CONSTRUCTION AND CALIBRATION OF A CONDENSATION NUCLEUS COUNTER FOR THE MEASUREMENT OF AITKEN PARTICLES IN THE HARMATTAN HAZE

By

SHEHU MUSTAPHA IBRAHIM

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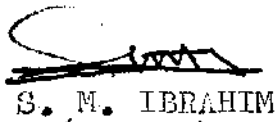
DECLARATION

The work reported in this Thesis has been carried out by the author under the supervision of Dr. J. Adetunji. It has not been accepted elsewhere for the award of higher degree or diploma. The works of other investigators are acknowledge and referred to accordingly.



S. M. IBRAHIM
(Author)
Department of Physics
Ahmadu Bello University
Zaria.

27/2/89
DATE

C E R T I F I C A T I O N

This thesis entitled CONSTRUCTION AND CALIBRATION OF A CONDENSATION NUCLEUS COUNTER FOR THE MEASUREMENT OF AITKEN PARTICLES IN THE HARMATTAN HAZE by Mr. Shehu Mustapha IBRAHIM, meets the regulations governing the award of the degree of Master of Science, Physics of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literacy presentation.

DR. J. ADETUNJI
Chairman Supervisory
Committee and Head,
Physics Department
Ahmadu Bello University
Zaria.

27/4/89
DATE

DR. I.V.S. RATHORE
Member Supervisory Committee
Physics Department
Ahmadu Bello University
Zaria.

27/4/89
DATE

PROF.
Dean Post-graduate School
Ahmadu Bello University
Zaria.

28/6/89
DATE

DEDICATION

To my parents:

Alhaji Ibrahim Ayinla Gidado

and

Alhaja Hauwa Alake Ibrahim

ACKNOWLEDGEMENT

Bismillahi ar-Rahaman ar-Rahim - Alhamdu Lil-lahi rabbil 'alamin. All praises are due to Allah without whose mercy this project and indeed, the course could not have been completed.

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A B S T R A C T

One type of atmospheric condensation nucleus is the Aitken particle which has radii ranging between 0.005 and 0.1 microns. In this work, a locally constructed condensation nucleus counter suitable for the measurement of the concentration of Aitken nuclei in the Harmattan haze is described.

Filtered air is drawn into the previously evacuated . system to a pressure of about 2×10^4 Pa and then released. The concentration of the Aitken nuclei in the air drawn into the apparatus is deduced from the reading of the photocurrents I_o and I through the pressurized and rarefied air in the system respectively.

Measurements of particles in ambient air with the counter show that the concentration of Aitken nuclei in the locality is up to 3×10^{11} particles per litre.

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1.00 INTRODUCTION

Atmospheric aerosol particles are minute dust particles that can remain airborne for a considerable length of time. The particles may be solid earth matter, salt particles, smoke particulates or gaseous molecules of marine, continental or extraterrestrial origin blown into the atmosphere.

Though they participate actively in the formation of rain clouds, they are mostly undesirable especially when present in large quantities. This is because of the far reaching environmental, climate and health effects their presence in the atmosphere produce.

Some of these undesirable effects are felt during the Harmattan season in Nigeria. The Harmattan dust has, over the years aroused global interest because of its enormous effects on communication, radiation, health et cetra in the country. As reported by Samways (1975) and Kalu (1979), the Harmattan dust is blown to Nigeria from the alluvian plain of Bilma ($18^{o}N$, $12^{o}E$) in Southern Niger and Faya-Lageau ($18^{o}N$, $19^{o}E$) in Chad by the North-East trade wind.

To be able to cope with and possibly reduce the adverse effects of aerosol particles, there is a need for a thorough study of the nature of the particles. In a study of airborne particles it is desirable to determine the size of the particles, the number concentration, the chemical composition, charge carried if any and radioactivity if any, at all points in the atmosphere.

The most numerous of any aerosol particles are usually those with radii between 0.005 and 0.1 micron (Byers, 1965). The aim of this project is to farbricate, locally, and calibrate a suitable instrument for determining the concentration of these particles in the atmosphere at any desired time.

In this Chapter, a brief discussion of the various classes of aerosol particles is given, followed by the various techniques of sizing in section 1.2. In section 1.3 the technique adopted in the present work is discussed.

1.1.0 CLASSIFICATION OF DUST PARTICLES

As reported by Mason (1971) atmospheric aerosols cover a wide range of particle sizes, from the smallest free ions of about 0.001μm radius to the largest salt and dust particles of radius 10μm. Particles larger than 10μm do not normally remain airborne for a long time since they are often too heavy and therefore precipitate under the action of the force of gravity on them.

On the other hand, the lower limit of aerosol particles (0.001μm) is fixed by coagulation, the smallest and most mobile particles collide and stick together to form larger, less mobile and thus more stable particles.

Due to the wide variety of particle sizes, it is often desirable in aerosol studies to classify the particle spectrum into four size groups. These groups,

shown in Fig 1.1, are:

(a) The so-called 'Giant'particles, (b) the large particles, (c) the Aitken particles, and (d) the small ions.

