.	price each 1–24	25+
1 kΩ	−40 °C / +25 °C	GM102 VA3400	151–136	£2·84	£2·56
4·7 kΩ	−5 °C / +70 °C	GM472 VA3404	151–142	£2·84	£2·56
47 kΩ	+50 °C / +150 °C	GM473 VA3410	151–158	£2·84	£2·56
470 kΩ	+110 °C / +240 °C	GM474	151–164	£2·84	£2·56

temperature sensor i.c. 590kH



The RS 590kH is functionally a two-terminal integrated circuit temperature transducer which produces an output current proportional to absolute temperature. For supply voltages between 4 V and 30 V d.c. the device acts as a high impedance, constant current regulator passing 1 μA per °K. Laser trimming of the chip's thin film resistors is used to calibrate the device to 298·2 ±2·5 μA output at 298·2 °K (+25 °C). The minimisation of support circuitry makes the RS 590kH an attractive alternative for many temperature measurement situations. Linearisation circuitry, precision voltage amplifiers, resistance measuring circuitry and cold junction compensation are not needed in applying the device. Apart from temperature measurements, applications include temperature compensation and correction of discrete components, biasing proportional to absolute temperature, flow indication and level detection of fluids. Since the RS 590 is a current sourcing device it is ideally suited for remote sensing applications where the output can easily be transmitted over an inexpensive two-wire twisted pair line without degradation of performance due to line resistance, connector resistance or noise.

technical specification

Operating voltage range 4 V to 30 V d.c.
Nominal current output 298·2 μA at +25 °C
Nominal temp. coeff. 1 μA/°K
Calibration error at 25 °C ±2·5 °C max.
Operating temperature range −55 °C to +150 °C

Data sheet 3992 July 83 available on request.

stock no.	price each 1–24	25+
308–808	£5·51	£4·96

For conditions of sale and servicing see pages 524 and 525
All dimensions are in mm unless otherwise specified

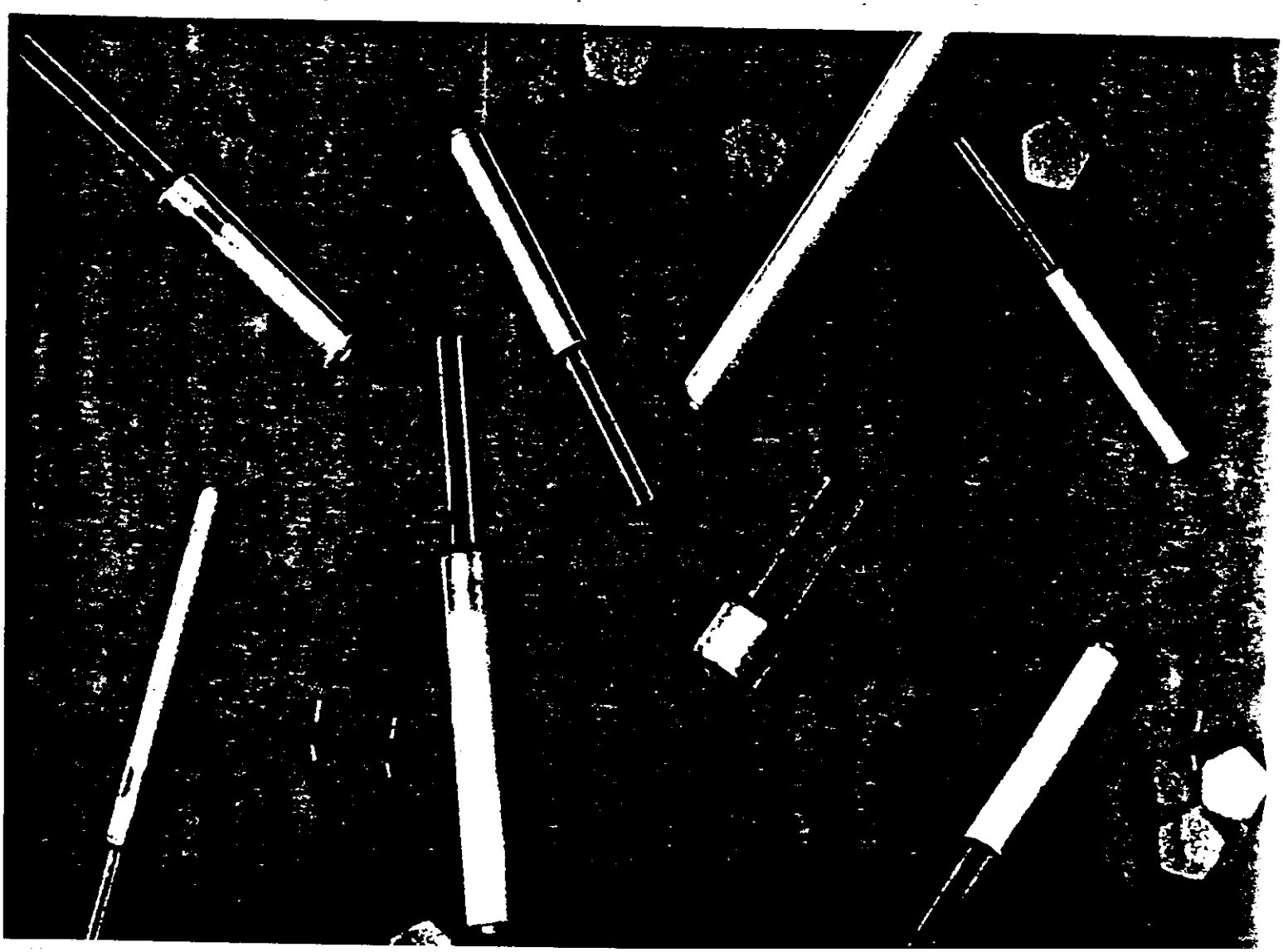
SDL

Short Form Catalogue
Platinum Resistance Temperature Detectors

Sensing Devices Limited

This Catalogue details the most commonly used detectors from the Sensing Devices range. They are appropriate for temperature measurement between −220 and +800°C. Elements having one, two or three windings are available, and there are leaflets giving full technical details.

All temperature detectors manufactured by Sensing Devices Limited conform to BS 1904/1964 and DIN 43760



	Resistance at 0°C Ohms	Tolerance at 0°C ± %	Fundamental Interval Ohms	Temperature Range °C	CERAMIC Length mm	CERAMIC Diameter mm	CERAMIC Sensing Length mm	LEADS Number	LEADS Diameter mm	LEADS Length mm	LEADS Material	R/T Relationship Chart	Recommended Maximum Current mA
	100	0,1	38,5	−220 to +800	30 ± 1	4,5 ± 0,013	28 ± 1	2	0,45	15	Palladium	1	5
	2 × 100	0,1	38,5	−220 to +800	30 ± 1	4,5 ± 0,013	28 ± 1	4	0,45	15	Palladium	1	2 × 5
	100	0,1	38,50	−220 to +800	25 ± 1	3,175 ± 0,013	22 ± 1	2	0,45	10	Platinum	1	5
	2 × 100	0,1	38,50	−220 to +800	25 ± 1	3,175 ± 0,013	22 ± 1	4	0,45	10	Platinum	1	2 × 5
	100	0,1	38,50	−220 to +800	25 ± 1	1,59 ± 0,013	22 ± 1	2	0,25	10	Platinum	1	3
	130	0,2	50,7	−220 to +800	25 ± 1	3,175 ± 0,013	22 ± 1	2	0,45	10	Platinum	2	5
	100	0,1	38,5	−220 to +800	15 ± 1	3,175 ± 0,013	13 ± 1	2	0,45	10	Platinum	1	5
	100	0,1	38,50	−220 to +800	15 ± 1	1,59 ± 0,013	13 ± 1	2	0,25	10	Platinum	1	3
	100	0,2	38,50	−220 to +800	15 ± 1	1,20 ± 5 %	13 ± 1	2	0,25	10	Platinum	1	2
	100	0,2	38,50	−220 to +800	15 ± 1	0,90 ± 5 %	13 ± 1	2	0,15	10	Platinum	1	1
	100	0,2	38,50	−220 to +800	6 ± 1	2,00 ± 3 %	6 ± 1	2	0,25	7	Platinum	1	1

* other tolerances available from 1 % to 0,01 %

Temperature Chart 1

Resistance. 38,5 Ohm Fundamental Interval. Platinum Resistance Temperature Detectors

	−10	−20	−30	−40	−50	−60	−70	−80	−90
	14,40	10,45	Resistance—Ohms						
	86,21	82,12	48,01	43,88	39,72	35,54	31,34	27,11	22,83
	96,09	92,16	88,23	84,29	80,32	76,34	72,35	68,34	64,32
	+10	+20	+30	+40	+50	+60	+70	+80	+90
	103,9	107,79	111,67	115,54	119,4	123,24	127,07	130,89	134,70
	142,29	146,08	149,82	153,57	157,31	161,04	164,76	168,46	172,16	
3	179,50	183,18	186,82	190,45	194,07	197,69	201,29	204,88	208,46
2	215,56	219,12	222,66	226,18	229,69	233,19	236,66	240,16	243,61
8	250,52	253,95	257,37	260,77	264,17	267,56	270,94	274,29	277,64
6	184,31	287,63	290,93	294,22	297,50	300,76	304,02	307,27	310,51
2	316,93	320,12	323,31	326,5	329,6	332,8	336,0	339,1	342,2
	348,4	351,5	354,6	357,7	360,8	363,8	366,8	369,7	372,7
	378,7	381,6	384,6	387,5	390,4	393,3	396,2	399,0	401,9
	407,8	410,5	413,2	416,1	418,8	421,7	424,4	427,2	430,0
	436,4	439,1	440,8	443,6	446,3				

Resistance/Temperature Chart 2

130 Ohm Ice Point Resistance. 50.7 Ohm Fundamental Interval. Platinum Resistance Temperature Detectors

°C	−0	−10	−20	−30	−40	−50	−60	−70	−80	−90
−200	22,68									
−100	77,67	72,32	66,94	61,53	56,10	50,62	45,12	39,57	33,99	28,36
−0	130,00	124,65	119,68	114,49	109,29	104,07	98,83	93,56	88,30	83,0
	+0	+10	+20	+30	+40	+50	+60	+70	+80	+90
+0	130,00	135,14	140,26	145,37	150,46	155,54	160,60	165,65	170,68	175,70
100	180,70	185,69	190,66	195,61	200,58	205,48	210,39	215,29	220,17	225,03
200	229,88	234,72	239,54	244,34	249,13	253,91	258,67	263,41	268,14	272,85
300	277,55	282,24	286,90	291,56	296,20	300,82	305,43	310,02	314,60	319,16
400	323,71	328,24	332,75	337,28	341,74	348,21	350,67	355,11	359,54	363,95
500	368,34									

SDL

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Stanley House, Stanley Street, Southport, Merseyside, England.
Telephone: Southport 35739/36162

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MIDDLESEX
Tel: 01-892 4327
Contact: Mr N. J. Riddett

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LYON 69003
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Contact: M. Maurice Caro

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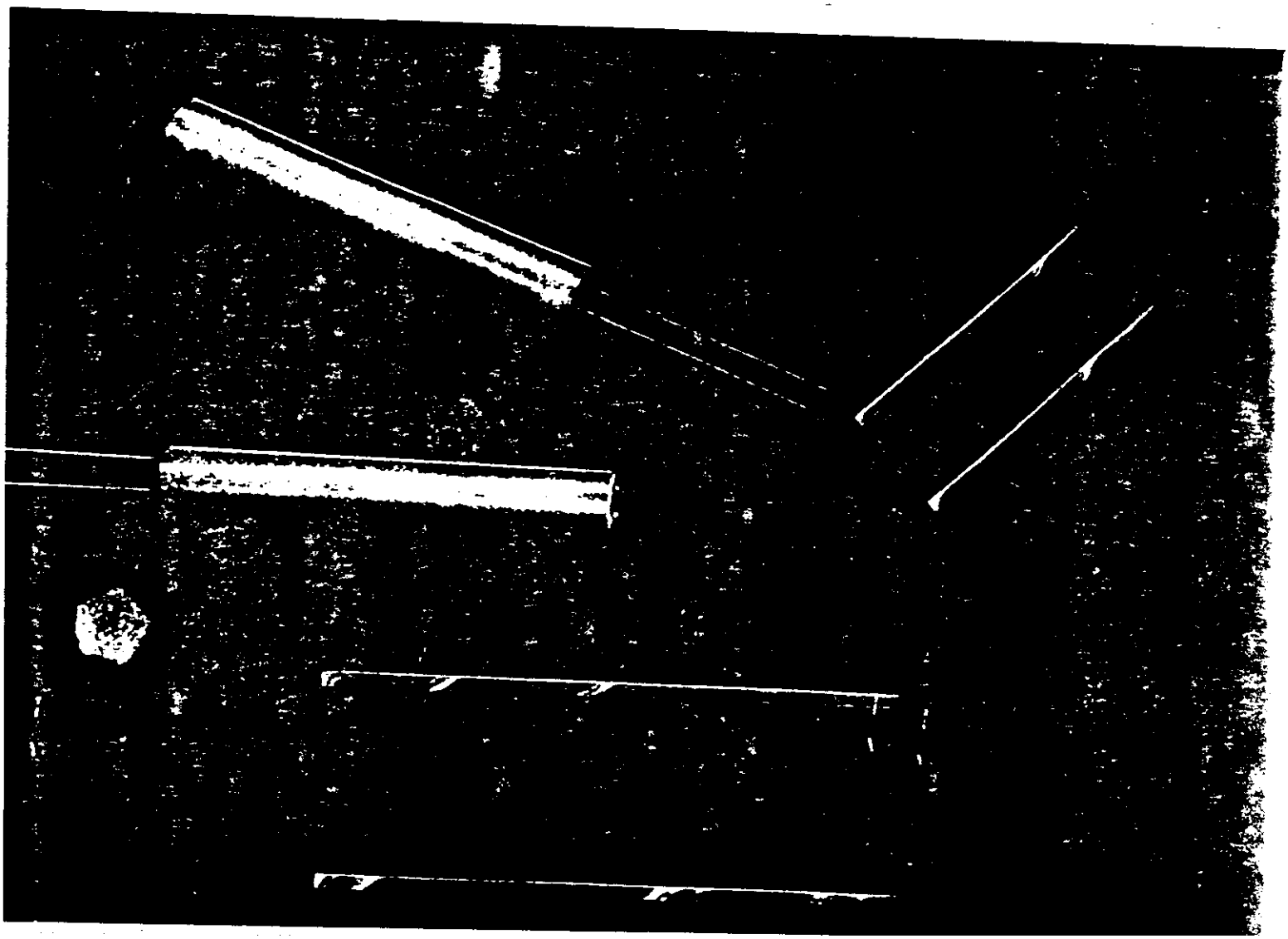


FLUKE

(16)

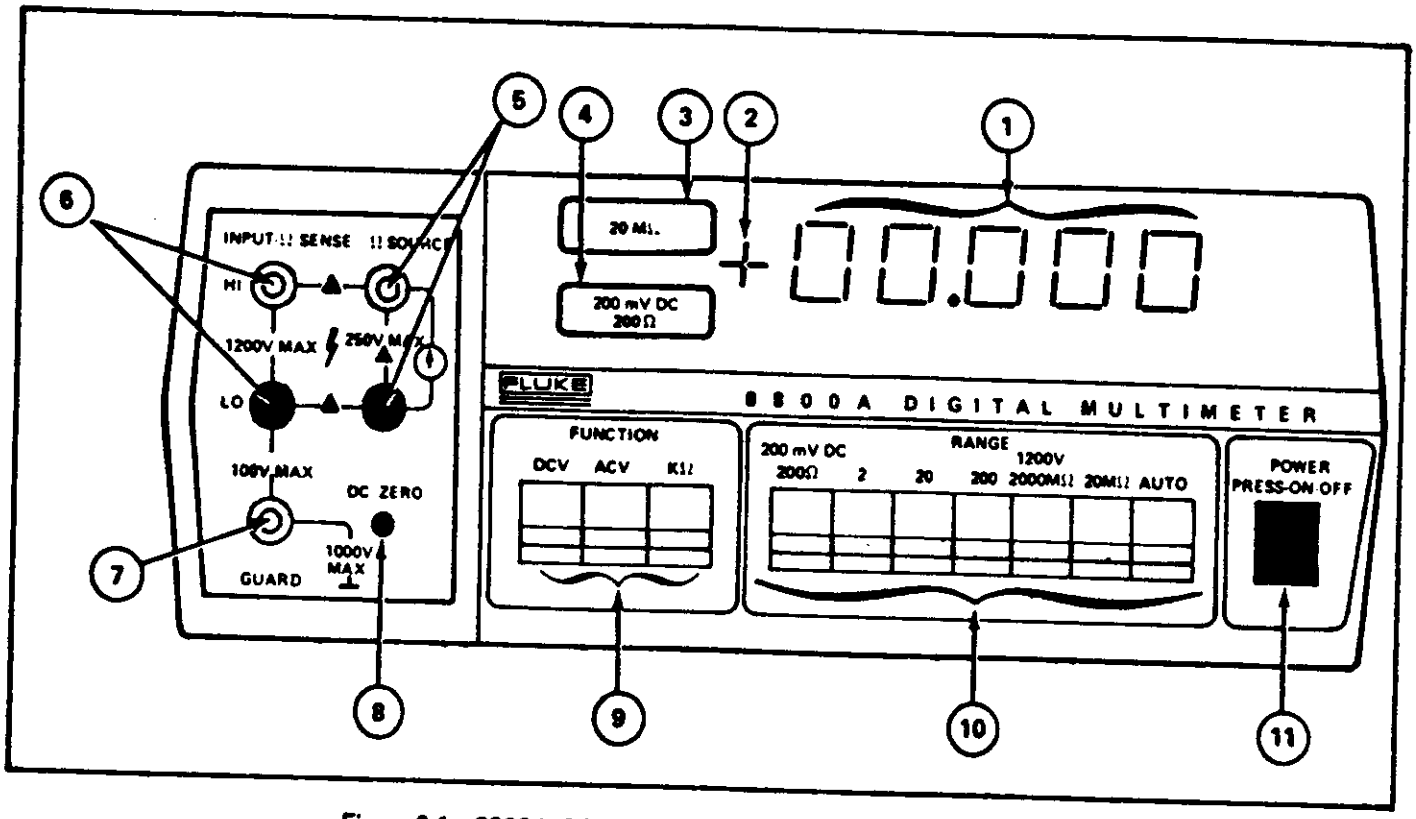


Figure 2-1. 8800A CONTROL AND INDICATOR LOCATIONS

Table 2-1. 8800A CONTROL AND INDICATOR FUNCTIONS

FIG 2-1 REF. NO.	NAME	FUNCTION
1	LED display	Provides a digital readout of the value of applied inputs.
2	Polarity indicator	Displays a + (positive) or – (negative) polarity indication for corresponding dc voltage inputs.
3	20 MΩ indicator	LED indicator lights when 20 MΩ RANGE is selected.
4	200 mVDC, 200Ω indicator	LED indicator lights when 200 mVDC, 200Ω range is selected
5	Ω SOURCE HI and LO terminals	Provide current through unknown resistance to be measured in KΩ FUNCTION.
6	INPUT - Ω SENSE HI and LO terminals.	Provides connections for ACV and DCV FUNCTION inputs and Ω SENSE input in KΩ FUNCTION.
7	GUARD terminal	Provides connection to internal voltmeter guard.
8	DC ZERO adjustment	Adjusts 8800A display for zero reading in ZERO ADJUST procedures. (See section –4, precalibration procedure)
9	FUNCTION pushbuttons	Selects the DCV, ACV or KΩ mode of operation.
10	RANGE pushbuttons	Selects discrete range or AUTO range in each function.
11	POWER pushbutton	Turns instrument on or off.

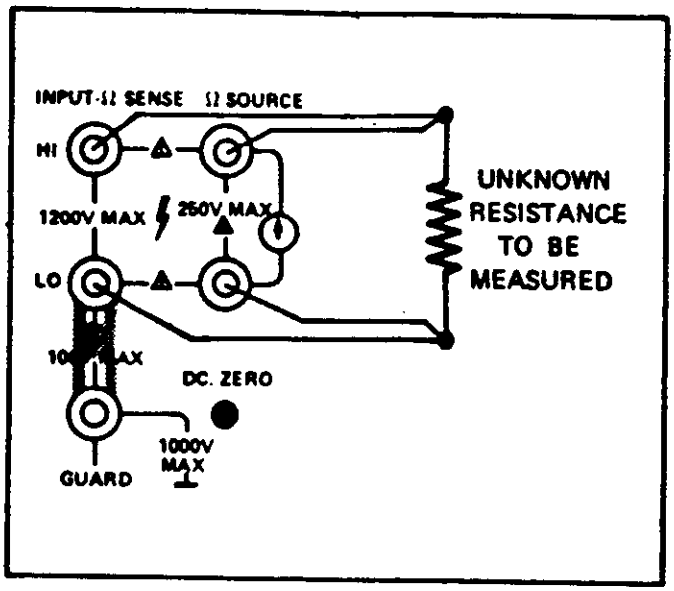


Figure 2-2. INPUT TERMINAL CONNECTIONS FOR 4-TERMINAL MEASUREMENTS

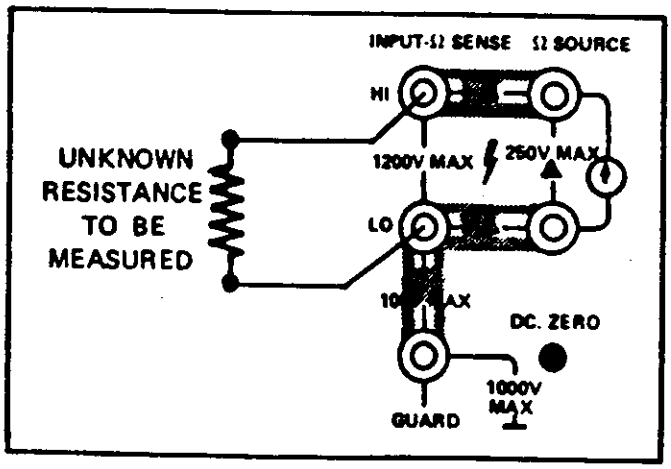


Figure 2-3. INPUT TERMINAL CONNECTIONS FOR 2-TERMINAL MEASUREMENTS

common mode current (Icm) via the test lead on the low input terminal, the guard to low-input shorting link, through the inner guard to outer case stray leakage paths, and back to the common mode source. This common mode current flow will cause a normal mode voltage drop across the lead resistance that will add to or subtract from the input voltage being measured. When the lead resistance increases (caused by long input leads or poor connections) or the common mode voltage increases, the common mode signal converted to a normal mode voltage can cause a noticeable error in the multimeter display.

2-23. The guard terminal on the 8800A front panel can be connected in a way that provides a signal path for the common mode current that does not go through the input leads carrying the normal mode voltage signal. These terminal connections, illustrated in Figure 2-5, provide for a guarded measurement of the applied input.

2-24. Guarded measurements can be obtained when the following conditions are met:

1. Remove link connecting guard terminal and low input.
2. Connect shield of the input leads to the guard terminal.
3. Connect input end of the shield to same point as the input low lead.

2-25. The above conditions, when met, will effectively extend the inner guard of the instrument out to the end of the input leads. The common mode current will then flow through the shield on the input leads to the guard terminal, across the inner guard to the outer case stray leakage paths, and back to ground. Therefore the current no longer flows through the input lead to create the error voltage.