(a) The Giant Particles

Particles in this group have radii between 1μm and 10μm. This corresponds to the size range of the set of largest particles that can remain airborne for a considerable length of time. They are therefore giant particles when compared with particles of the other groups.

In addition to the original particles formed by the source of the aerosol, particles in the group are continously being formed by the aggregation of smaller particles. However, coagulation of smaller particles on giant particles amay result into particles too heavy to remain airborne, therefore causing them to fallout.

(b) The Large Particles

The second group, called large particles comprises of particles of radii between 0.1μm and 1μm. They are next in size to the giant particles and some of them may coagulate either with other particles of the same class or smaller particles to form giant particles. At the same time smaller particles may aggregate to form these large particles.

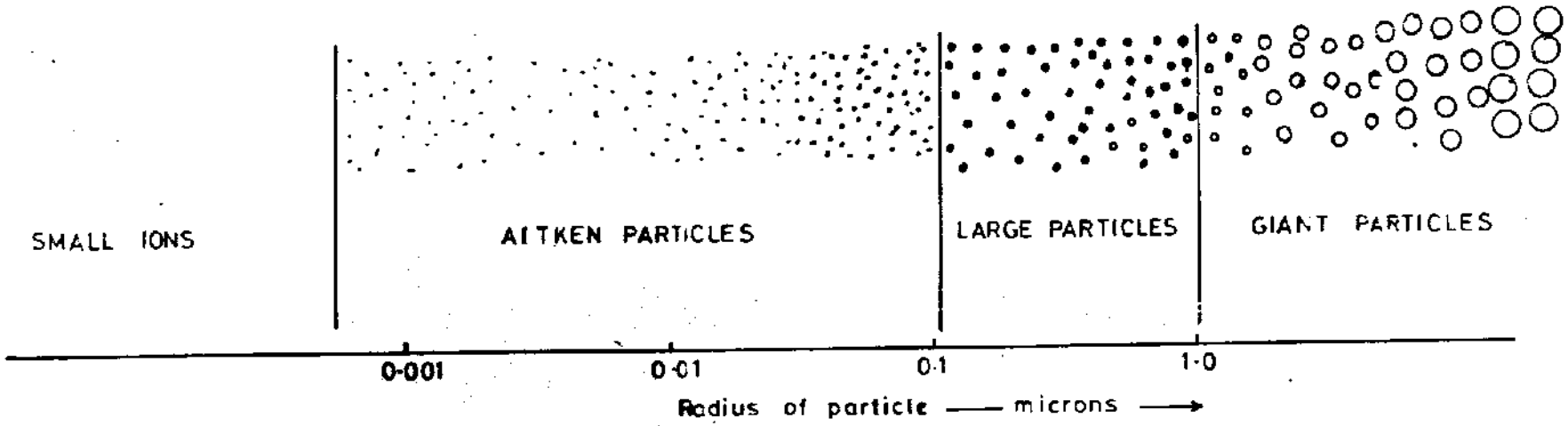


Fig.1.1: Diagram showing the classfication of air borne particles according to their sizes

(c) Aitken Particles

The third group, the Aitken particles, are so called in honour of John Aitkens who first demonstrated the effect of the presence of these particles on condensation. The group is made up of particles of radii between 0.005 and 0.1cm. As reported by H.R. Eyres (1965) Aitken particles are normally the most numerous particles in any aerosol. However, some of them may aggregate to form large particles or coagulate with large particles to form giant particles.

(d) Small Ions

The small ions are the smallest of the airborne particles. They are about 0.001cm in size and are made up of a few neutral air molecules clustered around a charged molecule. They are the most mobile of aerosol particles and some of them aggregate to form Aitken particles or large particles. Sometimes, some of the larger particles capture some of the ions to form large ions.

1.2.0 SIZING TECHNIQUES

Aerosol particle sizing involves the determination of the concentration, number of particles in a unit volume of air, of each size range present in the atmosphere at any particular time. Due to the wide variety of particle sizes involved in aerosol studies no single instrument or technique can be used to cover all the size ranges. Therefore different techniques and instruments have to be used for different size ranges.

Several ingenious techniques have been devised for sizing aerosol particles. These techniques can be broadly grouped into two. (1) the direct sizing techniques by which particle sizes and number concentrations are measured directly with the appropriate instrument; and (2) the indirect sizing techniques by which particle sizes and number concentrations are determined from a measurable effect of the presence of the particles.

1.2.1 The Direct Sizing Techniques

There are two methods of direct sizing of aerosol particles. These are the methods involving the collection of the particles and those that do not require a collection of the particles.

(a) Direct Sizing Technique with Collection

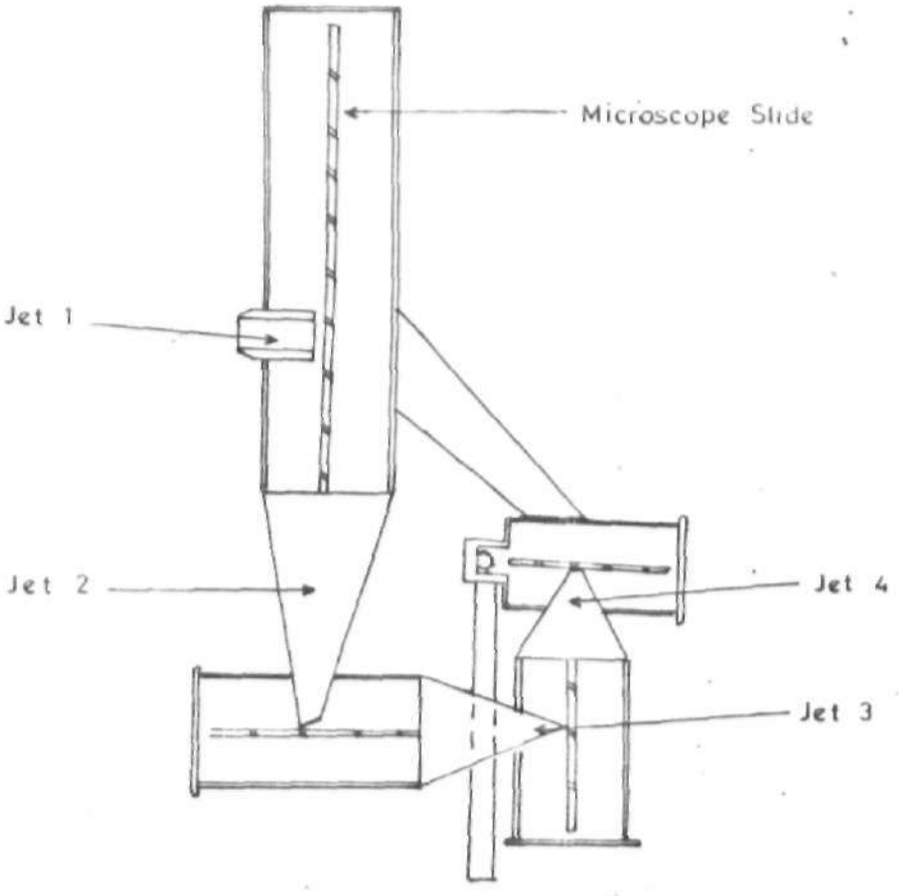
In this method the number concentration of the particles in the various size ranges are determined by first collecting or sampling the particles of the different size ranges for subsequent examination and counting under an optical or an electron microscope.

There are many ways of collecting aerosol particles. One of these is the use of special filters of known pore size. The filter traps particles of the required size while allowing particles of smaller sizes to slip through. A combination filters of chosen sizes may be used to collect particles of a particular size or size range. An elegant application of this method was developed by Dessens (1949) who caught aerosol particles on very fine spiders thread.

Another way is the use of impactor devices. An impactor as described by Mason (1971) has an opening through which air is sucked in by means of a pump resulting in an air jet which strikes a glass plate on which the particles are deposited. The plates can then be removed and counted under the microscope.

One type of impactor is the four stage cascade impactor which can sample particles of radius greater than 0.5cm into four different size groups. This impactor(shown in fig. 1.2) consisting of a system of four jets and sampling slides in series has been successfully used by Ahmed (1986) to determine particle size distribution in the Harmattan haze.

Centrifuge devices can also be used for aerosol collection. A device of this type is the conifuge described by Sawyer and Walton (1950) and illustrated in fig. 1.3. The instrument is essentially a conical centrifuge with an inner solid cone and an outer conical shell of the same vertical angle. In operation, the two cones are operated about their common axis in a stationary outer casing by means of an electric motor. The rotation of the cones causes an internal circulation of a stream of clean air which winnows the airborne, particles drawn into the apparatus in such a way that the particles are classified according to their sizes and deposited on a glass slide in a continously graded sample. The glass slide can then be removed and measurements made using a microscope.