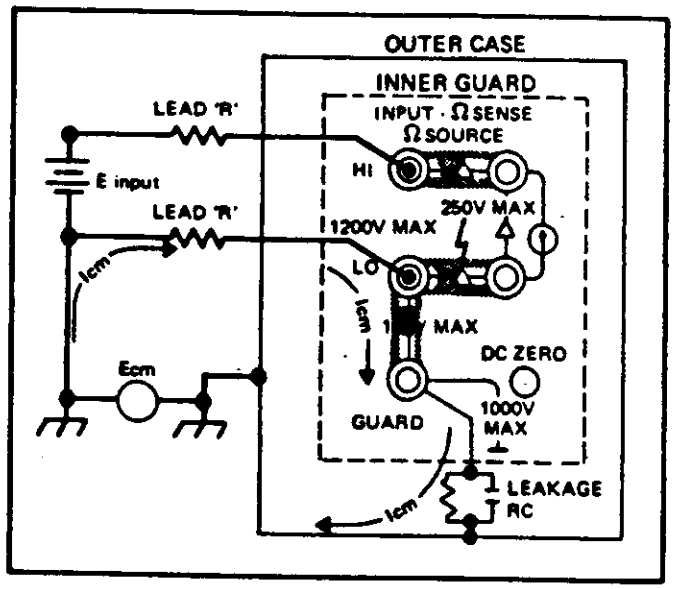


Figure 2-4. UNGUARDED MEASUREMENT TERMINAL CONFIGURATION

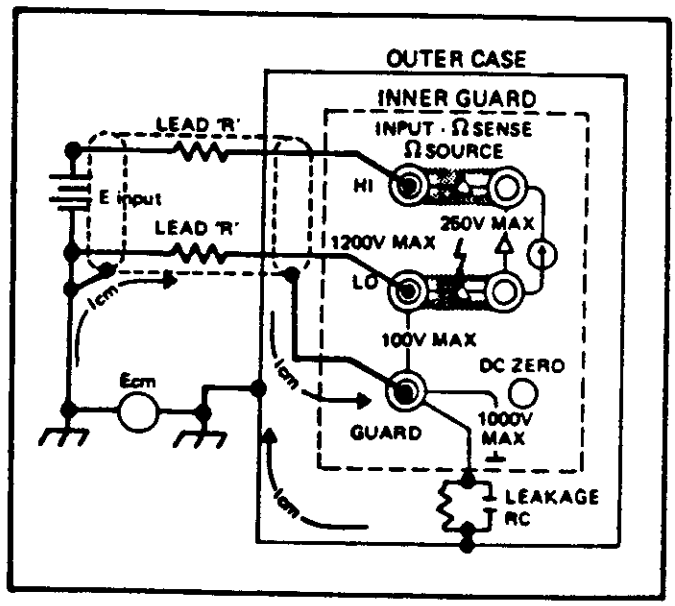


Figure 2-5. GUARDED MEASUREMENT TERMINAL CONFIGURATION

PDCR510

PDCR10–PDCR810

PTX200

Pressure Transducers

Rugged solid state construction

Good thermal stability

Excellent shock, vibration, overload characteristics

PDCR510 – general purpose pressure transducers

PDCR10/810 – high accuracy pressure transducers

PTX200 – 3–15 p.s.i. pressure to current converter

Ordering Information

Description	*Order Code*	*Price*
Pressure transducers PDCR510		
700 mbar/1 bar gauge	20-20-01	£110·00
2 bar gauge	20-20-02	£110·00
3·5 bar gauge	20-20-03	£110·00
7 bar gauge	20-20-04	£110·00
15 bar gauge	20-20-05	£110·00
35 bar gauge	20-20-06	£110·00
70 bar gauge	20-20-07	£110·00
135 bar gauge	20-20-08	£110·00
Pressure transducers PDCR10 and PDCR810		
1 bar gauge	20-21-01	£146·00
2 bar gauge	20-21-02	£146·00
3·5 bar gauge	20-21-03	£146·00
7 bar gauge	20-21-04	£146·00
15 bar gauge	20-21-05	£146·00
35 bar gauge	20-21-06	£146·00
60 bar gauge	20-21-07	£146·00
PTX200 3–15 p.s.i. 3-wire		
Pressure to current converter	20-22-01	£142·00

QUALITY PRESSURE TRANSDUCERS

The PDCR ranges of rugged pressure transducers are built to high quality standards. The PDCR510 is a general purpose pressure transducer with an impressive cost/performance ratio; and the PDCR10/810 is a high accuracy transducer with good shock, vibration and overload characteristics.

The PTX200, pressure to current converter, interfaces standard pneumatic 3–15 p.s.i. signals to 4–20 mA control systems, data loggers and other recording equipment.

Specification

Common specification
Pressure Media Fluids compatible with quartz and titanium, i.e. most common fluids.
Transduction Integrated silicon strain gauge bridge.
Pressure Reference Gauge, case vented to atmosphere.
Excitation Voltage 10 V at 15 mA (maximum).
Output Impedance 1000 Ω nominal.
Load Impedance > 100 kΩ.
Resolution Infinite.
Shock 1000 g for 1 ms/3 axes with no effect on calibration.
Cable 1 metre integral vented cable.

PDCR510
Ranges 700 mbar/1 bar, 1, 2, 3·5, 7, 15, 35, 70, 135 bar.
Connection Female G¼ BSP. Flat face to suit bonded seal.
Overpressure 3× (1 bar). 2× (2 bar range and above).
Output Voltage 150 mV (1 bar), 200 mV (2 bar range and above).
Accuracy Combined non-linearity and hysteresis ±0·2% B.S.L. for 1 bar to 35 bar ranges.
Span Setting and Zero Offset ±10 mV.
Operating Temperature Range −40 °C to +125 °C.
Temperature Effects. Total error band, ±1% from 0 °C to 50 °C. ±2% from −20 °C to +80 °C.
Natural Frequency 28–360 kHz (700 mbar to 70 bar).
Acceleration Sensitivity 0·006% to 0·0001% F.S.O./g from 700 mbar to 70 bar.
Dimensions 82 mm (body) × 22 mm (A.F.). **Weight** 75 g.

PDCR10 and PDCR810
Ranges 1, 2, 3·5, 7, 15, 35, 60 bar.
Connection Male G¼ BSP. 60° internal cone.
Overpressure 4× (from 1 to 135 bar ranges).
Output Voltage 100 mV for 1 bar range and above.
Accuracy Combined non-linearity and hysteresis ±0·1% B.S.L. to 60 bar range.
Span Setting and Zero Offset ±3 mV.
Operating Temperature Range −20 °C to +80 °C.
Temperature Effects Total error band, ±0·5% from 0 °C to 50 °C. ±1·5% from −20 °C to +80 °C.
Natural Frequency 28–360 kHz (up to 35 bar).
Acceleration Sensitivity 0·006% to 0·0002% F.S.O./g up to 35 bar.
Dimensions 58 mm (body) × 21 mm (dia.) **Weight** 50 g.

PTX200 PRESSURE TO CURRENT CONVERTER
Range 3–15 p.s.i.
Supply Voltage 15–35 V DC at 28 mA maximum (3-wire).
Output Current 4–20 mA.
Non-linearity and hysteresis ±0·1% F.S.O.
Zero and Span Shift <0·03%/°C.
Compensated Temperature Range 10 °C to 50 °C.

Please see page 232 for Conditions of Sale

Pressure Indicators

System accuracy better than 0·1% f.s.

Excellent long term and thermal stability

Bench or panel mounting

Ordering Information

Description	*Order Code*	*Price*
DPI203	20–18–00	£215·00
Analogue Output Option	20–18–01	£30·00
Configuration Charge*	20–18–02	£15·00

* Covers calibration/scaling with the PDCR range of pressure transducers.

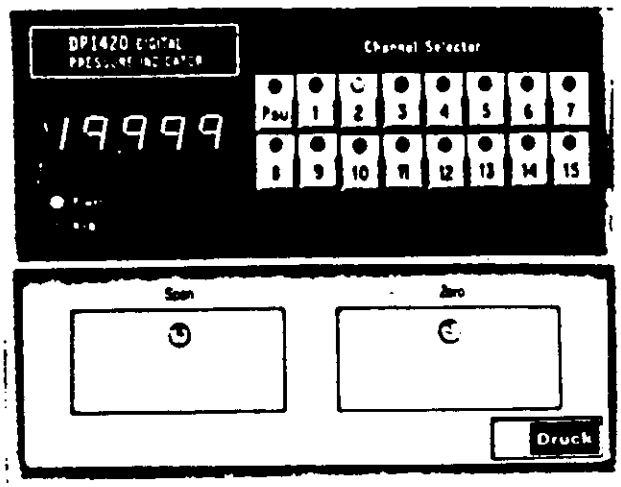
ACCURATE PRESSURE MEASUREMENT

The DPI203 contains stable transducer excitation and signal conditioning electronics, which combined with a high performance Druck pressure transducer, will give an extremely accurate pressure indication.

The low level transducer signal is converted into a 4½ digit display with a full scale count of 19999, giving a resolution of 0·005%. Electroplan can calibrate and scale the DPI203 to cover a wide range of pressures. The rugged case can be bench or panel mounted. Side panel clamps provide simple fixing into a DIN panel cut-out.

Specification

Readout ±19999 (4½ digits) 7·5 mm LED display.
Overload Indicated by flashing display.
Resolution 0·005% f.s. maximum (depends on range and units).
Accuracy Combined non-linearity, hysteresis and repeatability.
PDCR10 Transducers ±0·1% f.s. to 60 bar.
PDCR510 Transducers ±0·25% f.s. to 135 bar.
Transducer Excitation 10 V DC stabilised.
Maximum Current 30 mA.
Stability <0·02% (3 months). **Tempco** <0·01%/°C.
Zero and Sensitivity Controls For transducer calibration.
Temperature Range 0 °C to 50 °C (10 °C to 30 °C calibrated).
Analogue Output option 0–2 V f.s.
Power Supply 240 V 50 Hz.
Dimensions 44×97×200 mm (H×W×D).
Weight 600 g.



Multichannel Pressure Indicators

Excellent system linearity and hysteresis

7 or 15 channel capability

IEEE-488 and analogue output options

Ordering Information

Description	*Order Code*	*Price*
DPI420 7 Channel	20–19–07	£940·00
DPI420 15 Channel	20–19–15	£1325·00
7 Channel Analogue Output	20–19–01	£115·00
15 Channel Analogue Output	20–19–04	£230·00
IEEE-488 Interface	20–19–02	£255·00
Configuration Charge *	20–19–03	£50·00

* Covers calibration/scaling with the PDCR range of pressure transducers.

7 or 15 CHANNEL PRESSURE MEASUREMENT

The DPI420 is designed for use with Druck pressure transducers, to give high accuracy multichannel pressure indication. Each channel can be scaled and set to different ranges and pressure units, if required. The front panel layout gives a clear indication of channel selection; and each channel has a separate zero and span control.

The IEEE option allows pressure readings to be read into a computer for subsequent analysis. Contact Electroplan for full details of microcomputer software support.

Specification

Input Channels 7 or 15 channels maximum.
Readout ±19999. 11 mm LED display.
Overload Indicated by flashing display.
Resolution 0·005% f.s. maximum (depends on range and units).
Transducer Types Any combination with same excitation voltage.
Channel Selection Front panel switch or remote TTL signal.
Accuracy Combined non-linearity, hysteresis and repeatability.
PDCR10 Transducers ±0·1% f.s. to 35 bar.
PDCR510 Transducers ±0·25% f.s. to 135 bar.
Transducer Excitation 10 V DC stabilised at 300 mA.
Tempco <0·005%/°C. **Stability** <0·02% (3 months).
Zero and Span For transducer calibration.
Temperature Range 0 °C to 50 °C (10 °C to 30 °C calibrated).
Analogue Option 0–2 V f.s. (not retrofittable).
IEEE Option Talk/Listen capability plus Autoscan mode.
Power Supply 110 or 240 V. 50–400 Hz.
Dimensions 144×192×250 mm (H×W×D). **Weight** 3·5 kg.

ELECTROPLAN LIMITED P.O. BOX 19 ORCHARD ROAD ROYSTON HERTFORDSHIRE SG8 5HH

Portable Pressure Gauge

0·15% accuracy – fast response

Rugged construction

Intrinsically safe option

Ordering Information

Description	*Order Code*	*Price*
DPI700 200 mbar gauge	20–10–00	£200·00
DPI700 200 mbar I.S. option	20–10–01	£220·00
DPI700 2 bar gauge	20–11–00	£175·00
DPI700 2 bar I.S. option	20–11–01	£195·00
DPI700 20 bar gauge	20–12–00	£175·00
DPI700 20 bar I.S. option	20–12–01	£195·00

Cases and tube (1 m) supplied as standard.

PORTABLE PRESSURE INDICATOR

The Druck DPI700 is a low-cost battery-powered digital pressure indicator with a $3\frac{1}{2}$ digit LCD display. The internal pressure sensor has good overpressure and response characteristics, and overall accuracy is better than 0·15% of full scale.

The instrument is housed in a robust moulded case, making it suitable for use in harsh environments. The carrying case provides storage for the pressure hose and fitting.

Specification

Pressure Ranges 200 mbar, 2 bar, 20 bar gauge models.
Display 12·7 mm LCD. $3\frac{1}{2}$ digits.
Overpressure 200% of full scale causes negligible calibration change.
Media Compatible with most common fluids.
Display Indication for overload and low battery.
Resolution 0·05% full scale.
Accuracy Combined non-linearity, hysteresis and repeatability ±0·15% f.s. for all ranges (at 25 °C).
Temperature Effects 0·02% reading/°C (0–50 °C).
Zero Control Front panel adjustment.
Pressure Connection 6 mm O.D./4 mm bore, hose fitting (polythene tube up to 2 bar, nylon tube to 20 bar).
Power Supply PP3 (9 V) type.
Dimensions 60×155×90 mm (H×W×D). **Weight** 700 g.
INTRINSIC SAFETY (I.S.) OPTION Certified to EEXib group IIC T4. Certificate Ex 84 B2375.

Portable Pressure Calibrator

Pressure, voltage and current measurement

Excellent linearity and hysteresis

Intrinsically safe option

Ordering Information

Description	*Order Code*	*Price*
DPI600 2 bar gauge	20–15–00	£777·00
DPI600 2 bar I.S. option	20–15–01	£857·00
DPI600 7 bar gauge	20–16–00	£777·00
DPI600 7 bar I.S. option	20–16–01	£857·00

Supplied with case and probes.
Rechargeable options available.

CALIBRATION OF PRESSURE TRANSDUCERS AND TRANSMITTERS

The Druck DPI600 is a rugged, portable, battery-powered pressure indicator and calibrator, with additional voltage and current measurement facilities. The pressure sensor in the unit has excellent linearity, hysteresis and overpressure characteristics.

Specification

Ranges 2 bar or 7 bar gauge models.
Overpressure Negligible calibration change up to ×4 overpressure.
Positive Pressure Media Fluids compatible with brass, nylon, quartz and titanium, i.e. most common fluids.
Readout 19999 ($4\frac{1}{2}$) digits. 15 mm LCD.
Indicators On display for overload and low battery
Resolution 0·005% maximum full scale.
Accuracy Combined non-linearity, hysteresis and repeatability ±0·1% f.s.
Pressure Scales P.s.i., bar, in Hg and mH_2O.
Electrical Scales (f.s.) 199·99 V DC, 1·9999 V DC, 199·9 mA.
Integral Hand Pump Generates up to 3·5 bar.
Volume Adjuster For fine control of value setting.
Release Valve For releasing pressure without disconnection.
Operating Range −10 °C to +50 °C. Calibrated from 10 °C to 30 °C.
Pressure Connection G¼ B. 60° internal cone.
Power Supply 8×1·5 V cells (SP11 type) 50 hours continuous.
INTRINSIC SAFETY (I.S.) OPTION Certified to EEXib gas group IIC with a T4 rating to B.S. 5501 part 7. DC voltage and current ranges (f.s.) 30 V, 1·999 V and 30 mA.
Dimensions 305×108×110 mm. **Weight** 4 kg nominal.

Please see page 232 for Conditions of Sale

with finite size will have no inertia; and if gravity and electrostatic forces can be neglected, its center will follow the fluid streamlines—i.e., when Ψ, $\overline{g_L}$, and $\overline{F}$, are zero, $\overline{u} = \overline{v}$ as given by Equation 1. The streamlines for cylindrical and spherical bodies in ideal flow are given by

$$\beta_0 = \beta[1 - 1/(\xi^2 + \beta^2)] \quad \text{for a cylinder} \quad (3)$$

$$\beta_0^2/2 = (\beta^2/2)[1 - 1/(\xi^2 + \beta^2)^{3/2}] \quad \text{for a sphere} \quad (4)$$

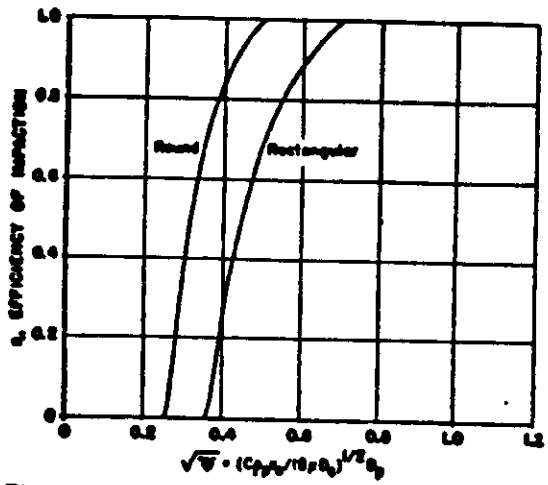


Figure 2. Theoretical Impaction Efficiencies of Aerosol Jets

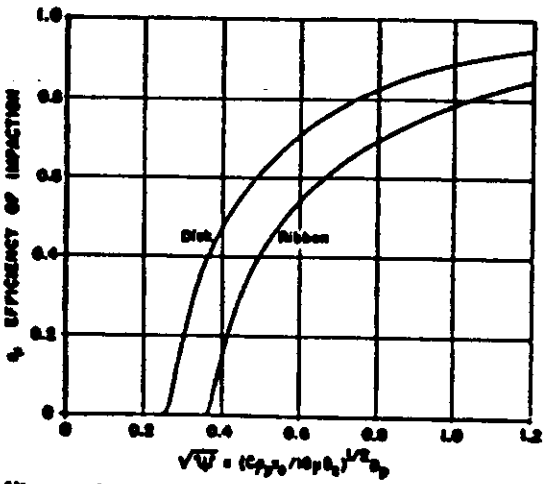


Figure 3. Theoretical Impaction Efficiencies of Disk and Ribbon

A particle will touch the collector whenever its center approaches within a distance $D_p/2$ of the surface; and for the given conditions, the efficiency of interception can be defined by the β_0 of streamlines which pass the collector at a position $\beta = 1 + R$ at $\xi = 0$.

$$\eta_0 = (1 + R) - 1/(1 + R) \quad \text{for a cylinder} \quad (5)$$

$$\eta_0 = (1 + R)^2 - 1/(1 + R) \quad \text{for a sphere} \quad (6)$$

Equations 5 and 6 are shown graphically in Figure 4. These efficiencies represent the minimum value of the impaction efficiency for inertia and interception in an ideal flow. At large values of R, where the particles have much larger diameters than the collector, the efficiency of interception approaches a value of $(1 + R)$ for cylinders and $(1 + R)^2$ for spheres, which are the same limits as those for $\Psi = \infty$. If the postulated physical situation corresponds somewhat to the actual physical situation, then the above results point out interesting facts. For example, a 20-micron spray droplet in a wet scrubber has a minimum impaction efficiency of about 15% for 1-micron particles, and 3% for 0.2-micron particles.

Landahl and Herrmann (*4*) have assumed arbitrarily that the efficiency of impaction caused by interception is equal to R and that it is additive with respect to the efficiency of impaction due to inertia. Rodebush (*10*) gives the same relationship for the interception effect, but states that it is applicable only to the limiting case of zero fiber diameter. The actual situation is much more complicated, although such a correction is in the right direction and of the proper order of magnitude.

NUMERICAL SOLUTIONS FOR EFFICIENCY OF IMPACTION BY INERTIA

In the case of cylindrical and spherical collectors, several attempts have been made to obtain step-by-step calculations of the trajectories of aerosol particles and numerical solutions for the efficiency of collection by inertia (*1, 4, 5, 11*). The results of these calculations are not in good agreement. The extent of the disagreement depends on the nature of the flow field assumed (i.e., the form of $\overline{v} = \overline{v}(x, y, z)$—on the boundary conditions used in the numerical calculation (a finite value of x, must be substituted for an infinite value), on the accuracy of the step-by-step procedure (the method employed and the spacing of the steps), and on the number of limiting trajectories actually determined (i.e., number of points on the efficiency curve). Figures 5 and 6 are graphical representations and comparisons of these theoretical results.

The smooth curves of Figures 5 and 6 are misleading, since they are empirically fitted to a small number of calculated values. Points of disagreement among the various results are the nature of the flow field to be used in calculations, the relative efficiencies of cylinders and spheres when compared on the same basis, and the existence or nonexistence of a critical Ψ. The calculations of Langmuir and Blodgett (*5*) indicate that the collection efficiencies of spheres are slightly higher than those of cylinders for low values of Ψ, but Sell (*11*) states that spheres have much lower efficiencies at all values of Ψ. Langmuir and Blodgett report $\Psi_c = 1/16$ for cylinders and $\Psi_c = 1/24$ for spheres; Ranz (*9*) gives $\Psi_c = 0.09$ for cylinders; other investigators give $\Psi_c = 0$. To emphasize the effect of particle diameter, Figures 5 and 6 have been plotted as η_0 vs. $\sqrt{\Psi}$, and it can be seen that the curves are comparable in form to those for the models of Figures 2 and 3.

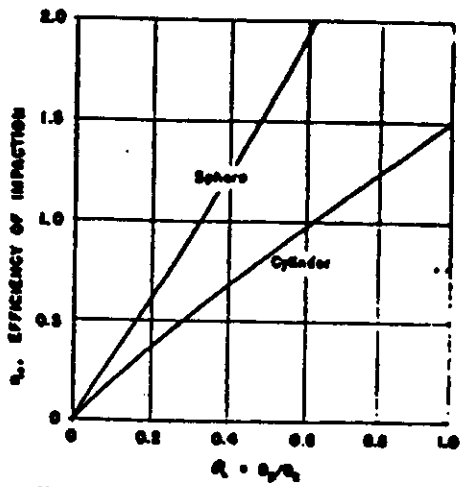


Figure 4. Interception Effect for Potential Flow

The assumption that the reduced velocity is a function of the reduced position coordinates alone is an oversimplification. Actually, the flow will be a function of the Reynolds number of the collector, $N_{Re} = D_c v_0 \rho/\mu$, as well as the reduced position coordinates, particularly near the collector surface where the viscous forces affecting fluid motion are of the same order of magnitude as the inertial forces. Under these circumstances η_0 is not only a function of Ψ and R but also of N_{Re}. This dependency on N_{Re}

WISHART (22)

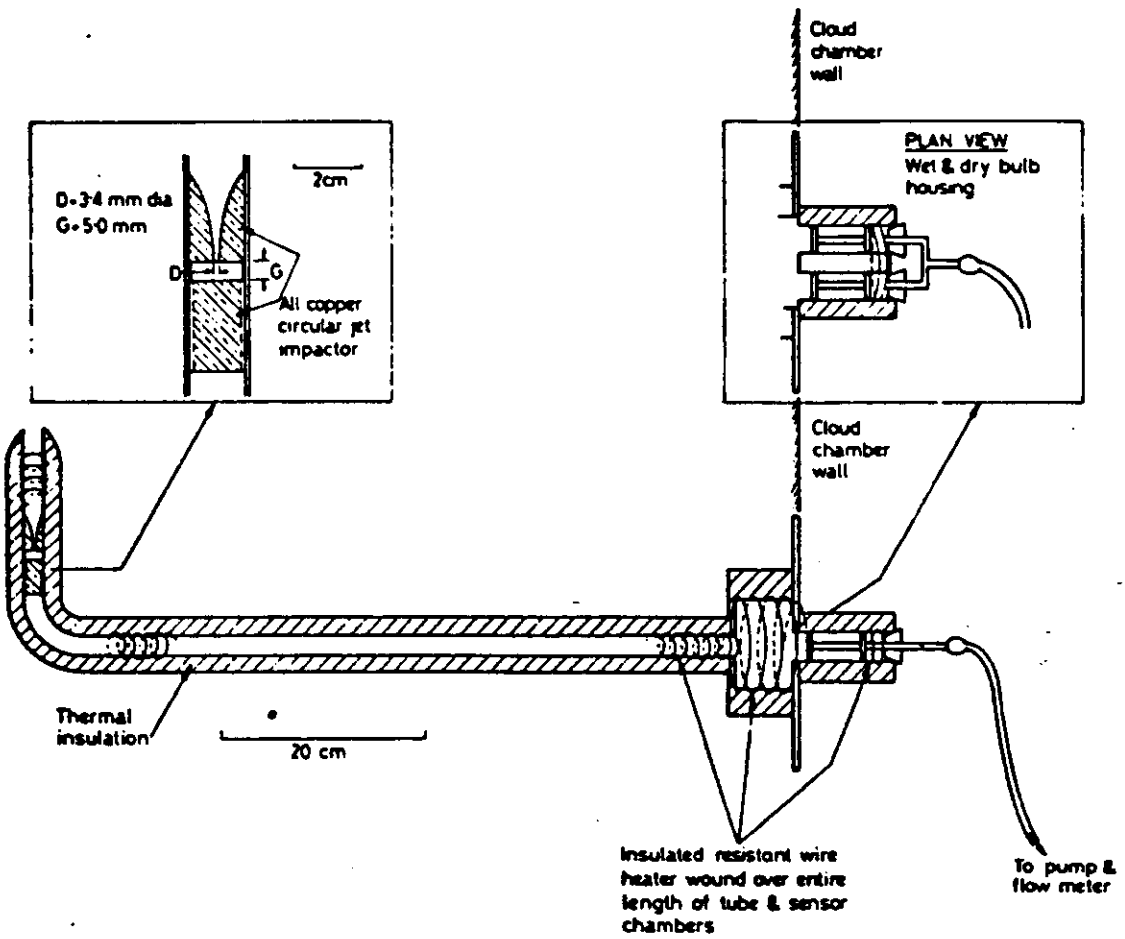


FIG. 1. — Side view of heated impactor, evaporating tube and sensor housings.

c) *Wet and dry bulb sensors.*

Sketches of the wet and dry bulb sensors are shown in Figure 3. Fine wire (75 μm diameter) copper and constantan thermocouples are used to reduce conduction losses and to obtain a reasonably fast response, consistent with mechanical rigidity. Junctions of both wet and dry bulb are matched radially and longitudinally to within 1 mm. Each unit is positively located in the heated housing tube by locating pegs.