Fig·1-2 : Diagramatic Section (elevation) of a Four – Stage Cascade Impactor

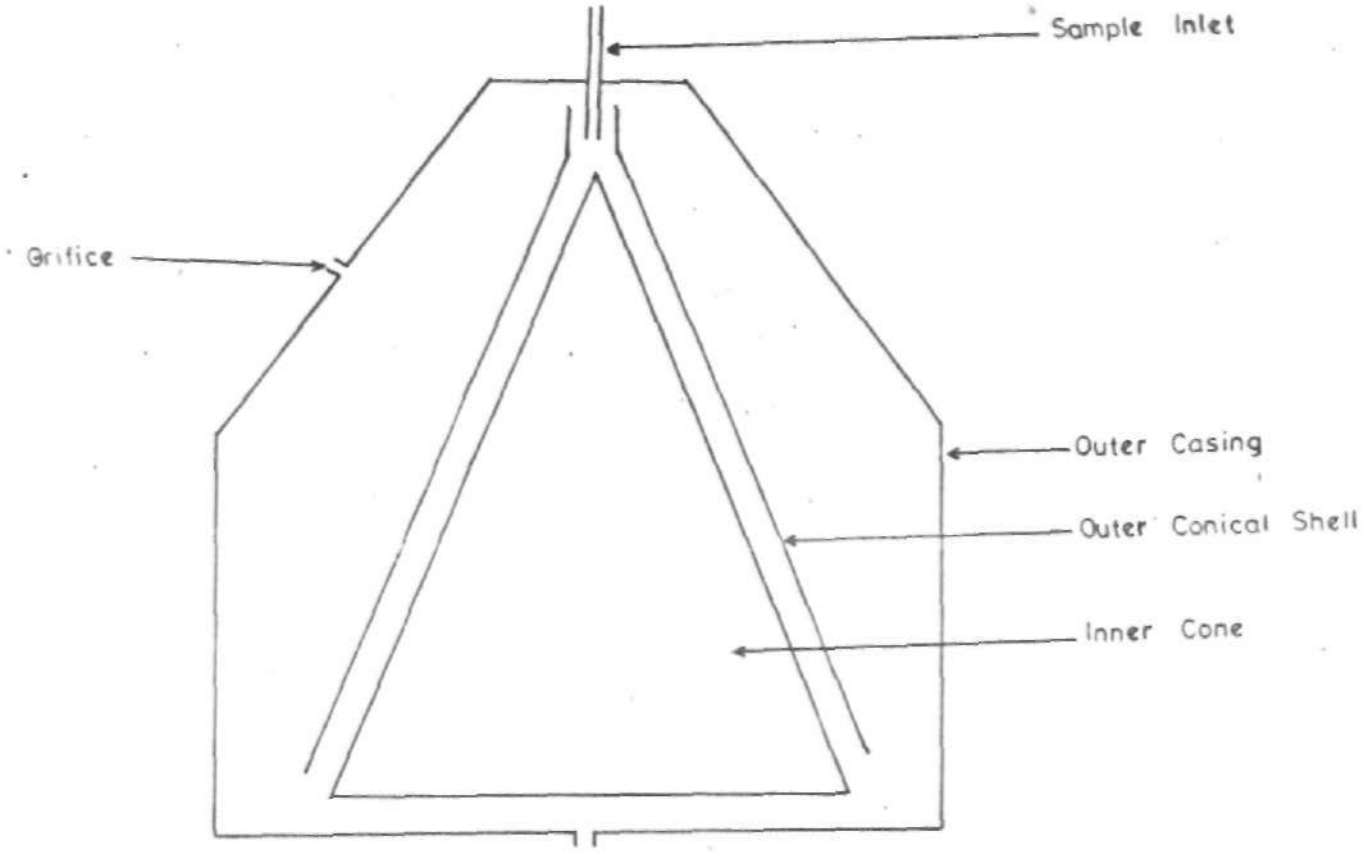


Fig. 1·3: Diagramatic Section of a Sawyer and Walton Conifuge

Aerosol sampling can also be carried out by thermal and electrostatic precipitation methods. The simplest form of a thermal precipitator consists of two parallel plates at different temperatures between which the air is drawn. Due to the temperature difference between the two plates, the particles in the air settle on the cooler according to their sizes with the smallest settling close to the entrance and the larger ones close to the end.

In an electrostatic precipitator, the particles are given a charge as the air passes around an ionizing wire at the entrance to a tubular duct. An electric field is imposed between the walls of the duct and a central electrode rod with a charge similar to that on the particles. In passing through the duct the particles migrate to the walls at speeds depending on their mobility (velocity per unit electric field) as ions. This is a function of the size of the ions and the strength of the applied field. Small particles are therefore precipitated faster than larger ones because of their mobility.

(b) Direct Sizing Techniques without Collection

In this method, no previous collection or sampling of the particles are required. Some of these methods include light scattering, elastic collision on microphone, and photographing of paths in a force field.

In the light scattering technique, the air under test is drawn into a vessel through which a beam of light passes. The particles of the aerosol scatter some of the light to the walls of the vessel. The concentration of the aerosol particles can be obtained as a function of the intensity of the scattered beam.

In elastic scattering method, the particles are made to collide on, say a microphone. The number of collisions in a given time depends on the concentration of the aerosol particles while the energy of collision depends on the size of the particle. Hence this method is suitable for aerosol sampling.

If the path of a particle in a force field can be obtained, then the size and the number concentration of the particles can be determined. On this principle is based the photography of path method.

1.2.2 INDIRECT SIZING TECHNIQUES

The indirect methods of aerosol particle sizing employs the effect of the presence of the particles in determining their sizes and concentration. The most widely used property is the nucleating effect of the particles. The particles can serve as cores for condensation under the right condition. Instruments based on this method include the low-supersaturation counter, the expansion chambers and the cold-air mixing chamber. However the most common are the condensation nucleus counter and the cloud chamber.

(a) The Condensation Nucleus Counter

This instrument, first introduced by John Aitken's (1883) is based on the rapid expansion of a chamber containing saturated air. Expansion produces adiabatic cooling until the air is sufficiently super saturated for the particles to act as condensation nuclei. The sizes of the particles serving as condensation nuclei depends on the expansion produced. The concentration of the particles is obtained by counting the resulting droplets using a suitable device. In one of Aitken's particle counters, the droplets are viewed through an eye-piece and counted against a graticule. The number of droplets in one square is then multiplied by the factor necessary to give the concentration in a unit volume.

(b) The Cloud Chamber

The cloud chamber, first used by C.T.R. Wilson consists of a chamber into which air saturated with water vapour is introduced. With the aid of a piston below the chamber, the pressure inside the chamber is reduced several times until an expansion ratio sufficient for small ions to serve as cores for condensation is attained. In this way the concentration of small ions in the air sample can be determined.

1.3.0 CHOICE OF TECHNIQUE

In a recent work Adetunji and Ahmed (1986), using a four stage cascade impactor for the collection of Harmattan dust particles in Zaria, found that no particle of radius less than 0.1μm could be collected on any of the slides. Hence the Aitken particles (radii between 0.005μm to 0.1μm) in the Harmattan haze could not be analysed. The implication of this is that the particle size distribution curve of the dust haze obtained in this work, shown in fig. 1.4, is grossly incomplete as the Aitken particles, which are the most numerous particles in any aerosol, are not represented.

That particles of radii less than 0.1μm could not be collected with the impactor can be explained by the minute size of these particles. They are so small that they can penetrate any filter and slip through impactor slides. Even if collected it will be difficult to count them since they can not be seen under a conventional optical microscope, while in the electron microscope they partially evaporate or get destroyed by electron beam. The direct sizing methods without collection are also not suitable for the same reason of minute size.

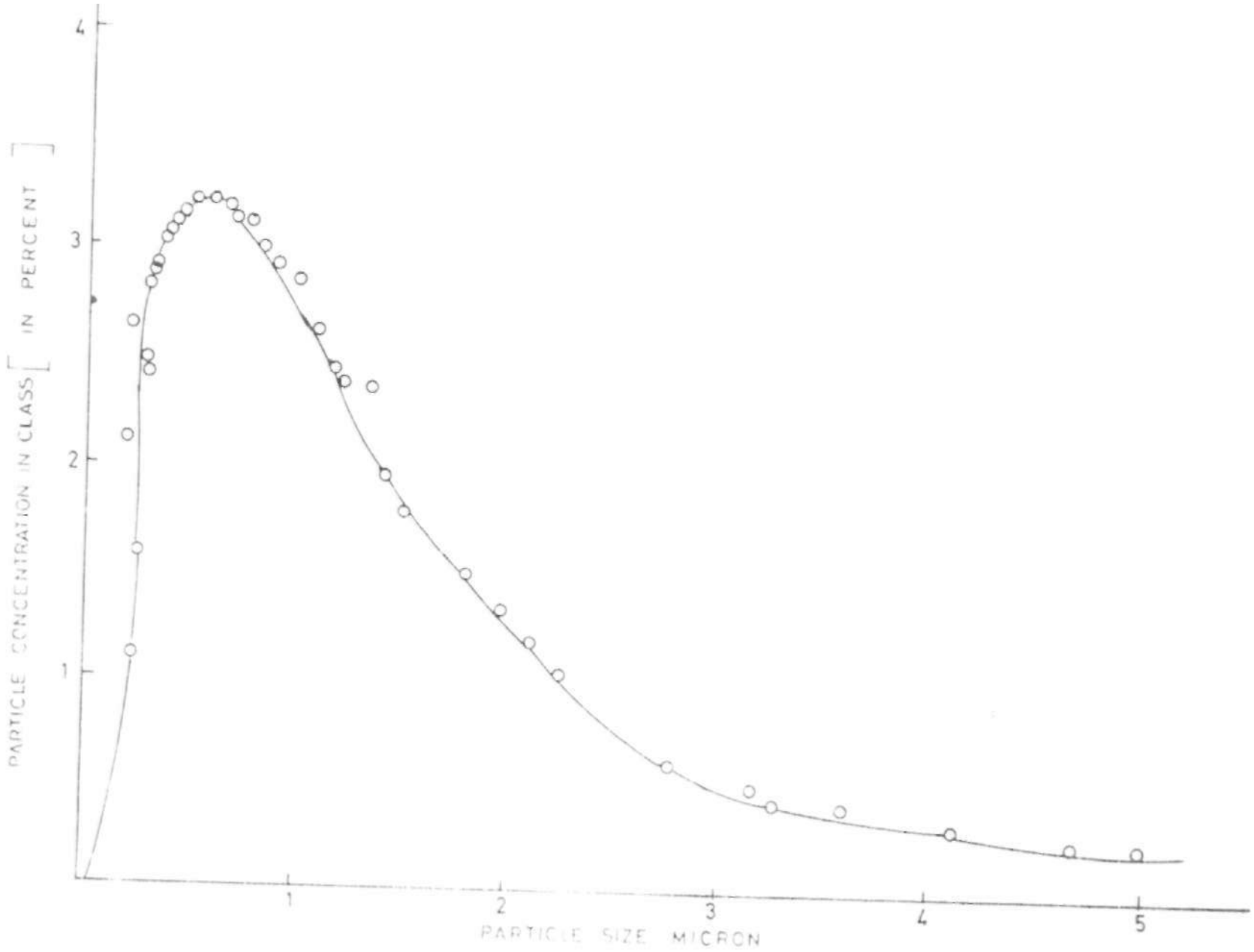


Fig. 1.4 THE PARTICLE SIZE DISTRIBUTION CURVE OF HARMATTAN DUST PARTICLES AS OBTAINED USING A FOUR STAGE CASCADE IMPACTOR (ADEYUNJI AND AHMED 1986)