It was determined in a separate experiment that the computed LWC remained constant for flow rates through the entire unit of > 4.5 *l* min^{-1}, indicating that correct wet bulb depression was obtained. Therefore a conservative flow rate of 5.5 ± 0.5 *l* min^{-1} was adopted.

d) *Accuracy.*

A calculation (McAdams, 1954 ; Fishenden and Saunders, 1965) shows that the junction of the dry bulb would be only about 0.003 °C lower than the true air temperature of 10 °C and cold room temperature of −10 °C. A similar calculation, with reasonable simplifying assumptions, made for the wet bulb also shows an insignificant error.

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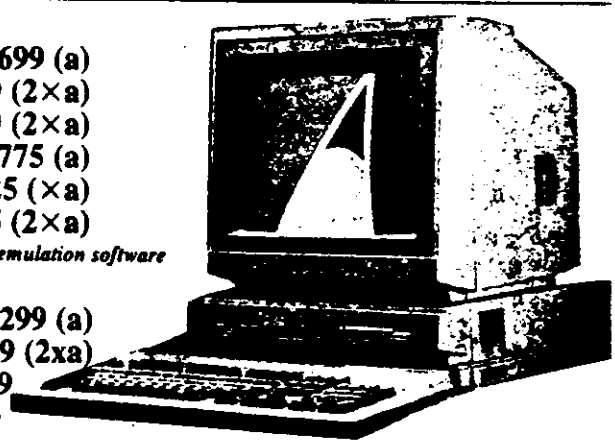

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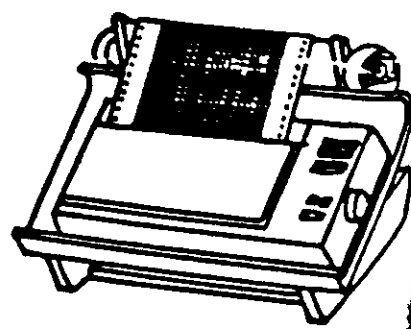

2 Particle Sampling

a) Laser Probes.

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1855 South 57th Court
Boulder, Colorado 80301, USA

i) ASASP-X (Active Scattering Aerosol Spectrometer Probe)
Particles 0.12 – 3.12 μm (diameter)

ii) FSSP-100 (Forward Scattering Spectrometer Probe)
Particles 0.5 – 47 μm.

iii) ASASP – 300 (0.15 – 3 μm)

iv) 2D Probe (Two Dimensional Imaging Probe)
Model OAP – 2D2 – C (25 – 800 μm)

v) 2D Probe for Laboratory use
Model OAP – 2D – GLT (10 – 640 μm)

vi) Data Acquisition Systems.

b) Formvar Replicator
Cloud Particle Replicator for use on a pressurised aircraft.
J. Hallett
Desert Research Institute
University of Nevada, Reno, Nevada, USA

c) Cloud Gun
Squires and Gillespie 1952
A Cloud Droplet Sampler for use on an aircraft
Quarterly Journal Royal Meteorological Society
78, 387 – 393

d) Foil Impactor (Latham J and Stow C D; Qu. J. Roy Met Soc 95, 486 – 500)

e) Slides

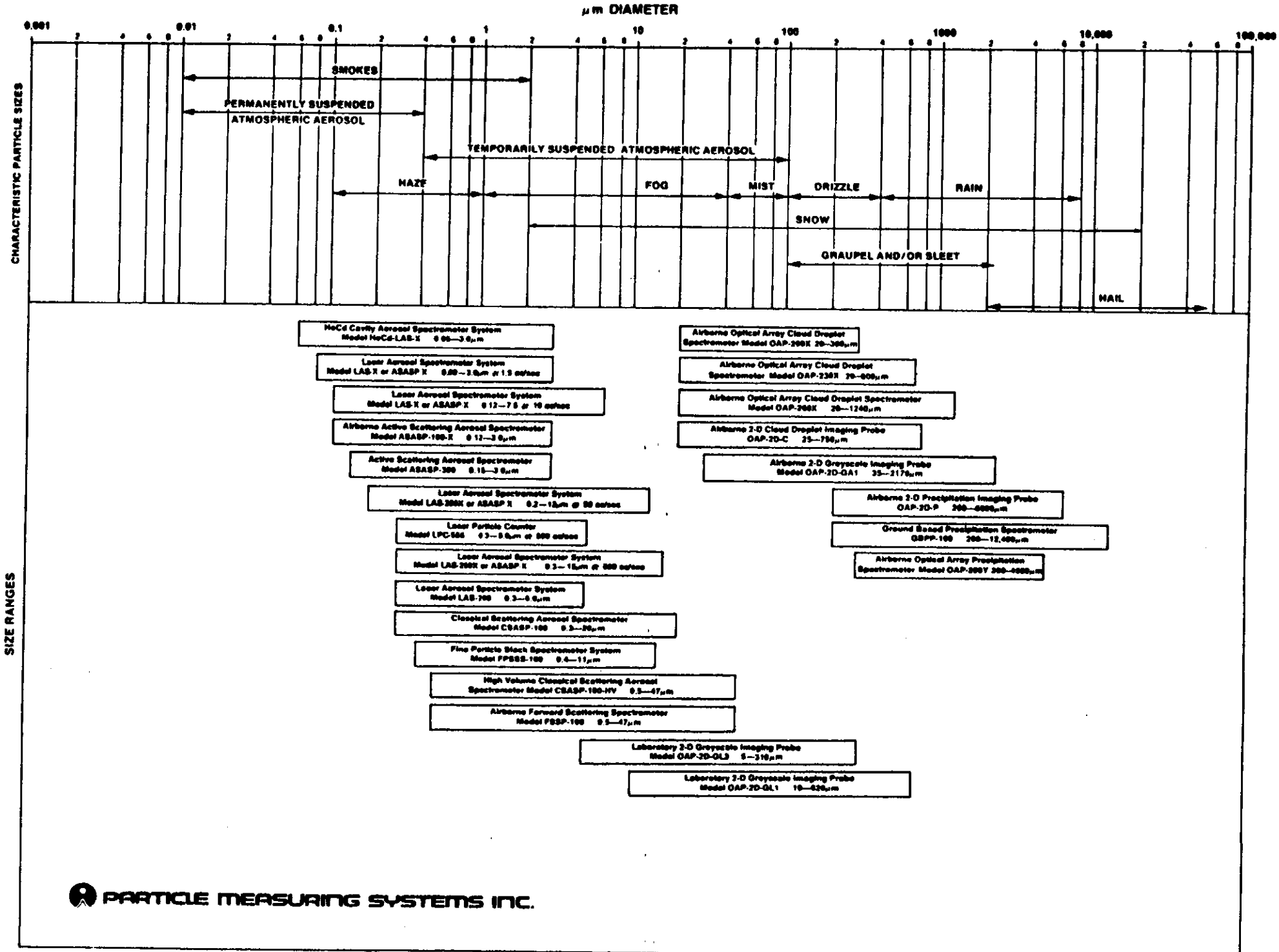
INTRODUCTION

Measurement of the size and mass distribution of atmospheric particulates is required both for understanding of precipitation mechanisms and also for applied problems relating to the operation of aircraft and space vehicles. The number concentration of particles in the atmosphere extends over many orders of magnitude depending on size:

	Typical Diameter	Typical Number Concentration in Air
Aitken nuclei	.01 μm	$10^{6} \rightarrow 10^{2}$ cm^{-3}
Cloud drops	20 μm	$10^{3} \rightarrow 10^{2}$ cm^{-3}
Rain drops	mm	$10^{3} \rightarrow 10$ cm^{-3}
Ice crystals	100 μm	$1 \rightarrow 10^{-4}$ cm^{-3}
Graupel	2mm	$10^{3} \rightarrow 10$ m^{-3}
Hail	cm	$10^{-3} \rightarrow 10^{-5}$ m^{-3}

This range of concentration and its intrinsic variability highlights the problems of instrumentation for measurement of number concentration. There is a practical limit in observing a concentration of one particle in 10^{-6} cc to one in 10^{5} m^{3} with a single instrument; there is a practical limit in sampling sufficient numbers of particles over the whole size range to give a meaningful statistical representation. Moreover, for aircraft operation, an averaging over a flight time as little as a few seconds to give spatial variability, adds to the difficulty. The practical solution of this problem has been to employ several instruments capable of sampling particles in a limited range of volumes, each instrument overlapping in part the range of that measuring larger and smaller volumes. Optical systems require a minimum of three instruments to cover the range, with sampling volumes of mm^{3}, 5 cm^{3} and 100 cm^{3}. Impactor systems have used sampling areas → 100 mm^{2} (exposed microscope slide), 1000 mm^{2} (foil impactor) and for surface measurements, 1.0 m^{2}.

SIZE RANGES OF STANDARD PMS PARTICLE SIZE SPECTROMETERS



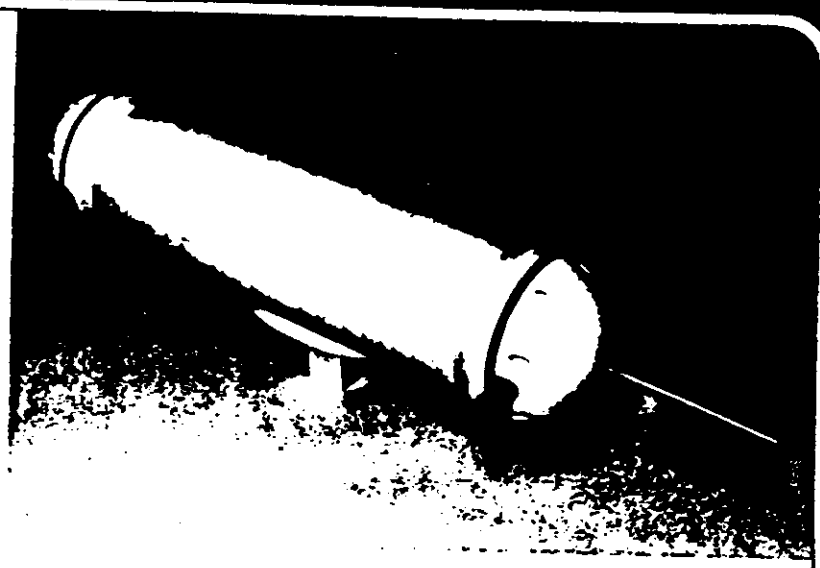
PARTICLE MEASURING SYSTEMS INC.

PARTICLE MEASURING SYSTEMS INC.

ACTIVE SCATTERING AEROSOL SPECTROMETER PROBE MODEL ASASP-100-X

FEATURES

- In site sampling
- Solid state photodetectors
- Long life He-Ne active cavity laser
- 0.12 μm sensitivity
- 2.2 π steradian collecting solid angle
- PHA reference to laser (AGC)
- Low coincidence error
- High sampling efficiency
- All-weather design



GENERAL DESCRIPTION

The ASASP-100-X Probe is a new concept in aerosol sampling for aircraft providing tenth micron sensitivity without plumbing and ducts.

The probe is specifically designed for aircraft operation; its particular size range is from 0.12 μm to 3.12μm (diameter). This size range is divided into 15 linear progressively weighted intervals. The first interval is 0.025 μm and each larger interval is 0.025 greater than the one preceding it. The ASASP-100-X utilizes an aluminum cylindrical enclosure to provide mechanical stability and weatherproofing, identical to other PMS airborne instruments. Laser and detector alignment is achieved with spring- loaded x-y screw adjustments.

The ASASP-100-X laser is a hybrid He-Ne (632.8 nm) tube with an aluminum envelope especially designed for the ASASP-100-X. The ASASP-100-X pulse height analyzer (PHA) has its reference voltage derived from the source of illumination, providing effective automatic gain control (AGC).

To provide high efficiency sampling the main sample stream enters the probe through a large bore inlet. A decelerator and flow straightener section are then used to provide isokinetic flow between the main sample stream and the sample jet inlet tube. The main sample stream flow is vented out the side of the probe. The sample jet is an aerodynamically focused jet; it constrains particle flow to a small diameter particle sample stream surrounded by a filtered sheath flow.

The particle sample stream is positioned at the focus of a 5 mm parabolic mirror. The collected light is collimated by the parabolic mirror and after reflecting off a 45° flat mirror is refocused by an aspheric lens. A single photodiode detector with over 50% quantum efficiency converts the collected light into a signal photocurrent.

The ASASP-100-X Probe is one of a series of PMS probes designed to interface directly with PMS data acquisition systems — PDS-200, PDS-300, PAS-2D, DAS-32, and DAS-64. System combinations involving several spectrometers and a central data acquisition system are particularly cost-effective. The ASASP-100-X Probe will also interface to minicomputers, computers, or other data acquisition systems with memory storage. All communication with the ASASP-100-X Probe is through high noise-immunity twisted-pair lines using line drivers/receivers or optical isolators. Particle size is encoded in binary form with an accompanying strobe pulse.

OPTICAL SYSTEM

The ASASP-100-X has a unique optical system featuring the largest collecting solid angle in the industry. The active laser cavity provides an energy density in excess of 50 W cm^{-2} with a beam width of 300-500 μm (0.1)5-3.125 μm range). The collecting optics include two front surface mirrors and an aspherical refracting element housed in a single aluminum block (optical/sample module). See Figure 1.

The primary collecting mirror is a parabolic element of 5 mm f.l. which has been gold-plated to provide 90% reflectivity at 632.8 nm. Particles pass through its focus when in the sampling volume.

The second front surface mirror is dielectrically coated to provide better than 99% reflectivity at 632.8 nm. The dielectrically coated aspheric collecting lens completes the collecting optical system. The combined imaging system has an effective magnification of 5X. The system collects light from 35-120°, providing a 2.2 π steradian solid angle.

AIRFLOW SYSTEM

The airflow system of the ASASP-100-X is designed with particle sampling efficiency in mind. It uses a large bore inlet with decelerator and flow straightener before inputting into a fully plumbed sampling system with aerodynamic focusing (see

PMS
DS-ASASP 100-X
JULY 1980

Fig. 1. Optical System Diagram

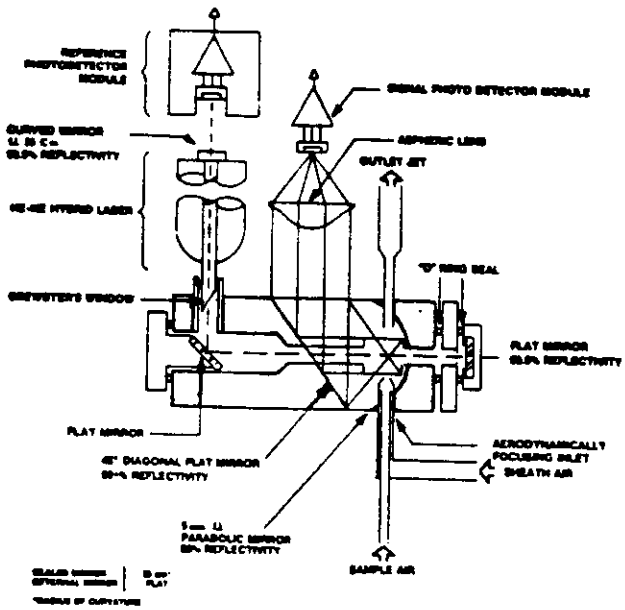


Fig. 2. Air Flow Diagram

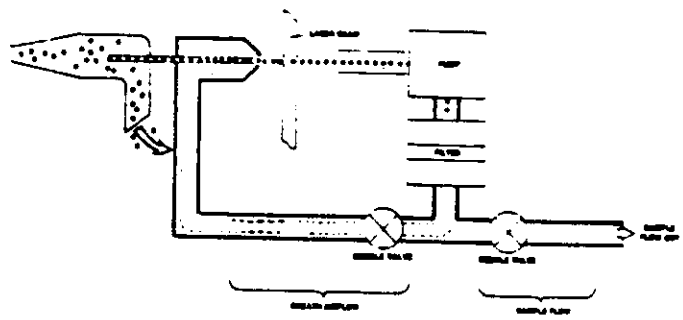


Figure 2). The shortest possible direct path is provided from the inlet to the illuminated sample volume.

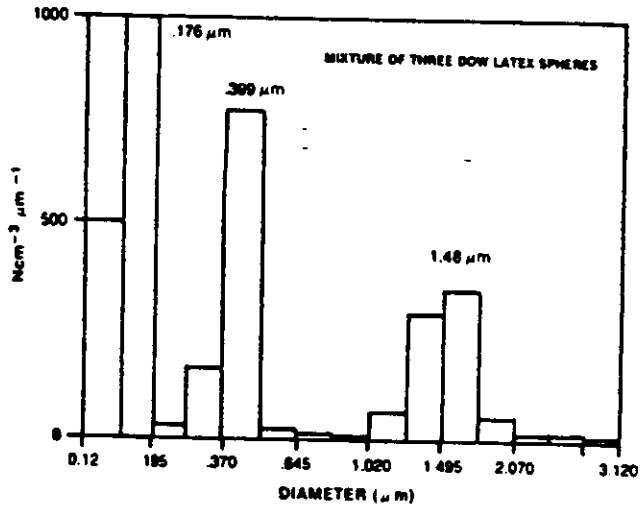
The aerosol sample passes through a short section of hypodermic tubing where it joins a flow of filtered sheath air. The flow remains essentially laminar and is aerodynamically focused by a nozzle. The aerosol sample stream is ~ 100 μm diameter when intersecting the laser beam.

The pump is a diaphragm pump having up to 6 liter min^{-1} capacity. The sample flow and sheath flow can be independently monitored and set by the metering valves. "O" ring seals are used throughout the optical/sample module. Connections are made with ⅛" pipe threaded fittings.

PERFORMANCE

The high resolution capability of the ASASP-100-X Probe is of great importance in the submicron sizes. Figure 3 illustrates the spectral resolution of the ASASP-100-X with a mixture of three DOW latex particles. The ASASP-100-X is a full spectrometer with all sizes being sampled simultaneously. Size channel information is encoded in the data outputs.

Fig. 3. Particle size spectrum from a mixture of 3 DOW latices showing resolution of ASASP-100 - X



SPECIFICATIONS

Size range	0.12-3.12 μm (diameter)
Number of size channels	15, 30, and 60
Channel intervals	Linear, progressively weighted Channel 1 = 0.025 μm (15 channel instrument) Each larger channel is greater than the adjacent channel preceding it by 0.025 μm
Minimum detectable size	0.12 μm
Sample flow rate	1-2 cm^3 sec^{-1}
Laser	He-Ne TEM_{00} mode active cavity
Optics	Collecting optics consisting of a 5 mm f.l. parabolic mirror, a 45° plane mirror, and an aspheric lens. Collecting solid angle 35-120° (2.2 π steradians)
Scattering detectors and preamps	Silicon photodiode detector low noise pre-amp 100 KHz response
Data output characteristcis	4-line binary code particle size plus strobe. TTL levels with line drivers/receivers. Data latched for minimum of 4 μsec. External read and reset signals can be provided. Data output compatible with all PMS data acquisition systems including PDS-200, PDS-300, DAS-2D, DAS-32, and DAS-64.
Environmental	Temperature: −40 to +40°C Altitude: 12.2 km (40,000 feet) Humidity: 0-100% RH
Power	115 V 60 Hz less than 1½ amp
Dimensions	100 x 18 cm (39 x 4 x 7.1 inches)
Weight	18.2 kg (40 lbs)

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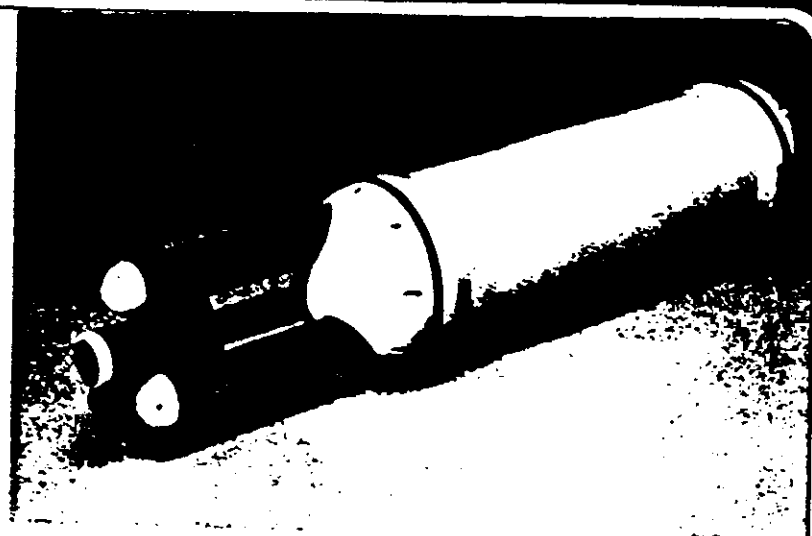
1855 South 57th Court, Boulder, Colorado 80301 (303) 443-7100 TWX 910-940-5891

PARTICLE MEASURING SYSTEMS INC.

FORWARD SCATTERING SPECTROMETER PROBE MODEL FSSP-100

FEATURES

- Solid state photodetectors standard
- Long life He-Ne laser
- Wide size range — 0.5 μm to 47 μm
- True *in situ* sizing
- High resolution — 0.5 μm
- Programmable size ranging
- Compatible with minicomputer
- PHA referenced to laser — AGC
- Low coincidence error
- Aircraft or ground installation
- Heated optics



U.S. Pat. 3956616

APPLICATIONS

- Cloud physics
- Precloud & haze measurements
- General air pollution monitoring
- Stack plumes
- Cooling tower plumes
- Wind blown dusts
- Fuel plumes
- Ground fogs
- Traffic pollution assessment
- Wind tunnel testing

GENERAL DESCRIPTION

The FSSP is an airborne instrument designed or *in situ* particle size measurements. It can also be used aboard ground vehicles. The FSSP has four overlapping size ranges with each size range divided into fifteen linear size intervals providing up to 60 size channels in the 0.5 to 47 μm range. The FSSP is packaged in a cylindrical pod as a plug-in assembly. Laser and detector alignment is achieved with spring-loaded x-y screw adjustments. The FSSP's He-Ne (632.8nm) laser tube has an extruded aluminum envelope and is configured in high order multimode. The FSSP pulse height analyzer has its reference voltage derived from the source of illumination providing effective automatic gain control (AGC). A programmable amplifier is used to gain switch and provide the size ranging to accommodate the large dynamic range.

The probe electronics are self-contained, the output being the particle size in binary code accompanied by a strobe pulse to increment an appropriately addressed memory channel in a data acquisition system.

The FSSP is one of a series of PMS probes designed to interface directly with PMS data acquisition systems — the PDS-200, PDS-300, DAS-2D, DAS-32 and DAS-64. System combinations involving several spectrometers and a central data acquisition system are particularly cost effective. The FSSP will also interface to minicomputers, computers or other data acquisition systems with memory storage. All communication with the FSSP is through high noise-immunity, twisted-pair lines using line drivers/receivers or optical isolators.

OPTICAL SYSTEM

The laser used in the FSSP is a high order multimode 5 mW He-Ne tube. The beam is focused to approximately 200 μm diameter using condensing optics with a 60 mm effective focal length. The point of focus coincides with the center of the sampling aperture. Particles passing through the laser beam in the sampling aperture, scatter energy into the optics. The amount of scattering for a given particle size is a function of the laser mode, as well as the exact chordal transect through the beam. With a high order multimode laser, the probability of intersecting the peak isophote is as high as 90% (typically 80%). Correction for edge effect errors can be accomplished statistically; however, in the FSSP, the particle transit times can be measured precisely allowing for edge-effect rejection using a patented pulse-width comparison technique.