Direct sizing methods are normally used for large and giant particles. The large particles can be detected using any of the sizing methods without collection. They can also be collected by thermal and electrostatic precipitation, by filters on coated slides, and on spider webs for subsequent counting under optical or electron microscope as described in the previous sections.

Giant particles on the other hand are mostly collected on coated slides by impactors and then counted under optical microscope.

The standard method of detecting Aitken particles is by the use of condensation Nucleus Counters (CNC) while the cloud chambers are mostly used for the detection of small ions.

The aim of this project is to design, construct and calibrate a condensation Nucleus counter suitable for local determination of the concentration of Aitken particles in the atmosphere at any desired time.

CHAPTER TWO

CONDENSATION NUCLEUS COUNTER: THEORY AND TYPES

2.0.0 INTRODUCTION

In a dust-free air saturated with water vapour aggregates of the condensed phase are formed as a result of chanced collision of molecules in the vapour phase. These small aggregates, refered to as embryos, are continously being formed and broken and can only continue growing if they are larger than a critical size.

Homogenous condensation results from the embryos if they grow large enough to be more stable than the vapour phase, at which stage they form nuclei for the development of the liquid phase. The formation of embryos of the critical size requires very high super-saturation. As reported by Wilson (1897), the required supersaturation is as high as 800 percent. If the supersaturation is produced by expansion, this corresponds to an expansion ratio in excess of 1.37.

However, as Aitken (1880) found out, in the presence of dust particles, especially hydroscopic ones, condensation commences even below saturation. The dust particles serve as ready-made nuclei for condensation, thereby reducing drastically, the supersaturation required to induce condensation.

Hence aerosol particles in an air sample can be made to serve as cores for condensation, thereby converting them into water droplets. If it is assumed that one particle produces one water droplet, this phenomenon provides a very good method of aerosol census since the water droplet are much larger then the particles and therefore easier to count.

2.1.0 THEORY

A suitable device in which Aitken particles can be made to serve as cores for condensation is the condensation Nucleus Counter (CNC). Since the introduction of the first type of the counter by Aitken (1883), a lot of improvements have been made and a number of varieties are now in use. However the principles of operation of the counters are the same.

The sample air is drawn into a vessel and made saturated by moisture from the wet lining of the vessel. The moist air is then made supersaturated either by increasing the pressure in the vessel and then suddenly releasing it or by expanding the volume using a pump for partial evacuation of the vessel. In both cases the effect is an adiabatic expansion of the air sample accompanied by a lowering of the temperature from its initial value of say T_1 to a new value T_2 according to the equation.

$$T_2 = T_1 \left(P_2 / P_1 \right)^{R/mc_p} \qquad \text{--- 2.1}$$

where P_1 is the initial pressure and P_2 is the reduced pressure P_2. This results into a super saturation ratio given by the equation

$$S = \frac{Ps_1 \, P_2}{Fs_2 \, P_1} \qquad \text{---- 2.2}$$

The saturation vapour pressures Ps_1 and Ps_2 are functions of the temperatures T_1 and T_2 respectively P_2 is always less than P_1 and T_2 is always lower than T_1, hence super saturation is always achieved. The Super saturation induces condensation on the dust particles.

The number of droplets formed depends on the expansion ratio as well as the number of active condensation nuclei (dust particles) in the air.

The size of the active dust particles depends also on the expansion ratio with the giant particles requiring the lowest ratios while to small ions require the highest ratios, about 1.25. In condensation Nucleus Counters, expansion ratios of about 1.21 are usually produced. This ratio is enough to activate all Aitken particles but too low for small ions. However the giant and large particles are first activated before the Aitken particles. So the droplets formed by the large and giant particles have to be allowed to settle out, before measurement is made to ensure that the water droplets counted are those formed by Aitken particles only.

2.1.1 Droplet Counting

The droplets formed can be counted directly as in the absolute counters or indirectly as in the relative counters.

In the absolute counters, the droplets are precipitated on a graticule and counted directly by eye through a magnifying glass or microscope in dark-filled illumination or on photomicrographic records.

In the relative counter, the number of droplets formed is determined either, by means of photo-multipliers, the intensity of scattered light from a light-beam passing through the chamber or with a photocell, the extinction of the beam of light.

2.1.2 The Principle of Extinction

When a parallel beam of light passes through a turpid medium, like a fog of water droplet, part of the beam is absorbed and part of it is scattered. Hence only a part of it will be able to traverse the medium. If the intensity of the incident beam is Io, then the intensity of the light beam at the detecting end is

$$I = Io - (Ia + Is) \qquad \text{------- 2.3}$$

where Ia and Is are the intensities of the light beam absorbed and scattered respectively.

According to Pollak and Metnieks (1957) the intensity of light at the end of the pipe is also given by the equation.

$$I = Io \exp\left(-\pi Z \sum_i n_i r_i^2 k\right) \quad --- \quad 2.4$$

Where n_i is the number of droplets of radius r_i encountered per unit volume in traversing a distance Z through the fog. K is a dimensionless coefficient depending on the refractive index of the scattering droplets (1.33 in this case) and a parameter a, given by

$$a = 2\pi r \lambda \quad --- \quad 2.5.$$

Where r is the radius of the droplet and λ, the wavelength of the light beam.

The percentage reduction in the initial intensity is the extinction

$$E = \frac{Io - I}{Io} \times 100\% \quad ---- \quad 2.6.$$

Combining equation 2.6 with 2.4 gives

$$E = \left(I - \exp\left(-\pi Z \sum_i n_i r_i^2 k\right)\right) \times 100\% \quad --- \quad 2.7.$$

Equation 2.7 does not take into account coherence in the scattering of a large number of particles, but assumes single scattering and monocromatic source of light. In addition, the summation has to be taken over all sizes of spheres present. It is therefore rather difficult to use equation 2.7 for the evaluation of the number of droplets encountered by the light beam in passing through the fog.

However as can be deduced from equation 2.3 and 2.7 the extinction depends besides other variables on the concentration of the droplets in the chamber. Hence it is possible to ascribe to every extinction, a corresponding unique concentration of droplets. Relative counters are therefore normally calibrated with reference to an absolute counter. The instrument normally hold this calibrations very well and give very reliable and reproducible results.

2.2.0 TYPES OF CONDENSATION NUCLEUS COUNTERS

There are many types of CNC counters. Most of these counters are improvements of the original Aitken's counters.

2.2.1 Aitken's Particle Counter

This is one of the first types of the counter developed by Aitken's himself. The instrument consists of a test chamber the walls of which are lined with wet blotting paper to keep the air saturated with water vapour. In operation the chamber is first flushed with filtered air to onsure that it is initially particle free. The sample air is then drawn in by a graduated hand piston which also serves to expand the chamber after the inlet value is closed. The expansion leads to a supersaturation large enough to activate the Aitken particles and the resulting droplets fall onto the graticule which is an illuminated piece of glass with small squares etched on it.

The number of droplets in the square are then counted and the expansion repeated until no more droplets are formed. The sum of the numbers of droplets in one square is multiplied by the necessary factor to obtain the concentration of the particles in the sample air.

As reported by Mason (1971) this instrument has several unsatisfactory features some of which include turbulence, leakages, counting difficulties and improper definition of the chamber volume. Turbulence produces a non-uniform distribution of droplets on the graticule while some particle are lost due to leakage and counting of droplets on the squares is a very cumbersome process.

A number of improvements have been made on the Aitken counter to eliminate these defects. One of such improvements was by Scholz (1931) who introduced a counter of cloud chamber volume 100 cm^3 (Mason, 1971) to eliminate turbulence. This counter was however still apt to develop leaks.

To ease the counting problem Pollak (1952) developed a modified form of Aitken counter which allows two observers to count the droplets as they are formed. Alternatively the extra counting point can be used for taking pictures simultaneously as the droplets are counted.

An instrument in which most of the defects and the counting difficulties in the Aitken counter are effectively eliminated is the Photo-electric condensation Nuclei counter.

2.2.2 PHOTO-ELECTRIC CONDENSATION NUCLEUS COUNTER

This instrument is a relative counter developed by Nolan and Pollak (1946), Pollak and O'connor (1955), and Pollak and Metnieks (1957). As shown in fig 2.1 the instrument consists of a chamber made of a vertical pipe 60cm in length, fitted with a wet porous ceramic pipe and sealed on both ends by electrically heated glass plates. To the top is fitted an illuminator, the light source of which produces a parallel beam of light which passes concentrically through the chamber. At the bottom is a photocell centrally placed to receive the parallel beam of light emerging from the chamber. The photocell is connected to a microammeter which records the photo current.

In operation, the air under investigation is drawn in through an inlet tap and then filtered air is pumped in to a predetermined over pressure. To allow the air become saturated with water vapour and to lose its heat of compression, the pressure is held for about a minute. While waiting, the photocurrent, Io is read andthen the pressure is released. The sudden expansion cools the moist air and vapour condenses on the nuclei.