The scattered energy is relayed from the object plane by a right angle prism to a 55 mm f/1.8 collecting lens and focused through an interference filter to a masked beam-splitting prism. The transmitted laser beam is dumped at a central stop on the prism. The masking on the prism is a central 1 mm dump spot on the 90° transmitting face creating an annular aperture. This serves to allow only light transmission from particle images when the particles are displaced a certain distance in

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DS-FSSP
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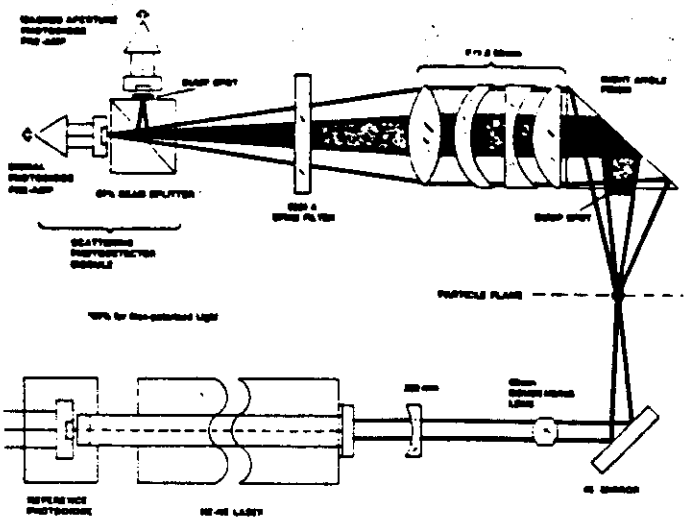
Fig. 1 FSSP 100 OPTICAL SYSTEM DIAGRAM



either direction from the object plane and no transmission when at or very near the object plane. The depth-of-field is truncated by comparing the light signals on the paired detectors.

PERFORMANCE

The single most important feature of the FSSP increasing its performance is its high magnification optical system which reduces sample volume to where coincidence errors are less than 10% at concentrations of $10^3 cm^{-3}$ Fig. 2A illustrates comparative cloud droplet spectra from a flight using the PMS 206 aircraft and a high framing rate data system having one-fifth second resolution. Fig. 2B illustrates pairs of droplet spectra from two different FSSPs. The results are typical of the intercomparisons of two identical instruments.

For cloud physics work the FSSP normally has a primary size range of 2 to 32 μm diameter, resolving particles into 15 size classes. Four switchable size ranges cover 0.5 to 47 μm. It is normally set up to size particles having velocities from 10 to 125 m $sec.^{-1}$

For ground work an optional fan powered aspiration system is employed. It provides a uniform velocity of approximately 26m sec^{-1} and true isokinetic sampling.

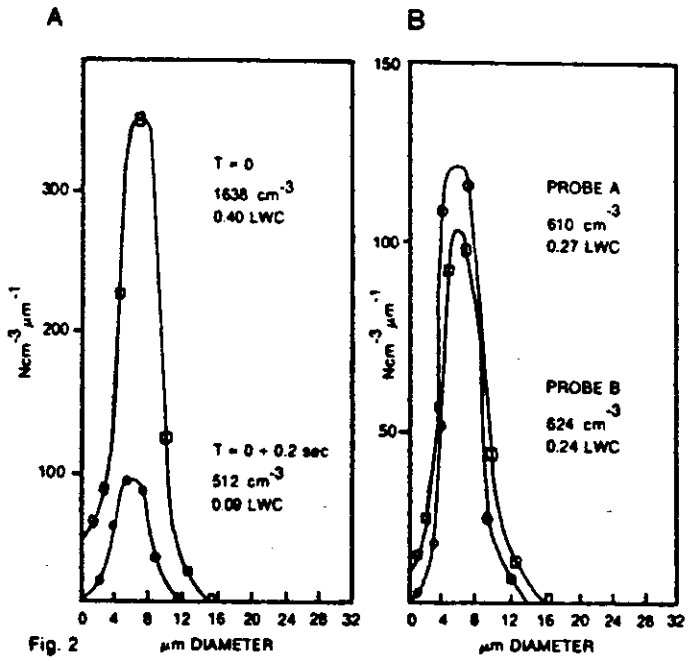


Fig. 2

SPECIFICATIONS

Size Ranges	Four ranges covering 0.5 to to 47 μm Typical: 0.5 - 8.0, 1 - 16, 2 - 32 and 3 - 47 μm
Number of Size Channels	4 ranges — 60 channels
Minimum Detectable Size	0.5 μm
Size Resolution	One channel, 0.5 μm typical in most sensitive range
Sampling Capability	Sample area: 0.3 mm^2 Volume sampling rate: 30 cm^3 sec^{-1} @ 100m sec^{-1}
Laser	He-Ne high order multimode
Optics	Collecting optics consisting of 4 element matched collecting lens set with interference filter. All optics ½ wave or better over required aperture
Scattering Detectors and Pre-amps	Silicon photodiode detectors standard. Low noise pre-amps 100 KHz response
Data Output Characteristics	4-line binary coded particle size plus strobe. TTL levels with line drivers/receivers. Data latched for minimum of 4 μsec. Data output compatible with all PMS data acquisition systems including PDS-200, DAS-20, DAS-32, DAS-64, and PDS-300
Environmental	Temperature: −40 to +40° C Altitude: 0 — 40,000 feet (0 — 12.2 Km) Humidity: 0 — 100% RH
Power	115V, 50 - 400 Hz, less than 1 amp (Optional 230 VAC 12-28VDC)
Dimensions	Probe: 40" L x 7" diameter (101.6 cm x 17.8 cm diameter)
Weight	40 pounds (18.2 kg)

PARTICLE MEASURING SYSTEMS INC.
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PARTICLE MEASURING SYSTEMS INC.

ACTIVE SCATTERING AEROSOL SPECTROMETER PROBE MODEL ASASP-300

FEATURES

- Solid state photodetectors
- Long life He-Ne laser
- Greatest sensitivity — 0.15 μm
- True *in situ* sizing
- Highest resolution — 0.01 μm
- Programmable size ranging
- Compatible with minicomputer
- PHA referenced to laser — AGC
- Remote monitoring (500m)

Class 1 Laser Product

APPLICATIONS

- Air pollution monitoring
- Hospital and clean room monitoring
- Milling and chemical process controls
- Volatile oils and fine mists
- Pharmaceutical manufacturing
- Smokes, dusts, and fine powders
- Filter testing
- Engine exhaust particulate analysis
- Chemical and biological studies
- Mining
- Meteorology
- Particle generation

GENERAL DESCRIPTION

The ASASP-300 Probe is designed with four overlapping size ranges with each size range divided into fifteen linear size intervals providing up to 60 size channels in the 0.15 to 3.0 μm range. The ASASP-300 Probe is packaged in an extruded aluminum enclosure for mechanical stability. Laser and detector alignment is achieved with spring-loaded x-y screw adjustments. The laser is a hybrid He-Ne (632.8 nm) tube with an aluminum envelope specially designed for the ASASP-300. The pulse height analyzer (PHA) has its reference voltage derived from the source of illumination providing effective automatic gain control (AGC). A programmable amplifier is used to gain switch and provide the size ranging to accommodate the large dynamic range of the instrument.

The primary method of aspiration is unlike any used in conventional aerosol counters. It is in essence a miniature wind tunnel. A 10:1 accelerator produces a flow rate of 6.22 msec^{-1} intersecting with a 3 cm length of the laser beam. The sample volume is positioned at the center of flow. This instrument relies entirely upon optical definition of the sample volume through a unique patented method. Problems associated with small bore tubing are eliminated. This makes the technique particularly useful for sizing volatile particulates and eliminates coalescence and coagulation effects produced by plumbing.

The ASASP-300 Probe is one of a series of PMS probes designed to interface directly with PMS data acquisition systems — the PDS-200, PDS-300, DAS-2D, DAS-64, and PDPS-11C. System combinations involving several spectrometers and a central DAS are particularly cost effective.

The ASASP-300 Probe will also interface to minicomputers, computers, or other data acquisition systems with memory storage. All communication with the ASASP-300 is through high noise-immunity, twisted-pair lines using differential line drivers/receivers or optical isolators. Particle size is encoded in 4-bit binary form with an accompanying strobe pulse for each particle encountered.

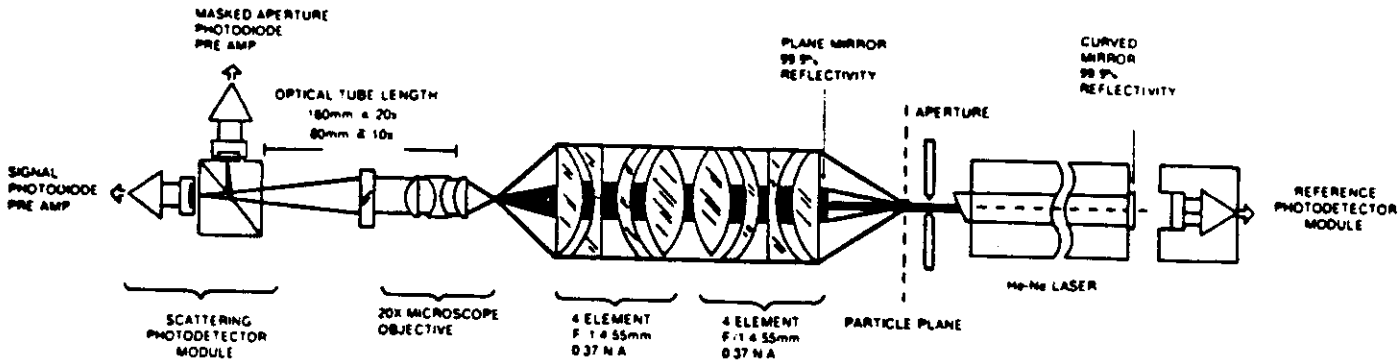
OPTICAL SYSTEM

The ASASP-300 optical system is unique in the industry. The optical diagram in Figure 1 shows the typical ASASP-300 laser cavity configuration. The plasma tube is sealed with a high reflectivity curved mirror and a Brewster's window. An external adjustable high reflectivity mirror completes a hemispherical cavity laser operating in TEM_{00} mode. At the sample volume location the laser beam is approximately 500 μm diameter and produces a power density in excess of 500W cm^{-2}.

The ASASP-300 uses an 11 element refracting imaging system in its collecting optics. This high resolution imaging system is used for particle trajectory analysis as well as light gathering. The scattered light is collected and reimaged at 10X magnification or greater within a dark field. The transmitted laser beam is dumped at a central stop behind the mirror on the first lens element. A masked beam-splitter derives two signals, which in conjunction with double pulse height analysis,

PMS
DS-ASASP 300
March 1983

Fig. 1. Optical System Diagram



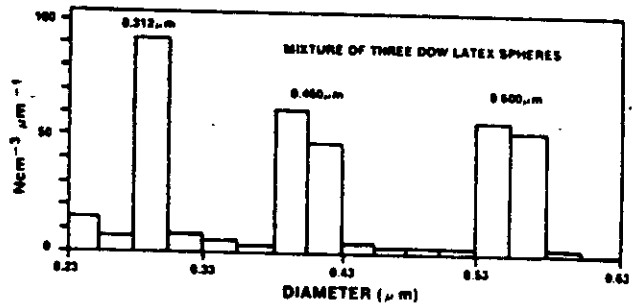
provides a means of determining a particle's position as well as the amount of light scattered. The sample volume includes only the region near the center of the laser beam. Both the width of the sample volume cross section and the depth-of-field vary inversely with the magnification used in the collecting optics, providing control over sample volume size and coincidence error without plumbing or dilution systems.

PERFORMANCE

The high resolution multi-ranging capabilities of the ASASP-300 Probe have greatest importance in the submicron size range. Figure 2 illustrates the spectral resolution of the ASASP-300 with a mixture of three DOW latices on Range 2. The ASASP-300 is a full spectrometer with all size classes sampled simultaneously in the selected range. Size ranges may be externally controlled.

Airflow rates in the ASASP-300 are invariant and determined to a greater accuracy than in plumbed systems. The constant speed axial blower varies less than 1% with a ±10 volt change in line voltage. Sample volume is unaffected by altitude changes. To provide airflow adaptation to existing plumbing, a "test section" is provided.

Fig. 2. Particle size spectrum from a mixture of 3 DOW latices showing resolution of ASASP-300



SPECIFICATIONS

Size Ranges	Four ranges covering 0.15-3.0 μm Typically: 0.15-0.3, 0.23-0.6, 0.4-1.0, 0.6-3.0 μm
Number of Size Channels	15
Minimum Detectable Size	0.15 μm
Size Resolution	0.01 μm typical
Sampling Capability	Sample area: 0.018mm² @ 10X magnification (diamond shaped)
	Volume sampling rate: 0.13 cm^3 sec^{-1} @ 10X magnification
Laser	He-Ne TEM_{00} mode
Maximum Number Density or Concentration for 90% Counting Accuracy	300 cm^{-3} without coincidence dead time loss correction
	3000 cm^{-3} with coincidence dead time loss correction using activity
Optics	Collecting optics consisting of an 11 element matched collecting lens set with optional interference filter. All optics ½ wave or better over required aperture.
Scattering Detectors and Pre-Amps	Silicon photodiode detectors Low noise pre-amps 100 KHz response
Data Output Characteristics	4-bit binary coded particle size plus strobe. Activity frequency for coincidence loss correction. TTL levels with differential line drivers/receivers. Data latched for minimum of 10μsec.
	Data output compatible with all PMS data systems. Includes PDS-200, PDS-300, DAS-2D, DAS-64, and PDPS-11C
Environmental	Temperature: −25 to +40°C Altitude: 0-40,000 ft (0-12.2 km) Humidity: 0-99% RH (noncondensing)
Power	115V, 50-60 Hz, less than 1 amp 100V, 220V, 240V, 50-60 Hz Optional
Dimensions	94.4 x 15.2 x 20.3 cm (37 x 6 x 8 in)
Weight	20.5 kg (45 pounds)

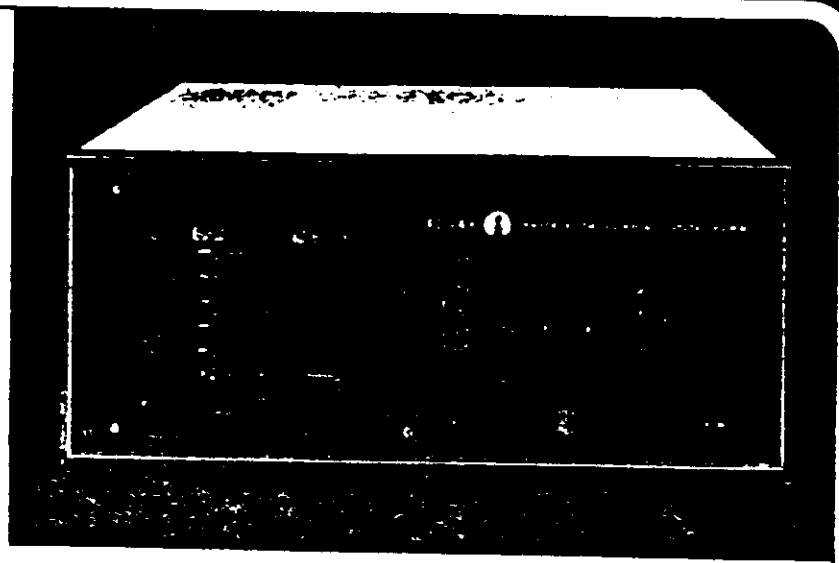
PARTICLE MEASURING SYSTEMS INC.
1855 South 57th Court, Boulder, Colorado 80301 (303) 443-7100 TWX 910-940-5891

PARTICLE MEASURING SYSTEMS INC.

PARTICLE DATA SYSTEM
MODEL PDS-400

EATURES

Real-Time Data Processing
Real-Time CRT Graphics
Up to 8 PMS 1-D Probes
RS-232 Serial Data Output
and/or Remote Control
Full Alphanumeric Keyboard
Menu Driven Setup
with Non-Volatile Memory
Non-Volatile Clock/Calendar
Go/No Go Diagnostics
Optional Printer/Plotter



ENERAL DESCRIPTION

The PDS-400 is a general purpose data system
r handling up to 8 PMS 1-D probes simultan-
ously. It offers powerful real-time data processing
cilities with real-time display on a built-in 7-inch
RT having full alphanumeric and graphics cap-
bility. An optional printer/plotter allows
mediate hard copy output of anything display-
le on the CRT as desired. A standard serial
S-232 I/O port transmits alphanumeric data to an
ternal recorder or computer and permits remote
ntrol of the PDS-400 by the external computer.

The system configuration is setup via a menu
hich displays the current configuration as
tained in non-volatile memory. Each field in the
enu has several selections which may be exam-
ed by simply stepping through the selections via
single keyboard key. Each field has a brief set of
planatory instructions associated with it which
ay be accessed by pressing the HELP key. In
fect, a brief operating manual is built into the
stem which often precludes the need for
parate documentation.

Two sampling modes are available. The double
ffer mode is used to monitor continuously active
ocesses without loss of data. The single buffer
de is used with processes that require a setup,
mple, print and teardown cycle.

Up to 8 PMS 1-D probes can be operated simul-
neously with up to 64 size classes per probe
ving up to 17 million population capacity per
ze class. Range control outputs are provided to
low multirange (up to 4 ranges) probes to be used
well as single range probes.

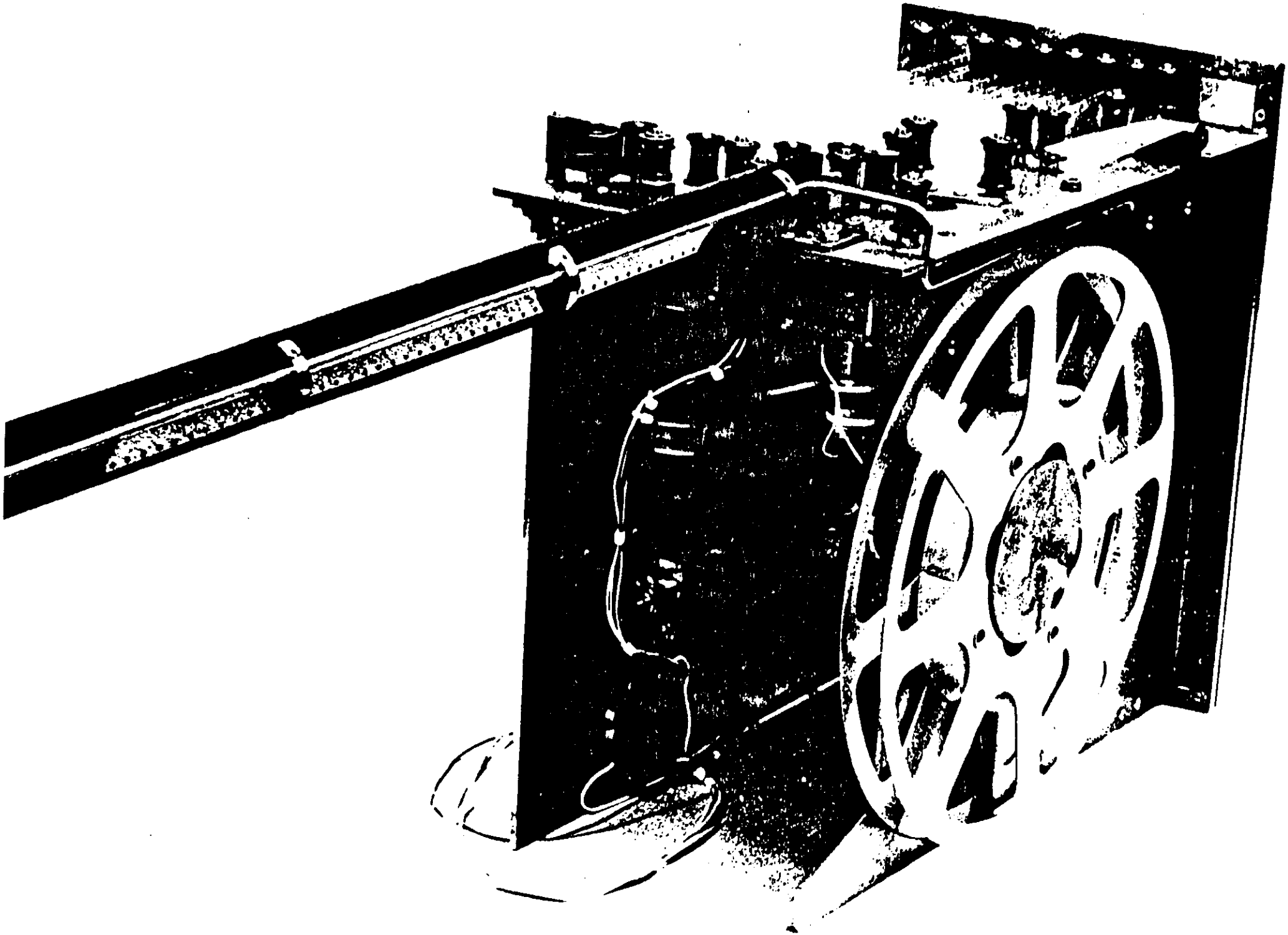
All data, setup configuration and operating in-
ructions appear on the CRT which has 256 x 256
tal resolution (42 characters x 32 lines of text).
ere are two particle memories, one for currently
cumulating particles and one for the last
mplete accumulation interval. When the
cumulation interval ends (timed or manually),
rrent data becomes complete data which may
output via an operator selectable program.
Complete data programs may have predefined attributes or have the same attributes as the current data display.

Go/No Go diagnostics are provided to allow self-testing of the system via an external CRT terminal. Diagnostics are self-identifying and self-instructing. They include RAM, printer, keyboard, serial port and probe DMA tests. The probe DMA test requires the optional programmable probe simulator module.

SPECIFICATIONS

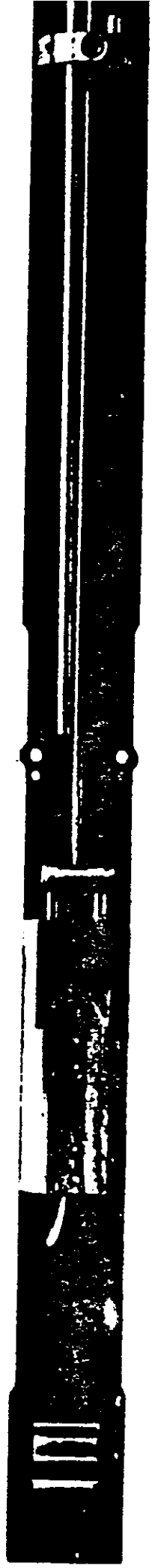
Number of PMS Probe Inputs	Available in 2, 4, 6, or 8 Probe Versions
Maximum Total Particle Rate	100K particles/second via DMA hardware
Number of Size Classes	64 per probe with 17 million population capacity per size class. Up to 4 ranges per probe.
CRT Display	7-inch diagonal green phosphor, 256 x 256 Pictal, raster scan
Keyboard	31 shiftable auto-repeating keys. Full alphanumeric plus special functions. 8 status LED indicators.
Processor	Z80, 2.5 MHz, STD Z80 BUS with 24K Bytes EPROM, 4K Bytes Volatile RAM, 2K Bytes non-volatile RAM
Clock/Calendar	Non-volatile 99 year calendar and time-of-day clock with 1 second per day stability.
RS-232 I/O Port	300 to 9600 Baud. RTS/CTS handshaking for data out. DTR/DCD handshaking for remote control
Printer Output Port	Available for either Okidata ML82A or Axiom EX-820 printer/plotter. Reproduce anything displayable on CRT. Regular 8.5-inch paper with 40 seconds per page on Okidata. Electrosensitive 5-inch paper with 20 seconds per page on Axiom.
Diagnostic Port	Suitable for any standard CRT terminal (RS-232)
Physical	Table top or EIA rack mount, 19"W x 17"D x 7"H, less than 30 lbs.
Environmental	Integral implosion protection CRT. 0 to 40 degrees C. 0 to 10K feet. No special ventilation requirements.
Power	47 to 400 Hz 90 to 125V at 1A or 180 to 250V at 0.5A

PMS
PDS-400
March 1983



FORMVAR REPLICATOR

(HEAD)



CRRS

Soot coated slides are exposed for a measured time to an airstream containing the cloud droplets. The air velocity through the sample volume is provided by a vacuum cleaner which at 240V 50Hz provides an air velocity of 3708 cms^{-1}. At this velocity the collection efficiency of the slide can be calculated from Ranz and Wong :-

$$\sqrt{w} = \left(\frac{C\rho_p}{18\mu D_c}\right)^{\frac{1}{2}} \left(v_o^{\frac{1}{2}}\right) D_p = \left(\frac{1}{18 \times 1.77\times10^{-4} \times 0.6}\right)^{\frac{1}{2}} v_o^{\frac{1}{2}} D_p$$

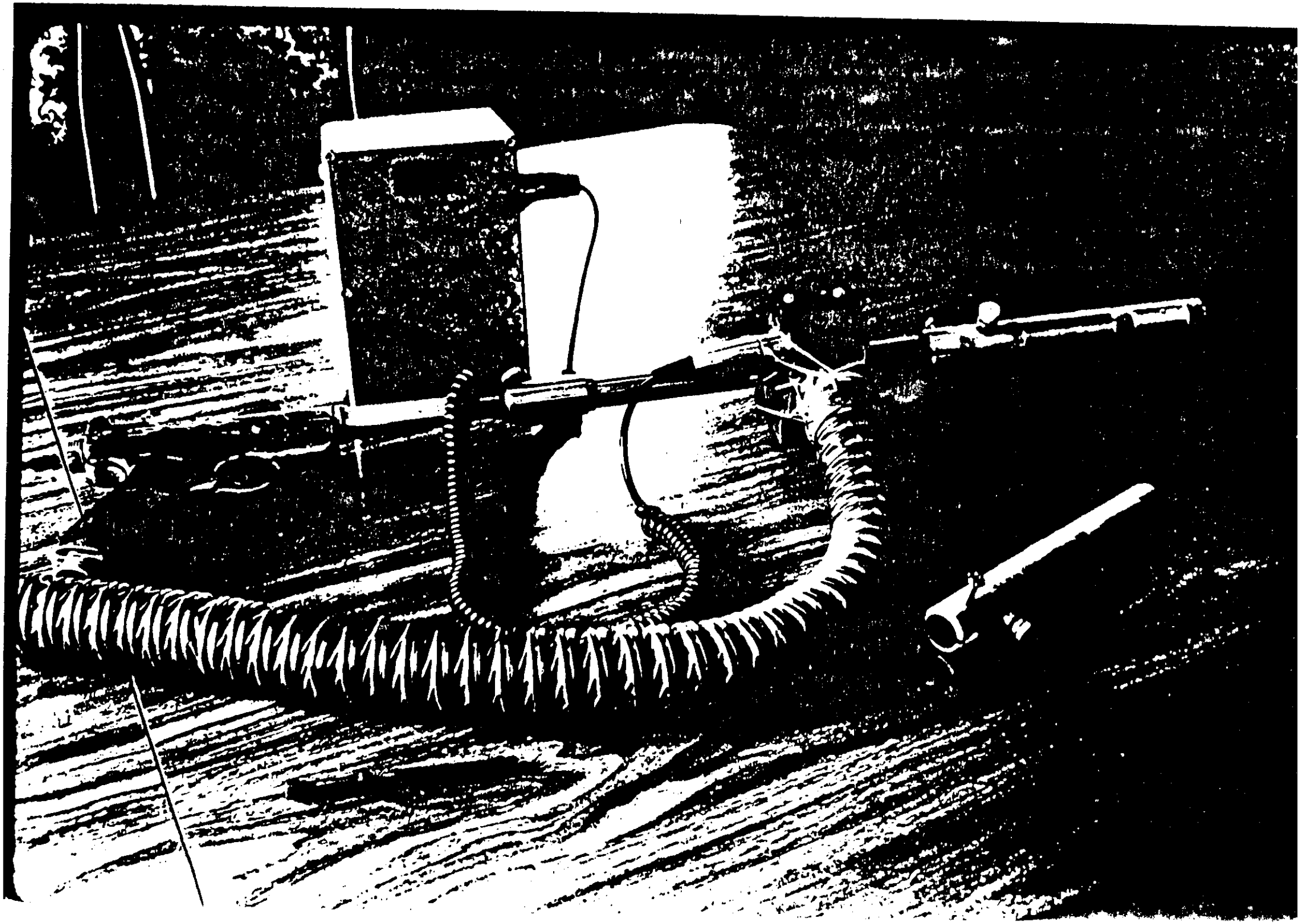
$$\sqrt{w} = 22.87 \times v_o^{\frac{1}{2}} D_p$$

Ranz & Wong give a graph of $\sqrt{w}$ against collection eff

[D_c = Width of slide ; v_o = Air Velocity ; ρ_p = Particle Density ; $C = 1$; D_p = Particle diameter ; μ = Viscosity of air $= 1.77 \times 10^{-4}$ @ 10°

The droplets impinge on the coated slide (obtained by moving the slide holder plus plastic insert gently through a candle flame) and the impressions made are related to the droplet size by the graph attached.

From the concentration of drops on a known slide sample area (eg a microscope field of view) the volume concentration can be determined from the sample time obtained from the timer unit.



CLOUD GUN COLLECTION EFFICIENCY FOR VELOCITY OF 3708 cm s^{-1}.

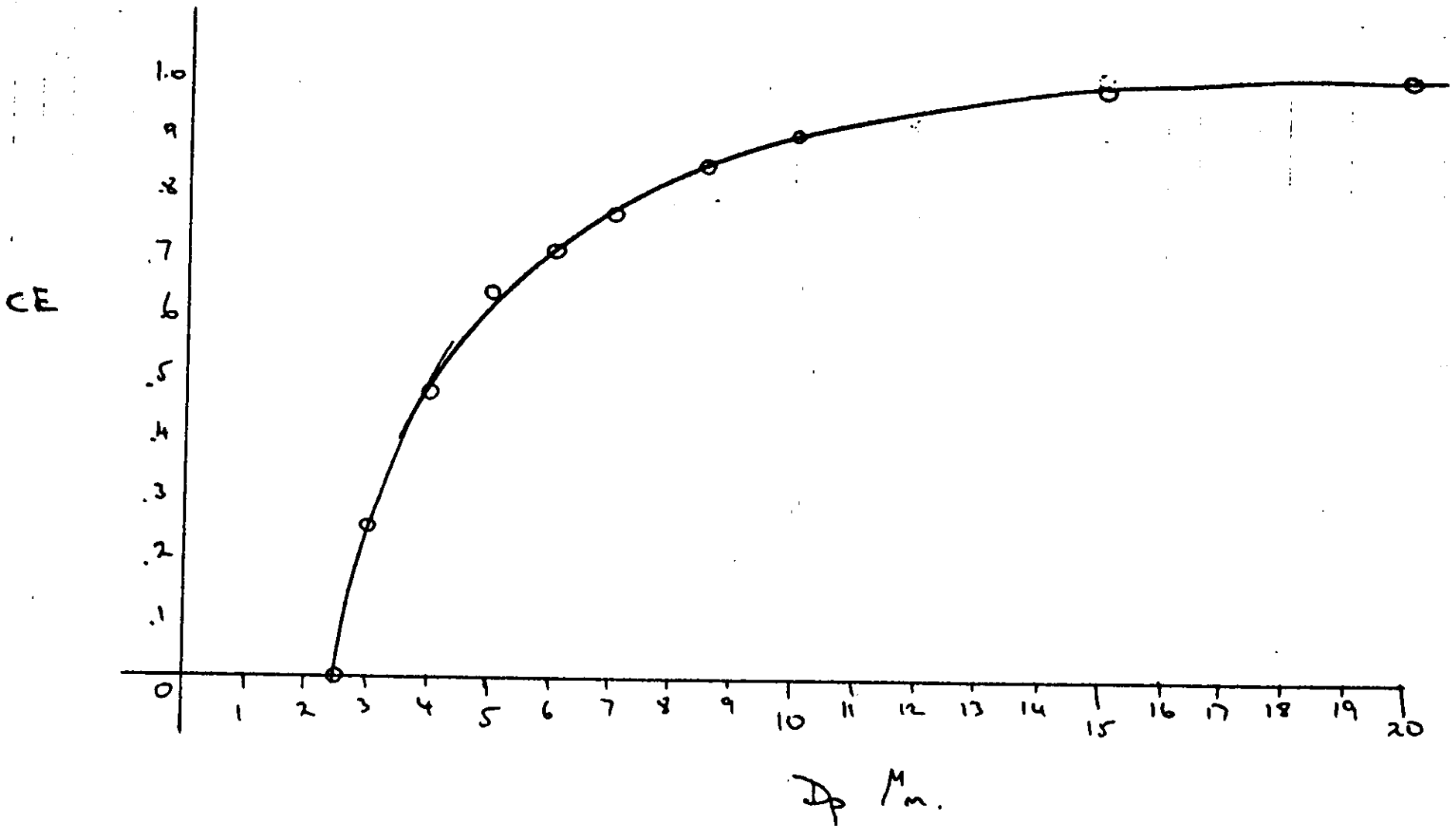
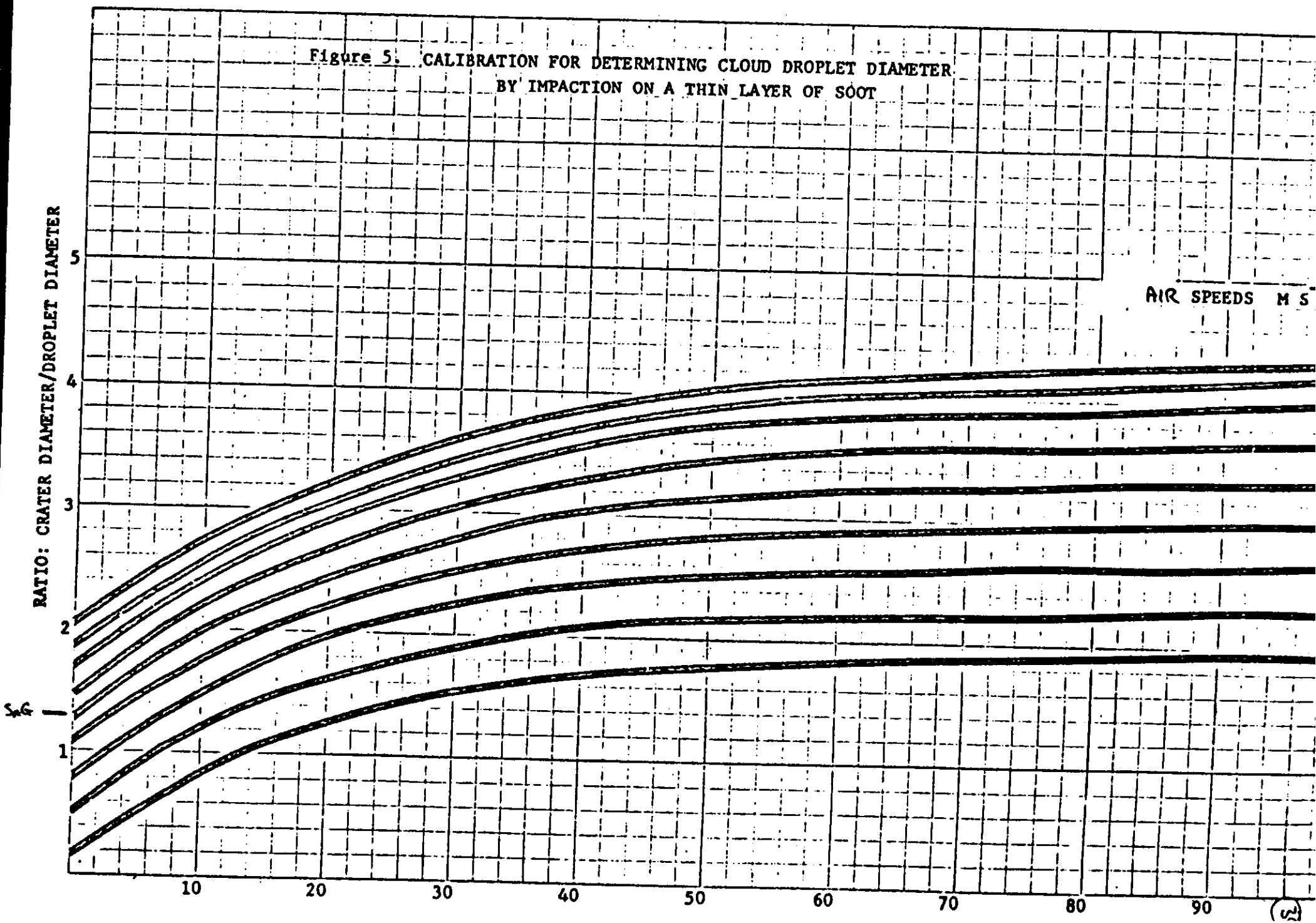


Figure 5. CALIBRATION FOR DETERMINING CLOUD DROPLET DIAMETER BY IMPACTION ON A THIN LAYER OF SOOT



3 Aerosol Measurements

i) Condensation Nuclei (CN)

See The Photoelectric Nucleus Counter
P J Nolan 1972
Scientific Proceedings
Royal Dublin Society Series A
Volume 4, p 161–180.

Calibration graph $E = 100(I_o - I)/I_o$ = Number/cm^3

10^3 to 10^6 /cm^3 $d \leq 0.1\,\mu m$

Pollak Counter; Rich Counter; GE Counter

(Environment One Corporation, 2773 Balltown Rd., Po Box 773, Schenectady, New York 12301 USA)

ii) Cloud Condensation Nuclei (CCN)

$10 - 5 \times 10^4$ /cm^3 (Function of Supersaturation.)

See Twomey S 1959 The nuclei of natural cloud formation, I. Geofis Pura Appl 43, 227–242.
and Twomey S 1963 Measurements of natural cloud nuclei. J Rech Atmos. 1, 101–105.
and Twomey S 1967 Remarks on the photographic counting of cloud nuclei. J Rech Atmos 3, 85–90.

Static Diffusion Chamber See page 44
Continuous Flow Chamber See page 45

See Hudson J and Squires P 1973. Evaluation of a recording continuous cloud nucleus counter. J Appl Met 12, 175–183.

Review article by J E Jiusto. Cloud Condensation Nucleus Counters. Atmospheric Technology. NCAR. Number 8. Spring 1976. 43–48.

iii) Ice Nuclei

Static Filter Processes
See: Gagin and Arnayo 1969 A Thermal Diffusion chamber for the measurement of ice nucleus concentrations. J Rech. Atmos 4, 115-122

Continuous Flow Method.
See: Hussain K and Saunders CPR. Ice Nucleus measurement with a continuous flow chamber Quart J Roy Met Soc, 1984, 110, 75-84.

Drop-Freezing Method
Vali G and Knowlton D, 1971, An automated drop freezer system for determining the freezing nucleus content of water. (Second International Workshop on Condensation and Ice Nuclei. Aug 1970, Colorado State University, Ft. Collins, Co.

iv) Optical Particle Counters

a) Royco

b) Climet

Counts and sorts into size ranges.

1 μm to 10 μm.

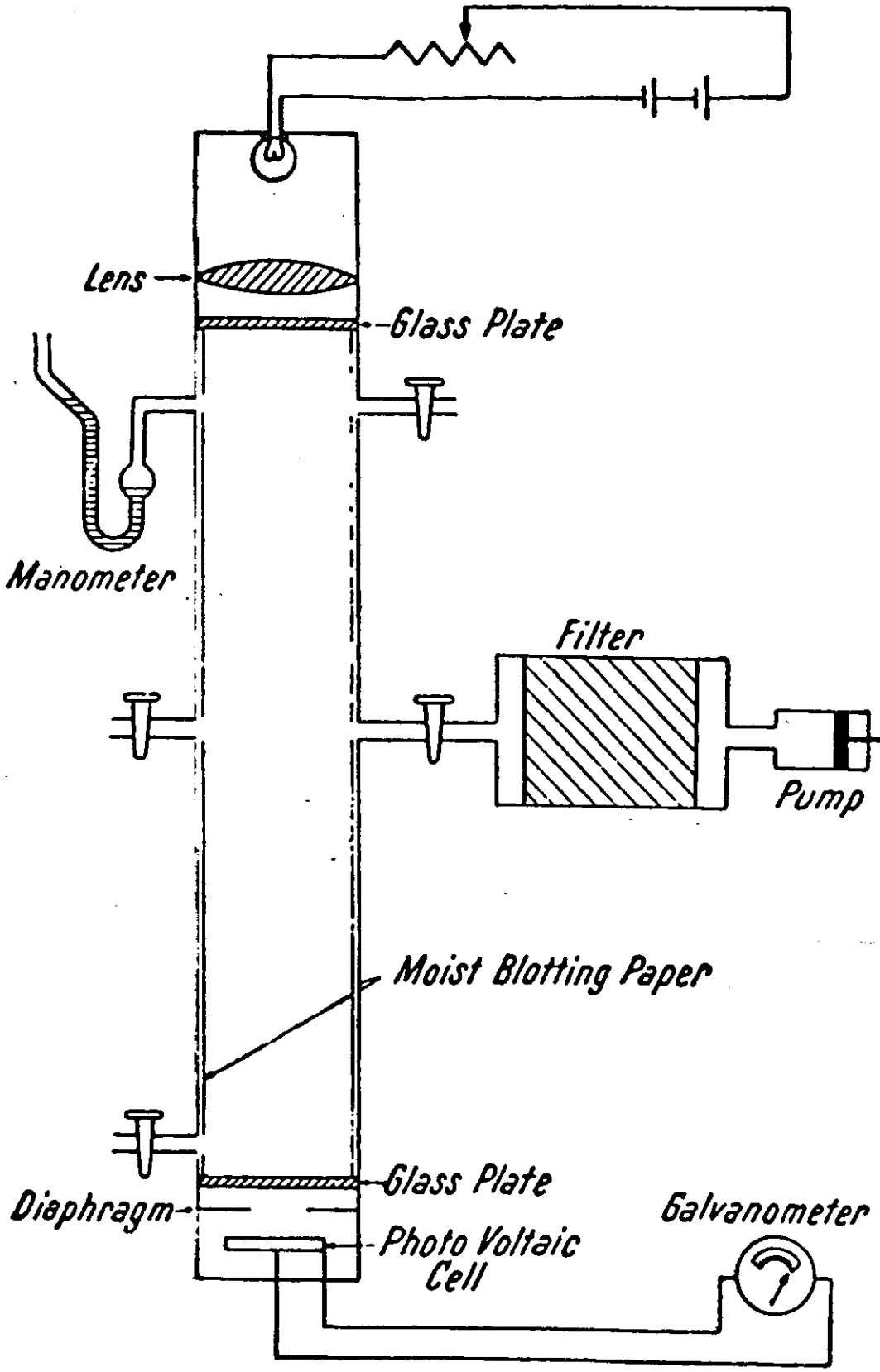
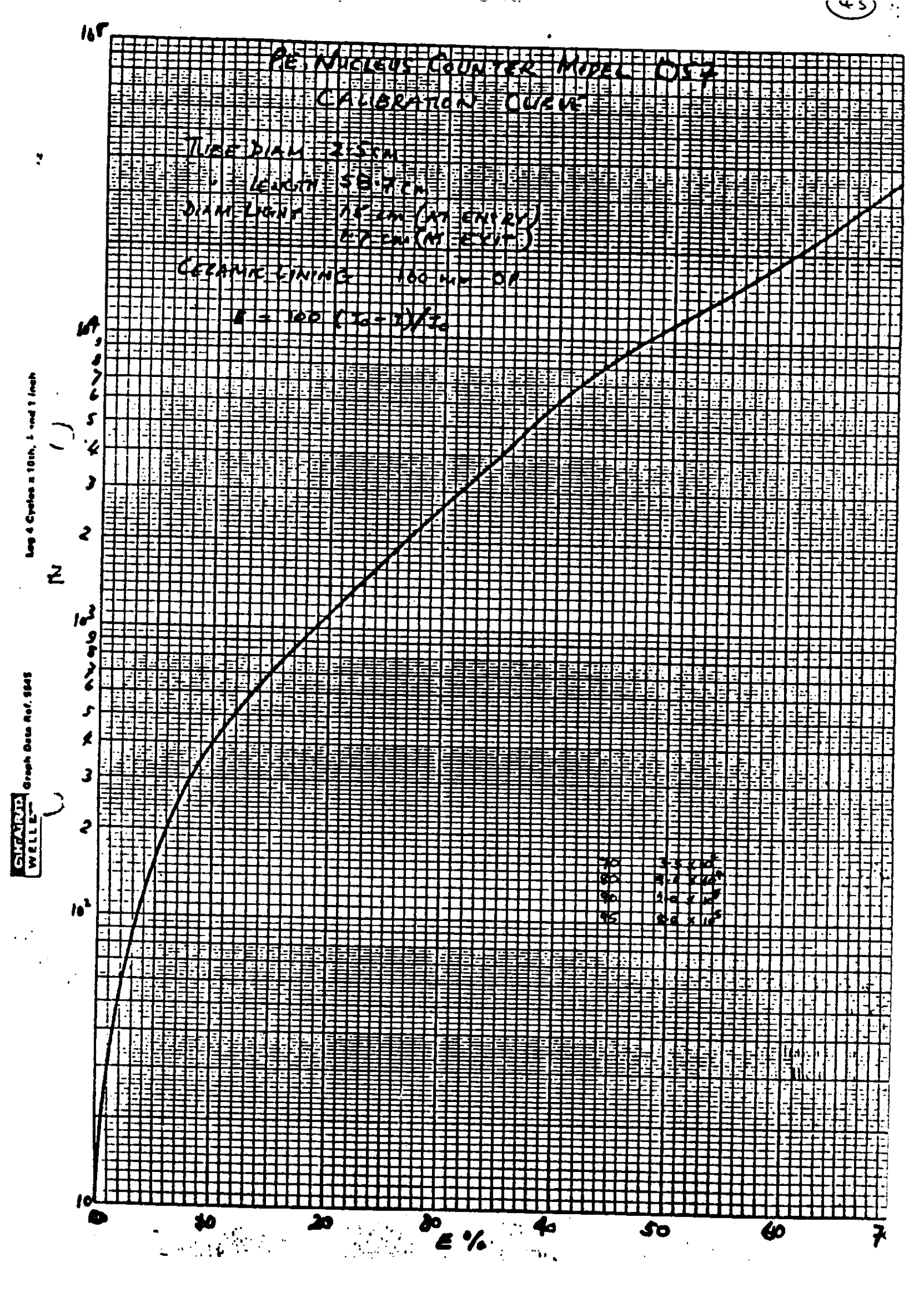


Fig. 1. Schematic diagram of photoelectric nucleus counter.


PE NUCLEUS COUNTER MODEL 1057
CALIBRATION CURVE
WIRE DIAM. 2.5 cm
WIRE LENGTH 58.7 cm
DIAM. LIGHT 16 cm (ACTIVE)
17 cm (METAL)
CERAMIC LINING 100 μm OD
E = 100 (N0 - N)/N0
N
E %
Log 4 Cycles x 10th, 1 and 1 Inch
GRAFLO WELLES Graph Data Ref. 5845

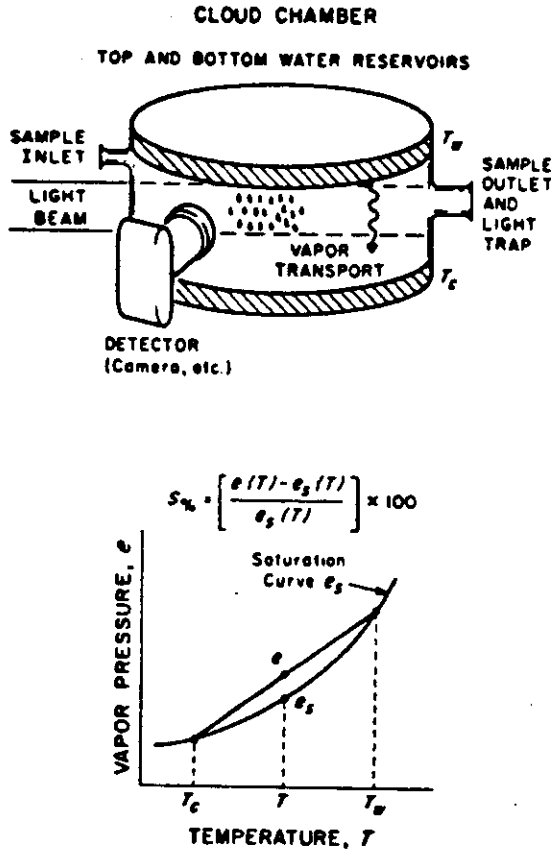


Fig. 1 Sketch of a thermal-gradient diffusion chamber for detecting cloud condensation nuclei. Temperature difference between upper and lower wet surfaces produces supersaturation, S, as illustrated in phase diagram (bottom) and in resultant droplet growth on cloud nuclei. In the diagram, e represents ambient vapor pressure at about mid-level of the chamber, and $e_s(T)$ represents the saturation vapor pressure with respect to water at that level.

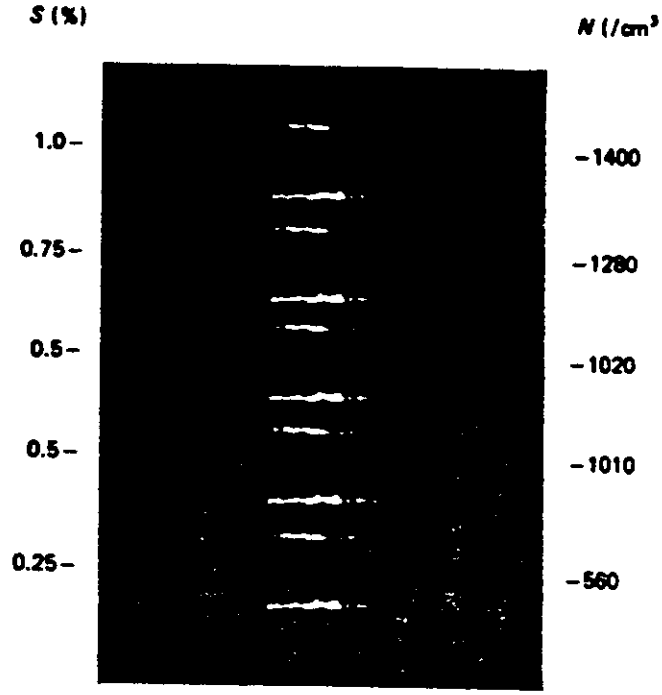
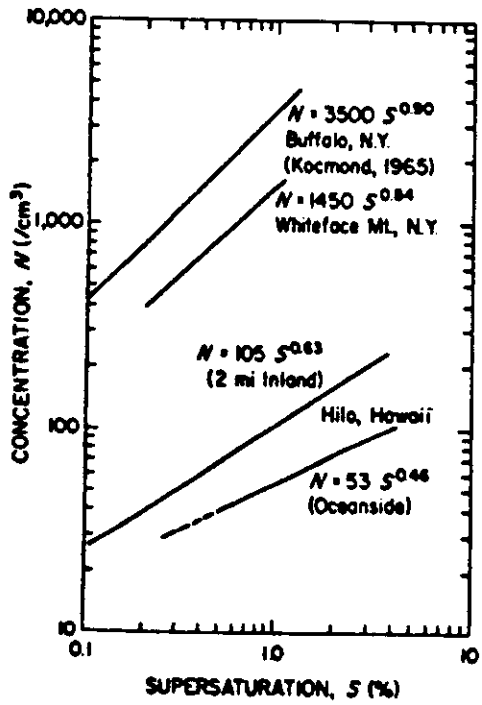


Fig. 2 Photograph of condensed drops formed in a cloud chamber from successive air samples at indicated supersaturations from 0.25 to 1.0%.

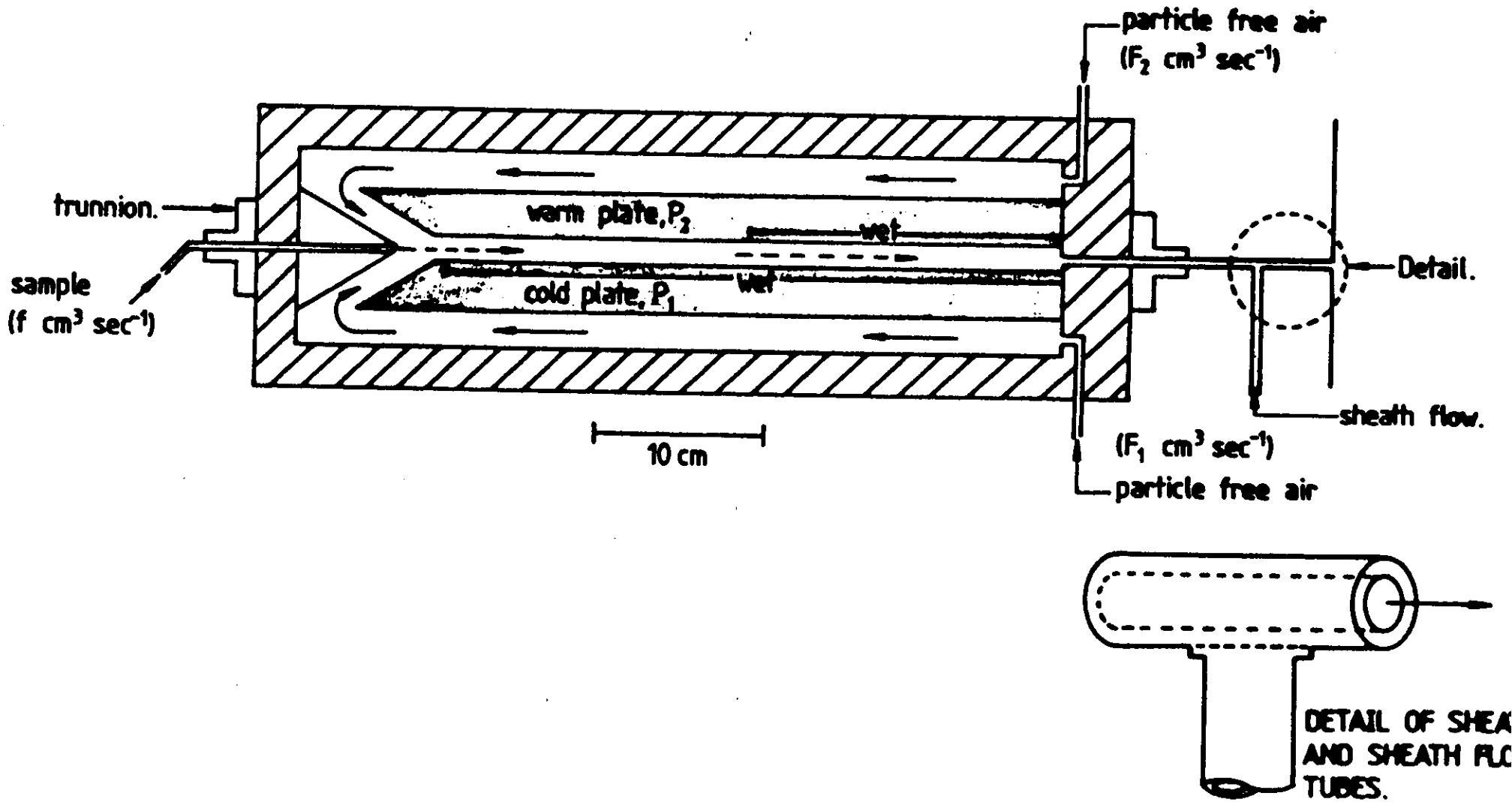
Table 1 Design Characteristics of Static Diffusion Chambers

Chamber aspect ratio (diameter to height)	> 5
Maximum chamber height	1 to 2 cm
Minimum reliable supersaturation	0.1 to 0.2%
Typical maximum supersaturation	1 to 3%
Maximum droplet concentration	1 to 2 × 10^3/cm³
Intake sample air temperature	Top plate T_w
Intake sample airflow, F	
(a) Type	Nonturbulent
(b) Chamber flushings	> 4 to 5
(c) Tube length, L, vs flow	F (cm³/s) > $\frac{L\ (\text{cm})}{10}$
Minimum drop size detected	$r \approx 1\ \mu m$

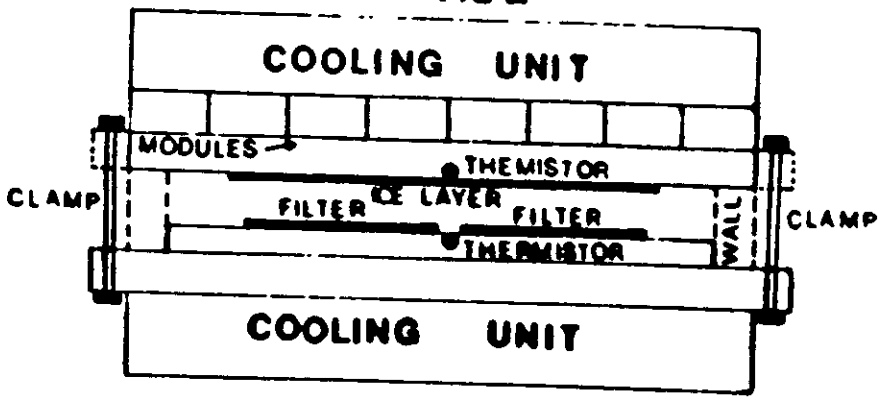
Fig. 3 Typical spectra of concentrations of CCN vs supersaturati Data can often be approximated by power functions of the form $N = cS^k$, where c and k are constants for a given aerosol. The dast portion of the line for oceanside at Hilo, Hawaii, represents extra, lated values.



Hudson and Squires CCN chamber



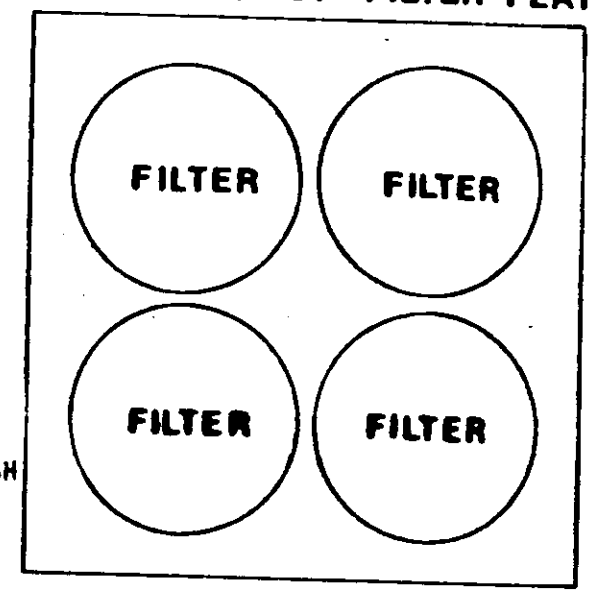
SIDE VIEW



Filter Specification
Hydrophobic Filters.
Type SM 13306
0.45μm Pore Size
47mm Diameter.
from

Sartorius - Membranfilter GmbH
PF 14 2
D-3400 Göttingen
Germany.

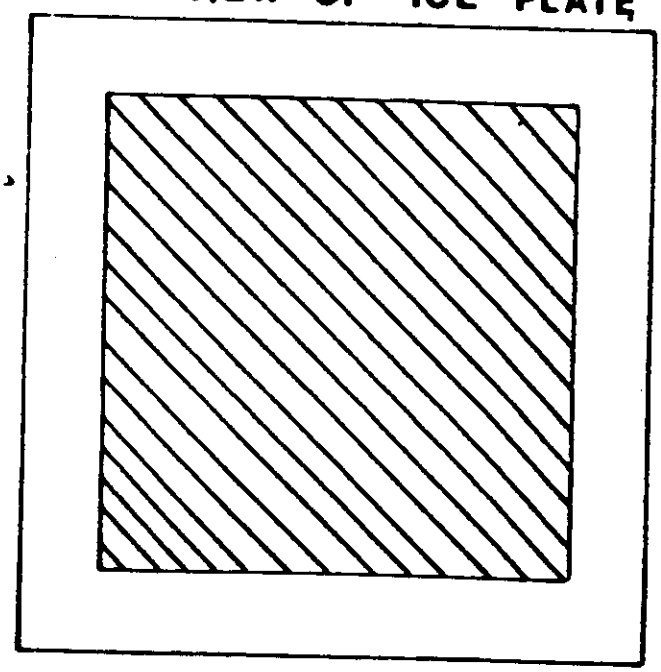
PLAN VIEW OF FILTER PLATE



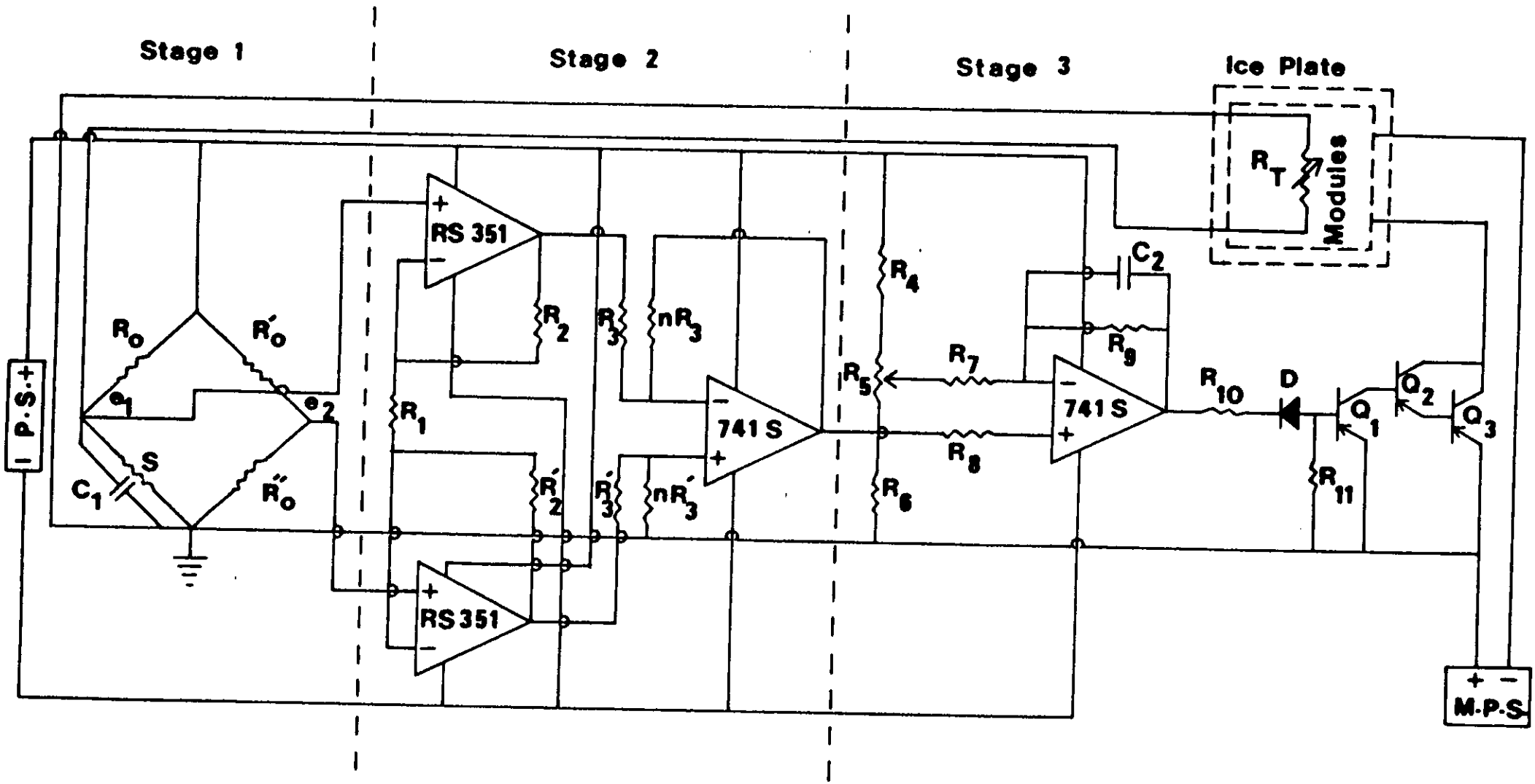
Filter Holder
Swinex 47mm
SX0004700.
from

Millipore Ltd
Millipore House
Abbey Rd
London
NW10 7SP

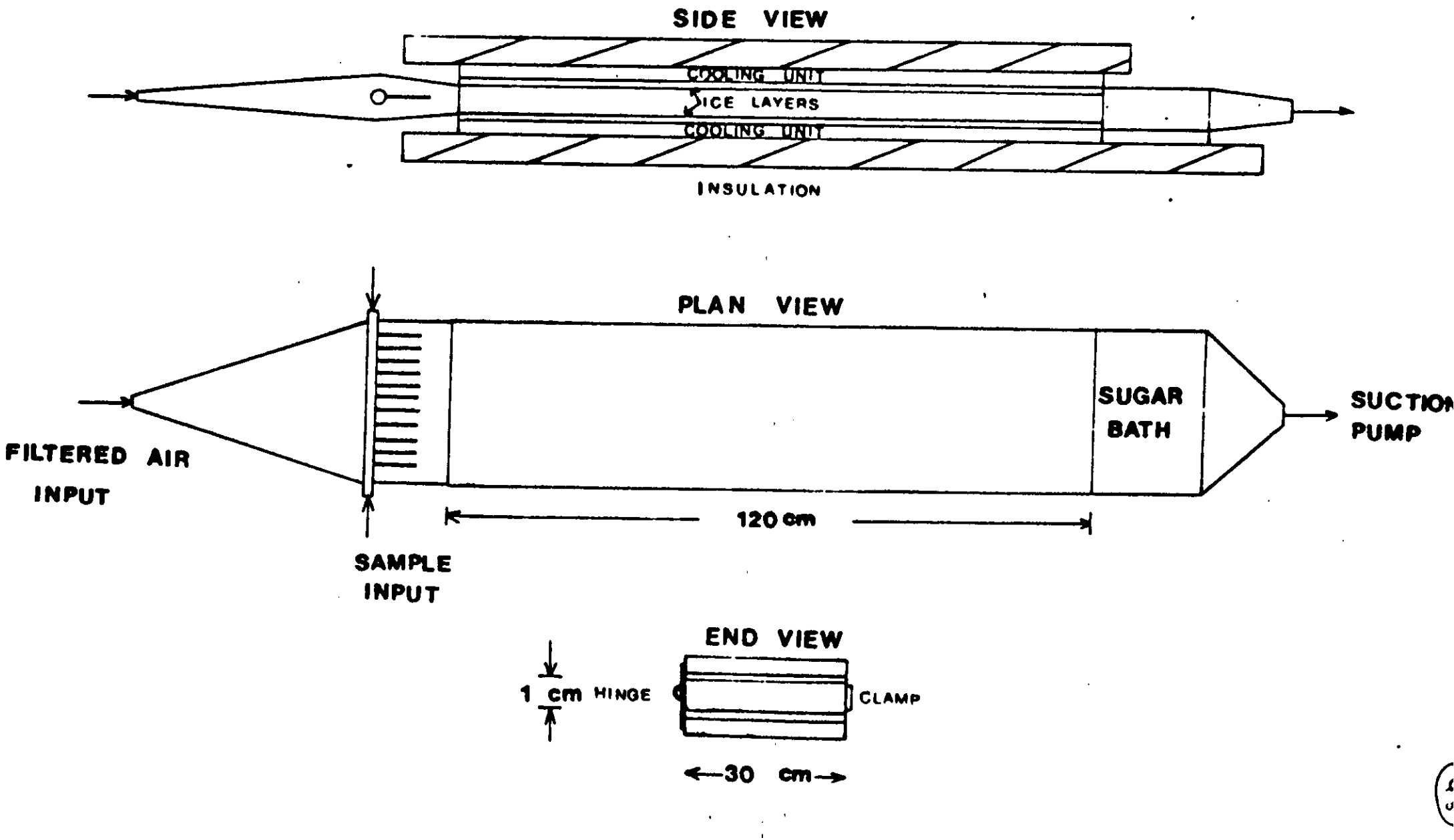
PLAN VIEW OF ICE PLATE

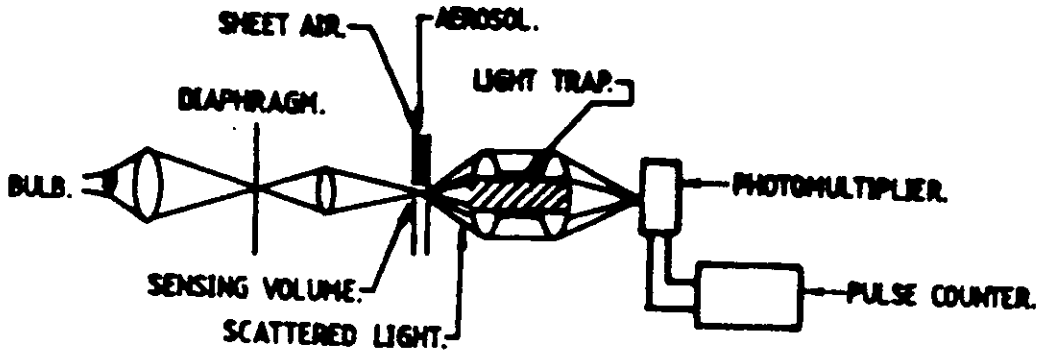


Temperature Control Circuit for Static Diffusion Chamber

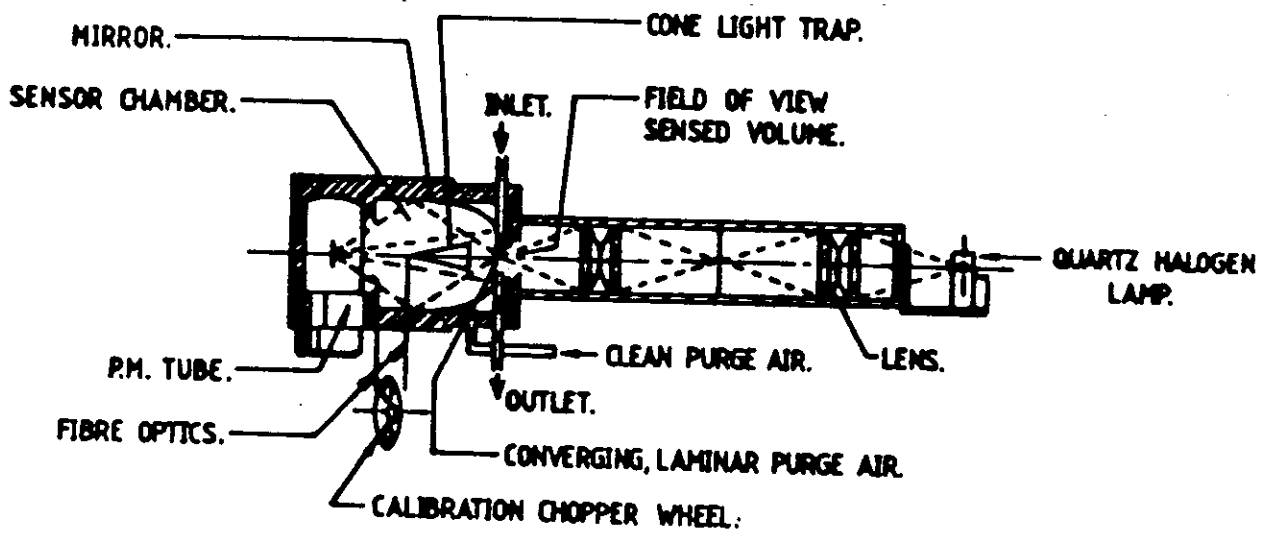


Continuous Flow Ice Nucleus Chamber





a. Royco optical system.



b. Climet optical system.

4 Cloud Measurements

a) Aircraft

i) Specification

ii) Instrumentation — probe location — derivation of parameters — data system.

iii) Decelerator and particle sampler.

iv) Bulk water collection.

v) Airborne CCN device.

vi) Rotating IN samples.

vii) In cloud air sampling. (Mylar bag, Evacuated tank)

b) Radar

Time for return of electromagnetic pulse gives distance.

Peak Power	10 to 5×10^3 kW
Wavelength	1 to 10 cm
Pulse Repetition Frequency	200 to 2000 Hz
Pulse Duration	0.1 to 5 Msec.
Averaging Time	$\sim$ 10 msec.

Reflectivity Factor $Z = \int N(D)\, D^6\, dD$

$N(D)\, dD$ is the number of scatterers per unit volume, with diameter in size range dD

Average Received Power = P $\quad P \propto Z$

$$P = \frac{k_1 k Z}{r^2}$$

k_1 = Constant . r = distance .

k, Proportionality constant due to refractive index of particle. $k^2 = 0.93$ for water.
$k^2 = 0.21$ for ice.

$10 \log P = 10 \log Z - 20 \log r + \text{Constant}$

P mW $10 \log P$ = Power in dBm (decibels relative to 1mW)

Z mm^6 / m^3 $10 \log Z$ = Reflectivity Factor, dbZ.

For rain $Z = 200 R^{1.6}$

Rain fall rate (mm/hr)	0.1	1	10	100
Reflectivity Z (mm^6/m^3)	5	200	7950	316,000
dbZ	7	23	39	55

(For snow, $Z \simeq 2000 R^2$)

Plan Position Indicator (PPI) 360° View.

Intensity shown on TV screen is proportional to reflectivity. Or intensities may be colour coded.

Range Height Indicator (RHI) (Vertical scan)

Constant Altitude PPI (CAPPI). PPI and RHI combined. Gives several plan views at different altitudes.

Doppler Radar.

Analyse frequency of returning signal relative to transmitted signal. Differences are due to moving cloud particles. Hence can find vertical velocities and obtain air trajectories in clouds.

Table 3: Summary of Requirements Versus Aircraft Specifications

RFP Requirement	Beechcraft 200	Aero Commander 690 B	Aero Commander 690 A
a) Endurance: 4 hrs or more at cruise speed (1)	6 hrs 11 min	5 hrs 34 min	5 hrs 34 min
1) typical mission fuel requirements	2367 lbs (4 hrs 47 min)	2034 lbs (4 hrs 47 min)	2034 lbs (4 hrs 47 min)
2) typical mission pay load (equipment and crew)	2433 lbs	1631 lbs	1466 lbs
b) Cruise speed: 150 knots or more IAS (2)	278 kts	277 kts	277 kts
c) Cloud penetration speed: 150 kts or less IAS	110 - 140 kts	100 - 140 kts	100 - 140 kts
1) pitch attitude	$+3^{\circ}$ to $+7^{\circ}$	$+4^{\circ}$ to $+8^{\circ}$	$+4^{\circ}$ to $+8^{\circ}$
d) Climb: S.L. to 25,000 ft in 45 min or less	20 min	16 min	16 min
e) Operational altitude capability: continuous light to moderate icing below 15,000 feet. Repeated light to moderate icing to at least 25,000 feet.(3)	Service ceiling: 32,800 ft Single engine service ceiling: 19,150 ft Certified into known icing: Yes	32,800 ft 19,700 ft Yes	33,000 ft 19,700 ft Yes
f) Airframe: stressed for severe turbulence.(4)	+G: 3.17 -G: -1.27 Certification: FAR 23	3.28 -1.31 CAR 3 + SC	3.28 -1.31 CAR 3 + SC
g) Crew: (minimum) pilot, scientist, and system operator	4 with no problem	3 maximum	3 maximum

RFP Requirements	Beechcraft 200	Aero Commander 690 B	Aero Commander 690 A
h) Flight and communication systems: (5)			
1) Fully equipped for IFR 2) VOR-DME: dual receivers with digital readouts	The aircraft selected will be equipped with a King Gold Crown digital display avionics system or equivalent. This system will include dual VOR-DME, R NAV, ADF, altitude reporting transponder and communication radios. The GFE/ONTRAC III will be installed.		
3) Full deicing equipment available	Certified for flight into known icing	Certified for flight into known icing	Certified for flight into known icing.
4) Transponder: L-band minimum 400 watts	King Gold Crown KXP-755 or equivalent, 700 watt transponder will be installed in selected aircraft.		
5) Oxygen system:	An oxygen system capable of supporting four people at 30,000 ft for a minimum of 3 hours will be installed using military A-14 diluter demand regulators certified in excess of 35,000 ft with pressure breathing capability. Masks with integral mics are included.		
6) Digital weather memory radar:	A digital memory weather radar, manufactured by Bendix or RCA will be installed in the aircraft selected.		
7) Communications: a)VHF: dual 360 channel, minimum of 10 watts	Dual King Gold Crown KTR-905 or equivalent, 720 channel transceivers will be installed in the aircraft selected.		
b)UHF: GFE	The FM radio will be interfaced to the aircraft communications system such that it can be used in the same manner as the VHF communication radios.		
c)Intercom: to all crew stations d)Comm system flexibility:	An intercom system will be installed at all crew stations so that each crewman can communicate with every other crewman with hot/mic or call capability and transmit or receive on any of the radios installed in the aircraft. Any radio can be selectivly monitored and transmit side tone will be selectable.		
e)Voice tape recording	A stereo recorder will be provided for each crew station. Each crew member can record at will any or all comments on one channel while the remaining channel will continuously record a time code when the recorder is operating.		
i) Particle sensing probe mounting potential (6)	Excellent	Good	Good

(9)

Table 6. Instrumentation for Proposed Research Aircraft

Parameter measured	Instrument type	Manufacturer and model number	Range	Response time	Accuracy	Precision
Temperature	Platinum Resistance	Rosemount Engr. Co. 510B amplifier Model 102 Probe	±50°C	1 sec	±0.5°C	0.1°C
Temperature	Platinum Resistance Reverse Flow	NCAR Probe Minco, Inc. Element	±50°C	0.2 sec	±0.5°C	0.1°C
Dew Point	Peltier cooled mirror	Cambridge System, Inc. Model 137C3	±50°C	3 sec	±0.5°C>0°C ±1.0°C<0°C	0.1°C
Heading	Magnetic	King Radio Corp. KPI 553	0-360°	1 sec	±1°	0.36°
Altitude	Total Pressure	Rosemount Engr. Co. Model 1301-A-4-Ax	0-15 psia	1 sec	0.015 psia	0.003 psia
Indicated Airspeed	Differential Pressure	Rosemount Engr. Co. Model 1301-D-4-A	0-3 psid	25 ms	0.003 psid	0.003 psid
Rate of Climb	Differential Altitude	Rosemount Engr. Co. Model 1241-A-58CE	±3000 fpm	550 ms	1% to 15,000' 5% to 30,000'	
Position - Azimuth	VOR	King Radio Corp. KNR 615	0-360°	1 sec	1.5°	1.5°
Position - Distance	DME	King Radio Corp. KDM 705A	0-200 nm	1 sec	0.2 nm	0.1 nm
Horizontal Position	VLF	Communications Components Corporation ONTRAC-III	--	4 sec	100 meters	18.5 m
Vertical Acceleration	Vert. Stab. Accelerometer	Humphrey Model SA-09-0501-1	0-2 g	10 μs	0.001 g	0.001 g
Pitch Attitude	Vert. Stab. Gyro	Humphrey Model SA-09-0501-1	±50°	10 μs	0.2°	0.15°

Table 6 (continued)

Parameter measured	Instrument type	Manufacturer and model number	Range	Response time	Accuracy	Precision
Ground Speed	Doppler Radar	Singer Model SKK-1000	0-1000 kts	1 sec	0.17%+.35 kt	0.17%
Drift Angle	Doppler Radar	Singer Model SKK-1000	±40°	2 sec	0.17°	0.17°
Yaw Angle	Vane	Univ. of Wyoming	0-360°	300 μs	0.1°	0.1°
Angle of Attack	Vane	Univ. of Wyoming	0-360°	300 μs	0.1°	0.1°
Horizontal Wind	Doppler Radar and Vanes	Singer and Univ. of Wyoming	--	2 sec	±1 m sec^{-1}	±1 m sec^{-1}
Vertical Wind	Vert. Acc, Gyro and Vanes	Humphrey and Univ. of Wyoming	--	1 sec	±1 m sec	±1 m sec^{-1}
Turbulence	Pressure	Meteorology Research Model 1120	0-10 IT	3 sec	10%	5%
Liquid Water	Hot Wire	Bacharach Inst. Model LWH	0-3 g m^{-3}	2 sec	0.26 g m^{-3}	0.1 g m^{-3}
Filler Sequencer Manifold Pressure	Differential Pressure	National Model LX 1602D	0-15 psid	1 sec	3%	1%
Time	Crystal Oscillator	PMS	1 year	1 sec	1 sec/day	1 sec

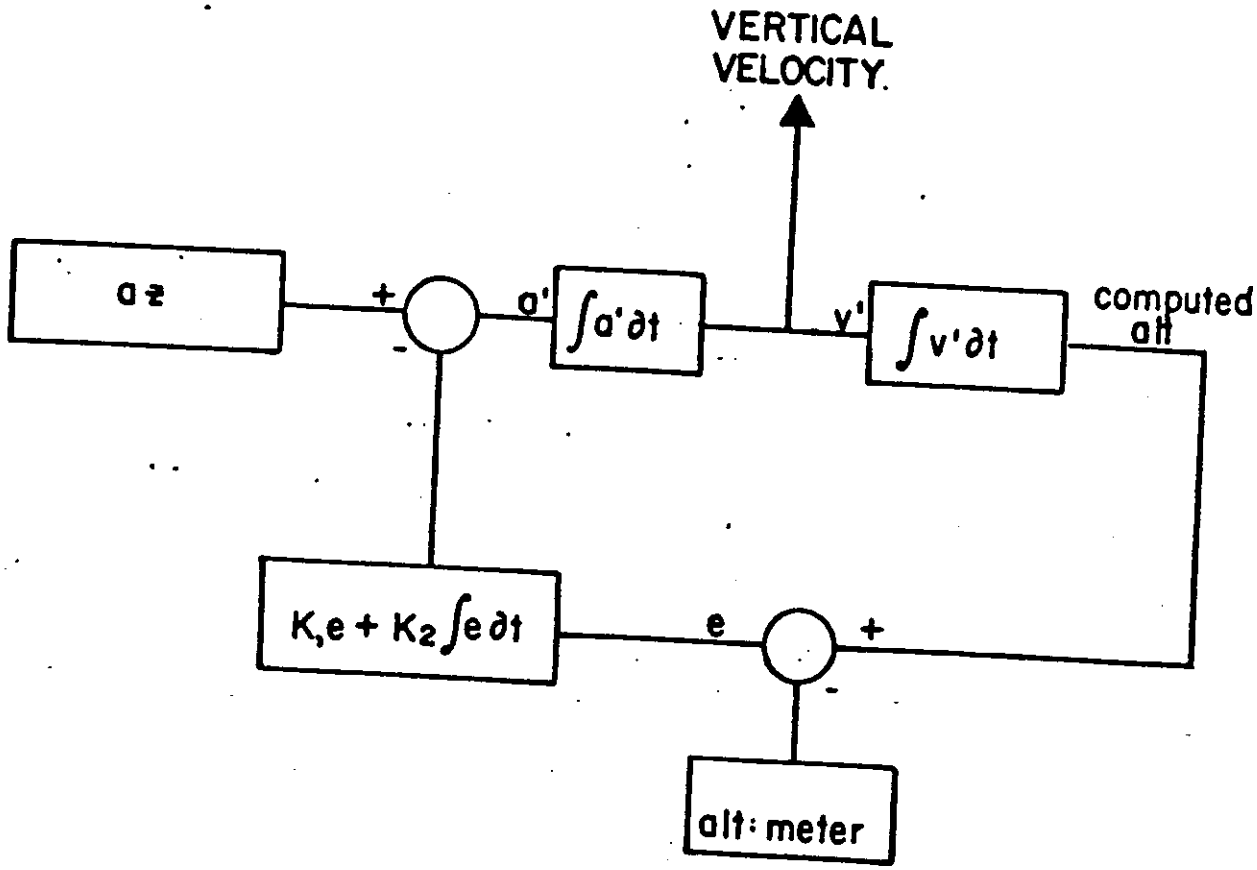


Figure 21. Block diagram illustrating vertical wind computational scheme.

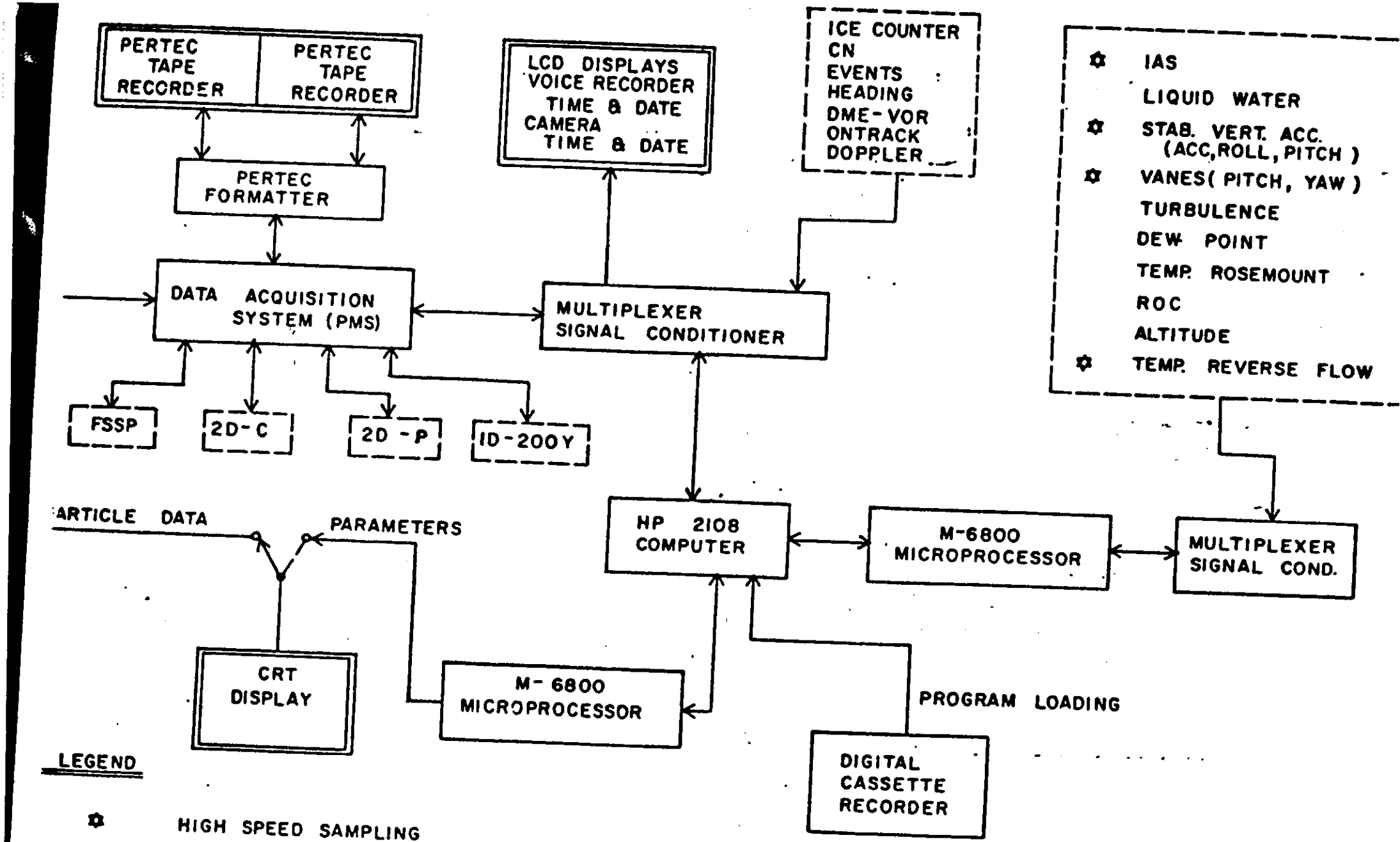
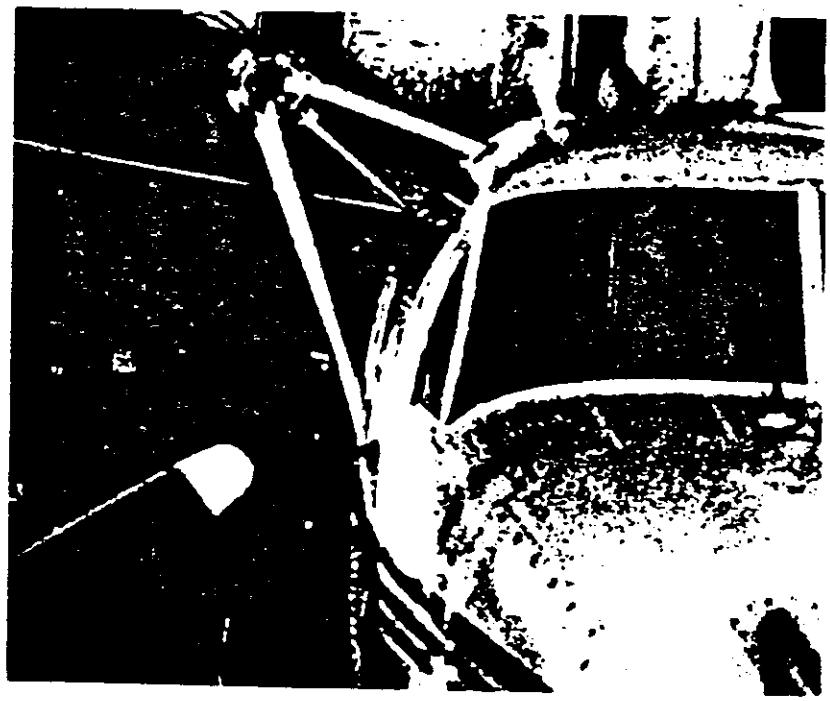
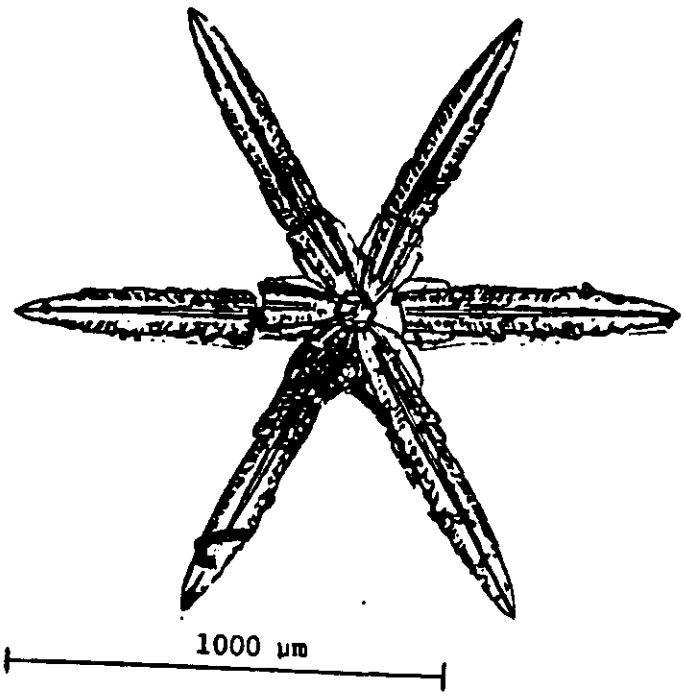


Figure 22. Schematic for proposed data systems.

Figure 5.
Installation of decelerator on University of Wyoming aircraft.





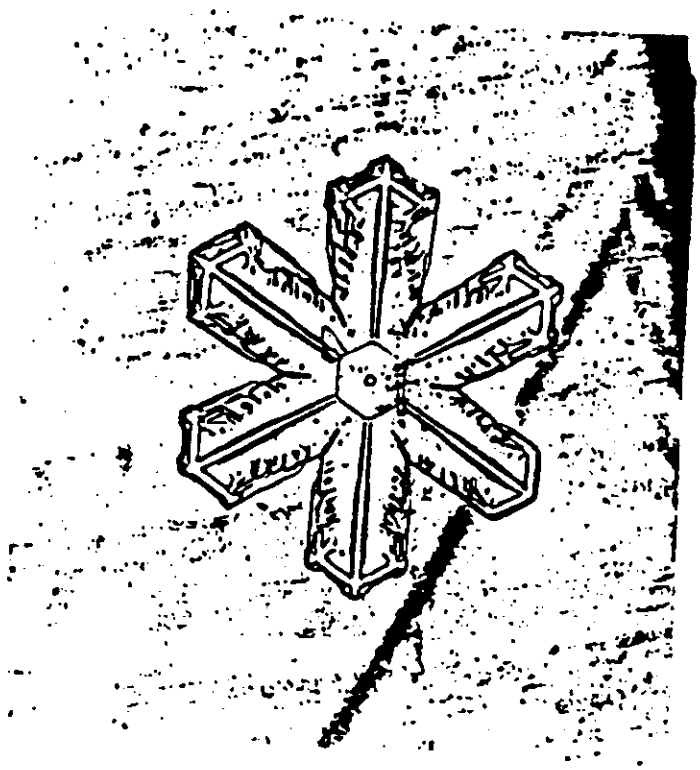


Figure 20. Examples of ice crystals collected using the decelerator and oil-hexane technique. The scale shown applies to all crystals.

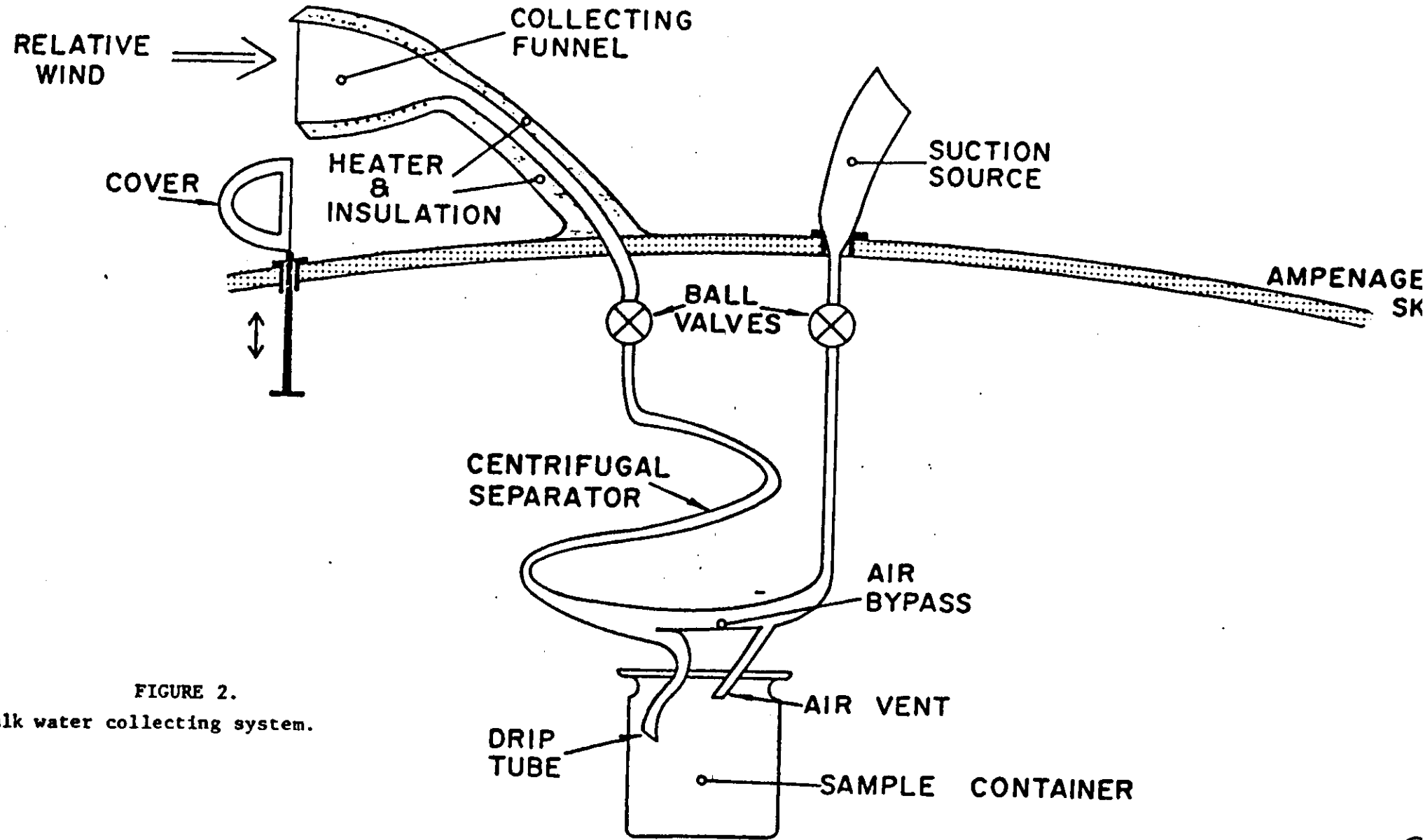


FIGURE 2.
Bulk water collecting system.

J. Rech. Atmos., 15 (1981), n° 3-4, pp. 225-229.
THIRD INTERNATIONAL CLOUD CONDENSATION NUCLEI WORKSHOP.
Section V. Instrument Descriptions.

A CLOUD CONDENSATION NUCLEUS SPECTROMETER DESIGNED FOR AIRBORNE MEASUREMENTS

by

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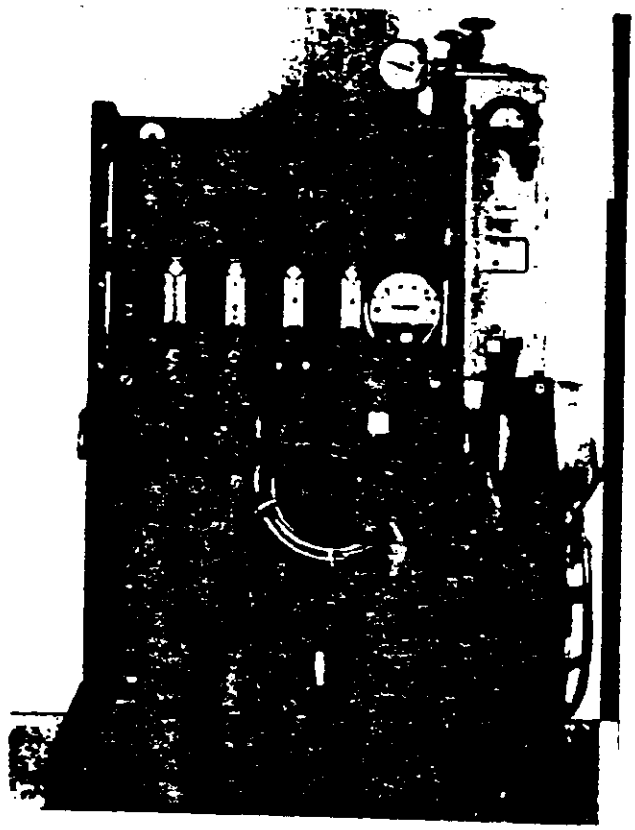


1. — INTRODUCTION.

In 1970, at the Second International Workshop on Condensation and Ice Nuclei, all but one of the cloud condensation nucleus (CCN) counters were horizontal static-diffusion chambers operating in a manner little changed from those used in the 1950's

5 Other Techniques

a) Cloud Seeding

Artificial modification of clouds to
i) stimulate precipitation
ii) dissipate cloud or fog
iii) suppress hail.

i) In warm clouds ($>0°c$) introduce 20–30 μm water droplet or inject salt particles to act as cloud condensation nuclei.

In cold clouds ($<0°c$) can introduce ice nuclei to activate ice crystals to overcome natural shortage of ice nuclei. Agents — CO_2, AgI. For stratus clouds warmer than $-15°c$, seeding agents at cloud top can produce rain. In cumulus clouds prevented from further vertical development by a temperature inversion can be seeded to release latent heat which promotes vertical development and hence precipitation.

ii) Fogs at airports and roads are hazardous. Warm fogs ($>0°c$) may be dissipated by sprays of water. Cold fogs can be removed with seeding with AgI or CO_2. However, ice fog is hard to remove.

iii) Hail damage can be reduced if the hail is stopped from growing large. Seeding causes the supercooled droplets to freeze so that hail cannot grow by collecting supercooled water.

Seeding agents can be introduced from aircraft or from the ground, or by firing rockets into the cloud.

b) Ground-based sampling.

Mobile laboratories can collect precipitation samples for analysis.

Hail damage can be monitored with the aluminium-foil-covered "hail-cube".

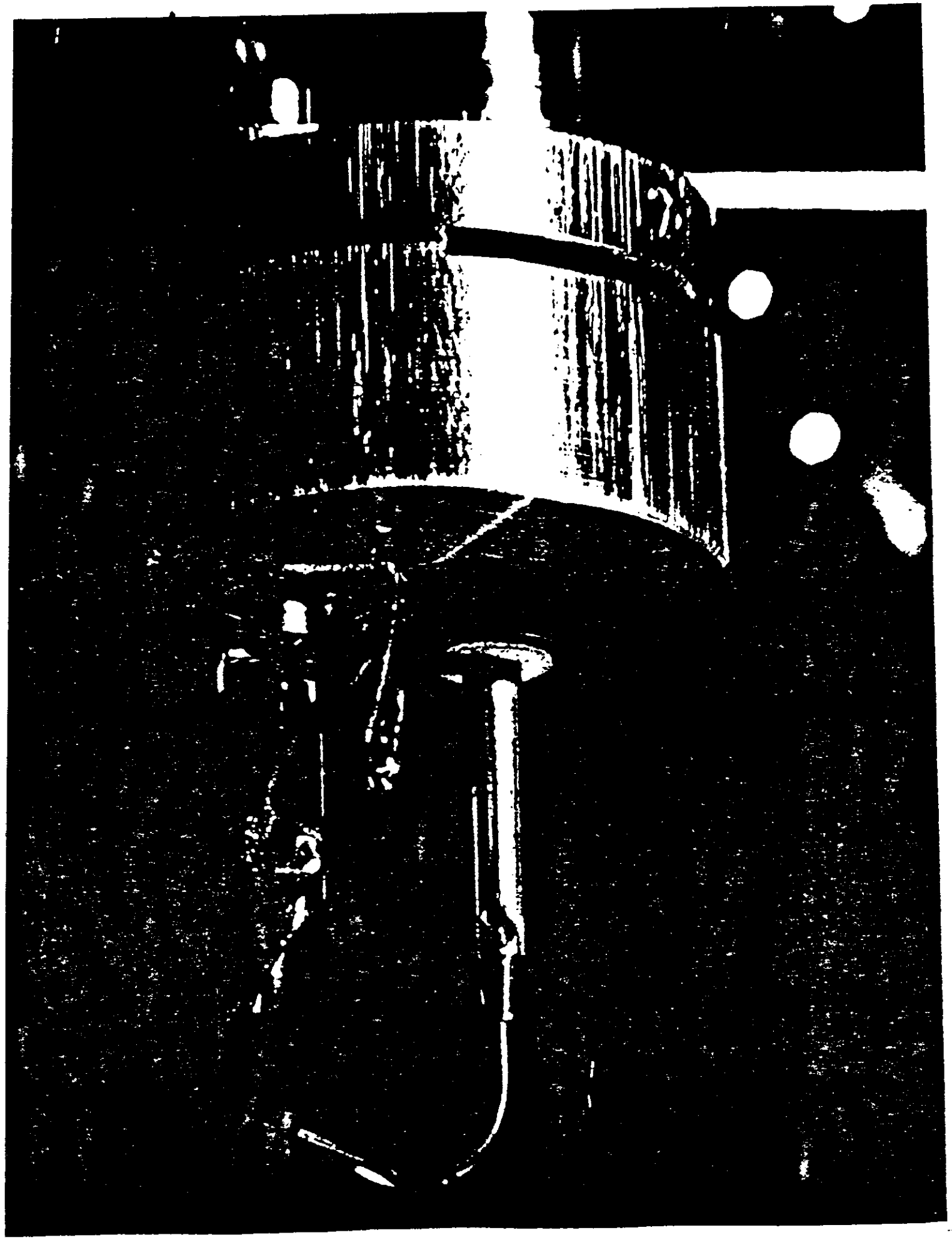
Ground meteorological conditions from a wide network of stations can be telemetered to a central site.

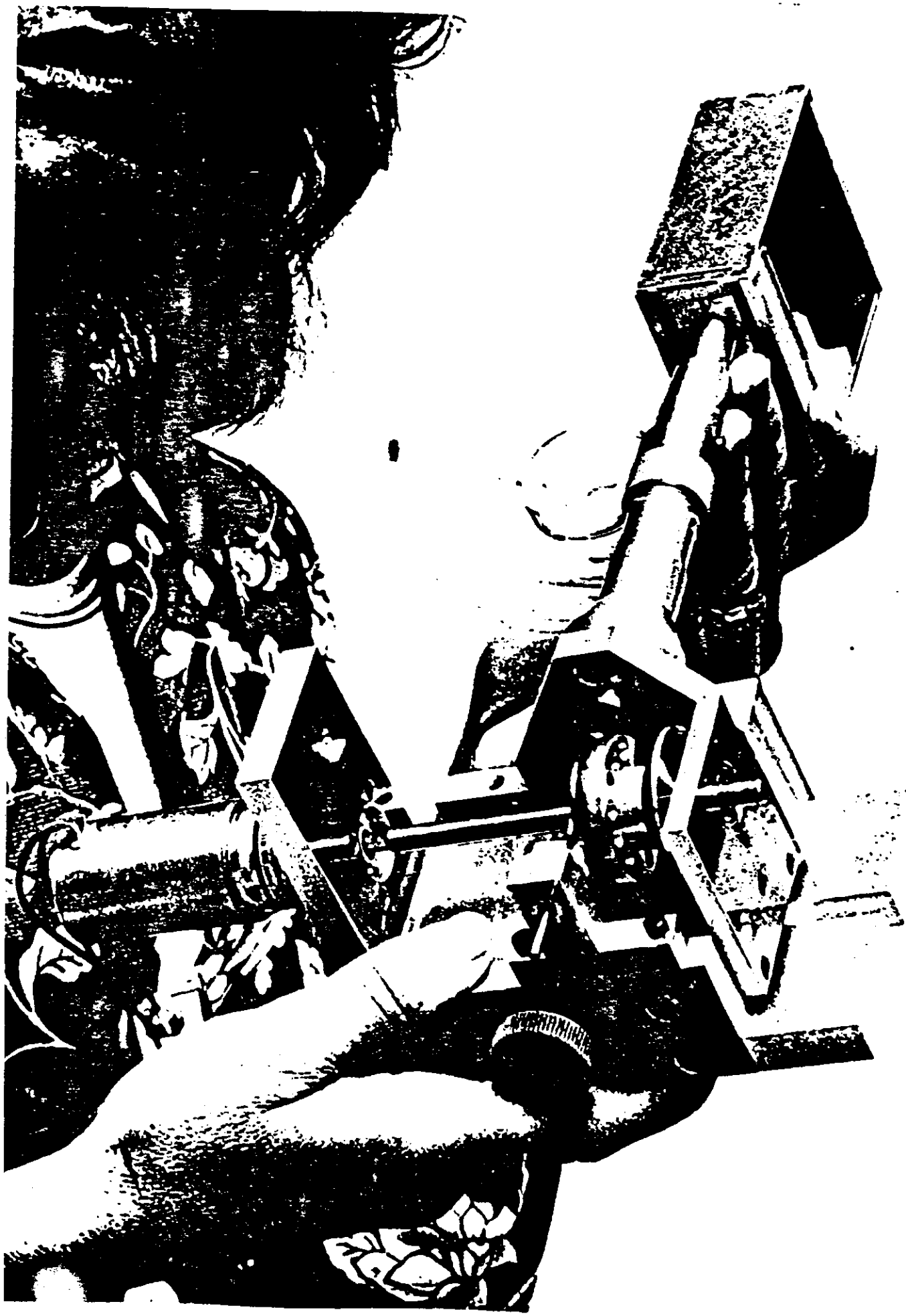
c) Droplet Generation.

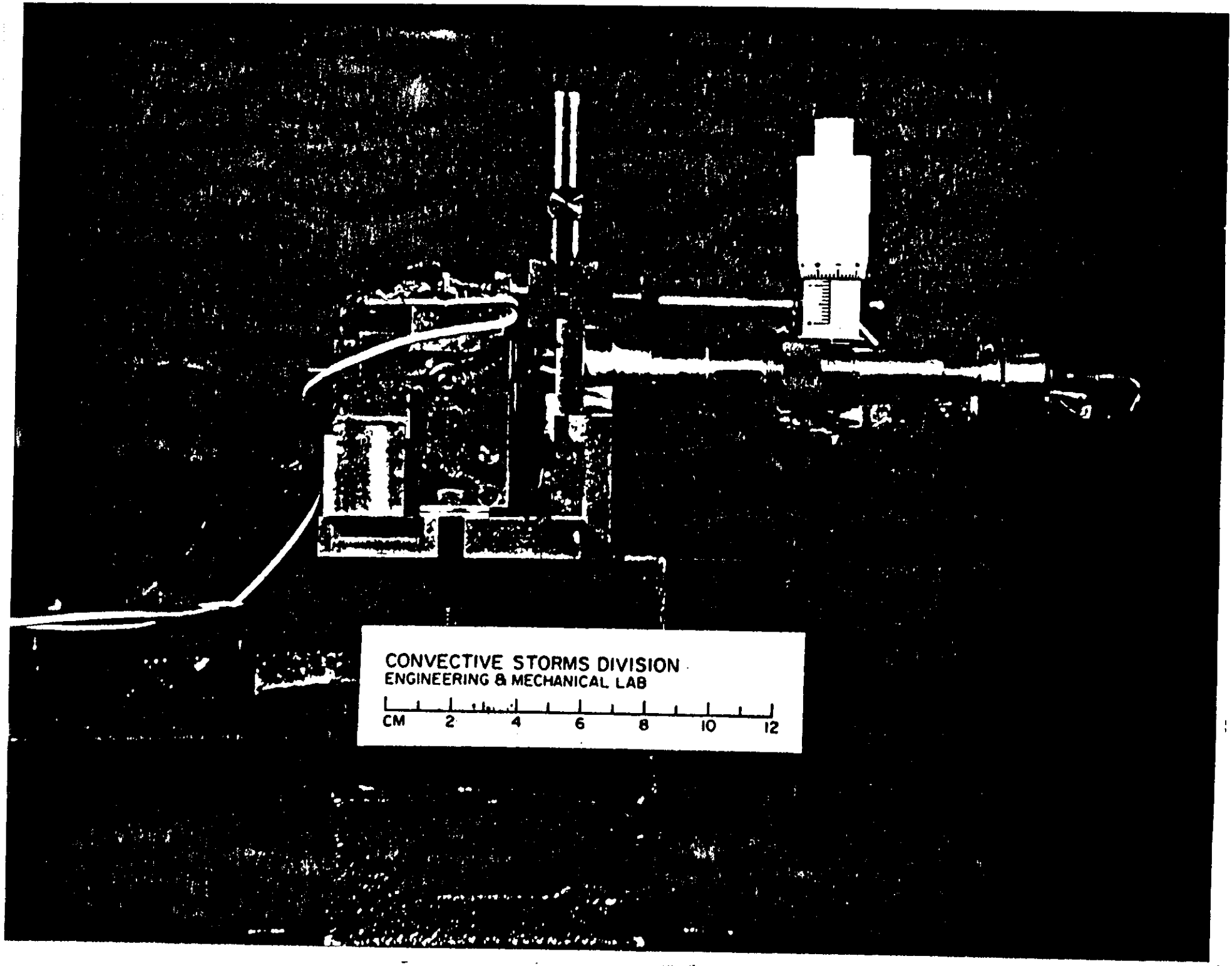
Various methods of drop and droplet production are possible for experiments in ground-based laboratories. For example, vibrating hypodermic needles, spinning discs, collision atomisers, ultrasonic atomisers and drop-plucters.

d) Atmospheric Electricity.

Remote sensing of lightning can help prevent forest fires.
Airborne measurements of electric fields may be made with field-mills while particle charges can be detected with shielded induction tubes.



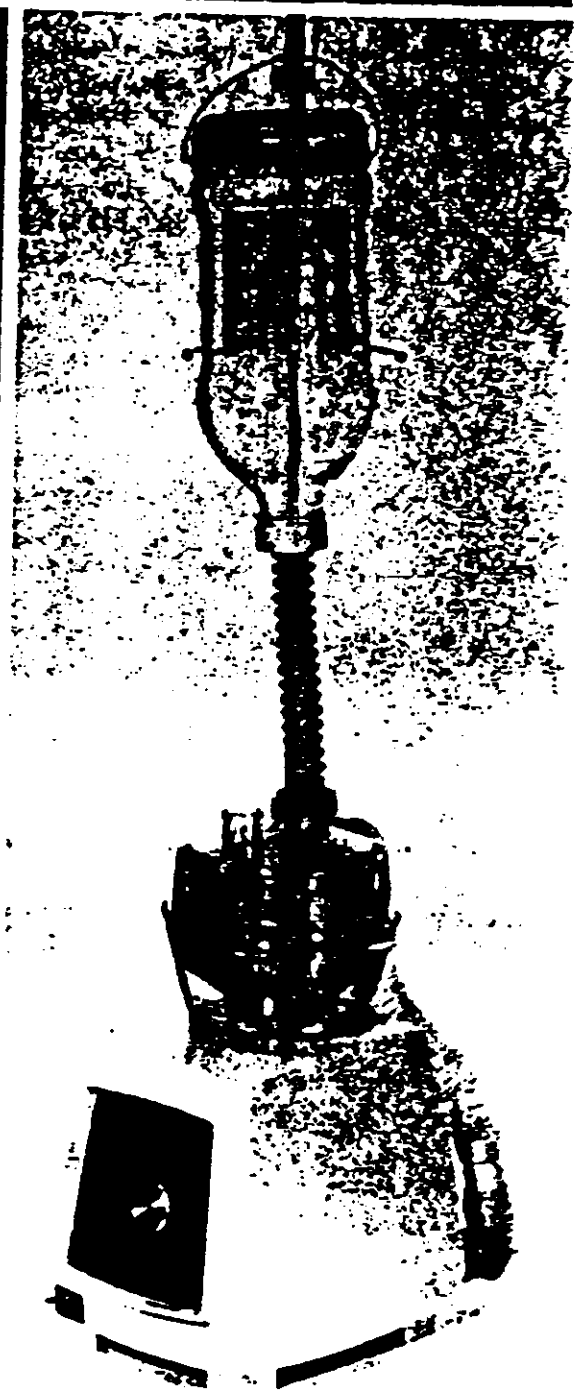


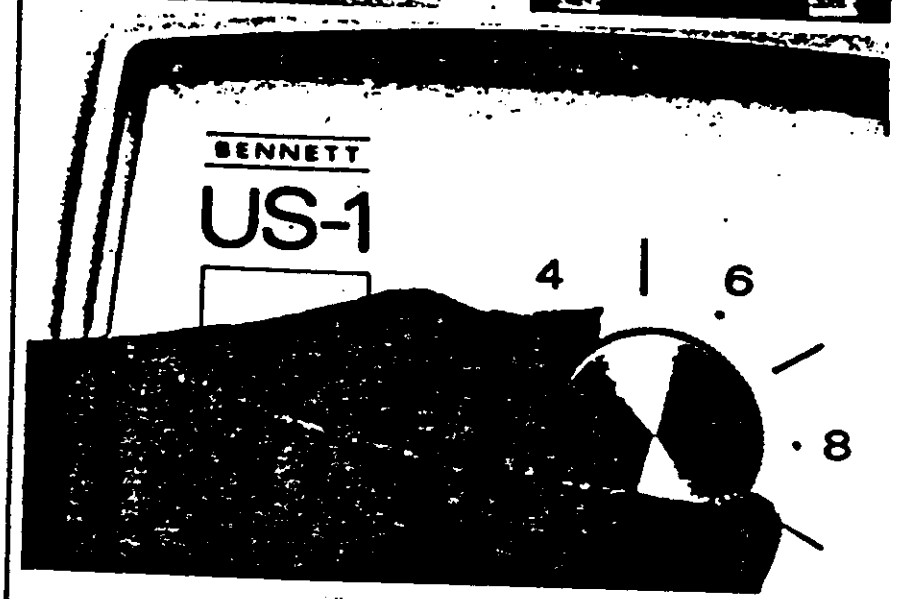

CONVECTIVE STORMS DIVISION
ENGINEERING & MECHANICAL LAB
CM 2 4 6 8 10 12

Dry Counter

BENNETT

ULTRASONIC NEBULIZER





BENNETT
MEDICAL EQUIPMENT

12655 BEATRICE STREET • LOS ANGELES, CALIFORNIA 90066

Atmospheric Electricity

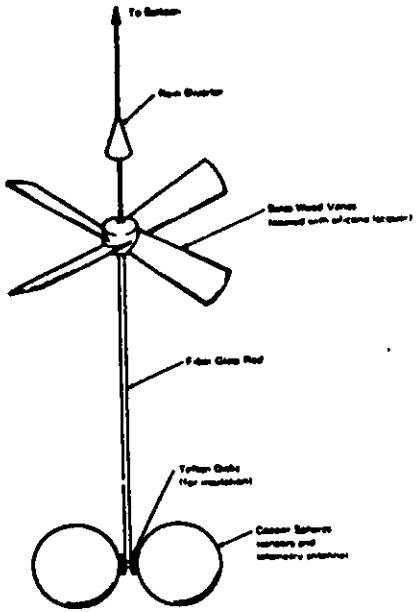
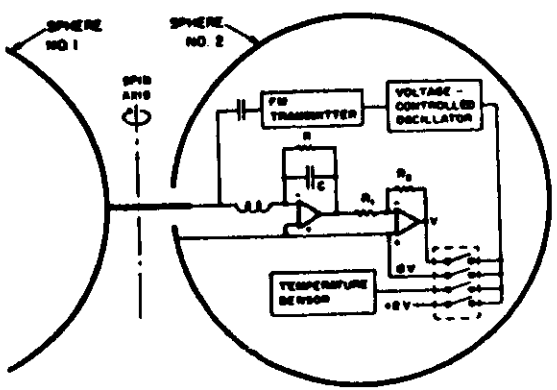


Fig. 3 Sketch of the field meter designed to measure the horizontal electric field by ascending below a balloon and then descending on a parachute. (After Winn and Byerley, 1974.)

Fig. 4 Simplified schematic diagram of the field meter for measuring the horizontal components of electric field aloft. (Winn and Byerley, 1974.)



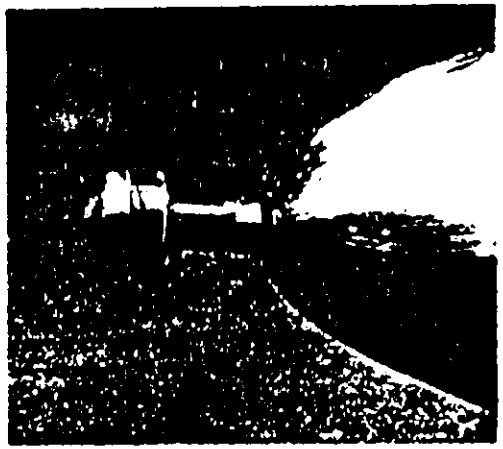


Fig. 5 A cylindrical field mill mounted on the nose of an aircraft and used to measure two components of the electric field. (Kasemir, 1972.)

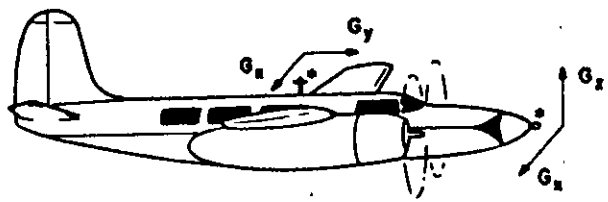


Fig. 6 Cylindrical field mills (indicated by asterisks) are located along lines of aircraft symmetry; shown is a typical coordinate system used to define the three components of the electric field, described here in terms of potential gradients, i.e., G points toward positive charge.

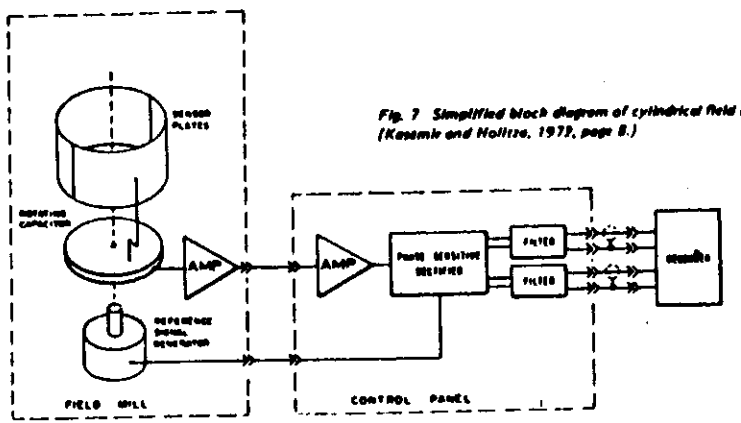


Fig. 7 Simplified block diagram of cylindrical field mill system. (Kasemir and Hollitz, 1977, page 8.)

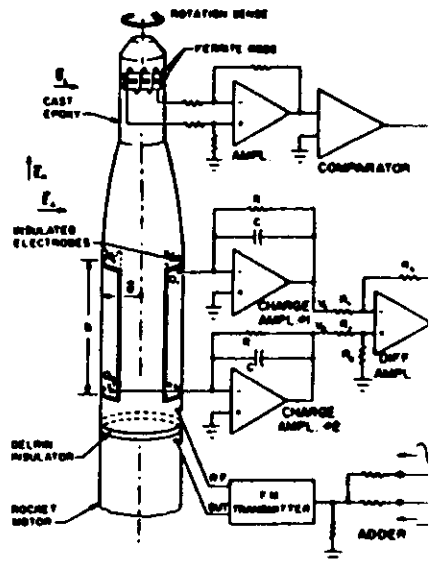


Fig. 1 Schematic of instrumented rocket payload for me electric field components perpendicular to the rocket bod Moore, 1971.)