Due to the absorption and scattering of part of the light beam by the resulting water droplets, the photocurrent falls to a new value, I. The extinction E given by equation 2.6 depends on the number of water

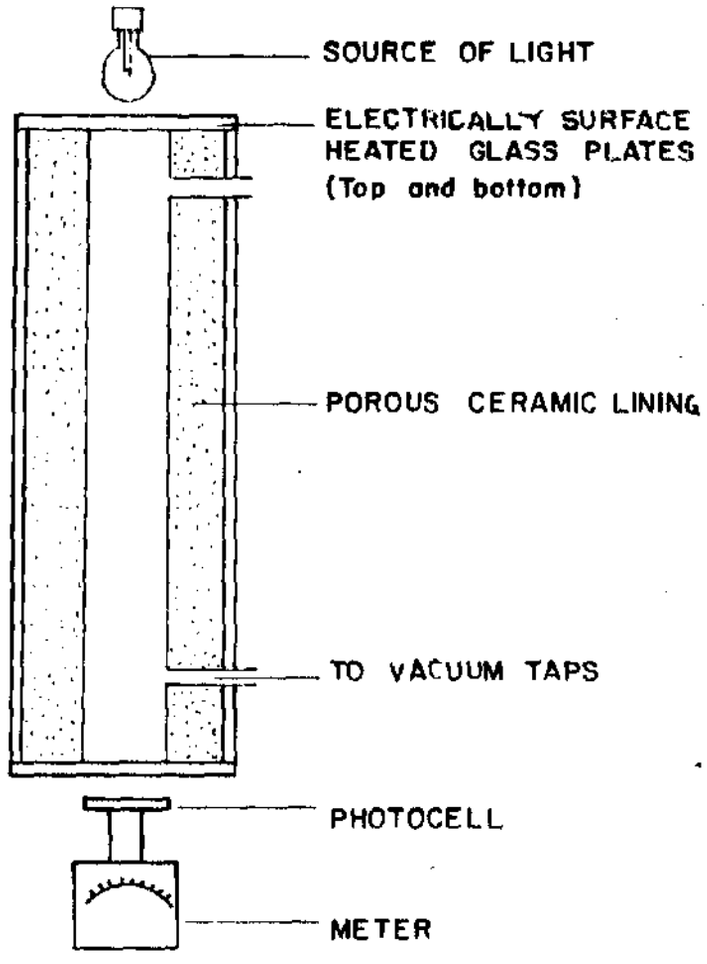


Fig. 2-1 : A SKETCH OF A PHOTO-ELECTRIC NUCLEUS COUNTER

droplets formed. The number of water droplets formed give the number of particles activated assuming that only Aitken particles are responsible for the water droplets and that one droplet is formed from only one particle.

The counter is usually calibrated by reference to an Aitken absolute counter. The instrument holds its calibration very well and gives very reproducible results.

2.2.3 Riche's Counter

This photo-electric condensation nucleus counter described by Rich (1955) allows size discrimination of the particles to be counted. The counter has two chambers into which the sample air at atmospheric pressure expand after evacuation. The expansion into the first chamber is made rapid to ensure a required saturation. The expansion into the second is slow enough to permit the growth of water drops and bring the supersaturation below the initial value, and yet fast enough to be adiabatic. Only those nuclei smaller than the size determined by the initial supersaturation are activated in the second expansion and contribute to the extinction of light, measured photo-electrically.

2.2.4 Automatic Photo-Electric Counter

This counter described by Hayes and Scott (1969) is a photo-electric counter in which all operations are carried out automatically. The taps are fitted with solenoid valves controlled by solid-state timers used in association with relays. The over pressure is controlled by the use of a mercury manometer. The illuminator is connected to a constant current circuit and the photocurrent registered on a pen recorder. With the instrument readings can be taken every four minutes.

CHAPTER THREE

DESIGN AND CONSTRUCTION OF ZCNC

3.0.0 For the purpose of this project an instrument capable of a hourly measurement of Aitken particles on the atmosphere is required. It is required that this instrument, like any other aerosol measuring instrument satisfies the following characteristics based on a report by Tropp et al (1970).

i) High accuracy and consistency:- Results obtained with the instrument should be highly accurate, consistent and dependable.

ii) Sensitivity over a wide range of concentration:- The instrument should be very sensitive to both high and dilute concentrations. This is necessary since it will be used during the Harmattan and the rainy seasons when particle concentrations are very high and low respectively.

iii) Small response time:- The instrument should be able to yield results within a very short time.

iv) Ease of Calibration:- The calibration of the instrument should be easy and the instrument should hold its calibration well over all concentrations.

v) Large volumetric sampling rate:- The volume of air required for measurement should be large enough to give a representative measurement of the atmosphere.

vi) Inexpensive:- The counter should not be expensive to fabricate locally. The parts should be available and cheap.

Of all the counters described in the last chapter the one that meets most of these requirements is the photo-electric condensation nucleus counter. Though a relative counter, the instrument is easily calibrated using an absolute counter. Once calibrated, the instrument holds this calibration very well and gives very accurate, consistent and dependable results for both high and dilute concentrations of Aitken particles in the atmosphere.

Absolute counters of the Aitken particle counter (APC) type do not give very accurate results for low concentrations and have to be diluted with particle free air whenever very high concentrations are to be determined. The absolute counters are therefore unsuitable. On the other hand some of the components required for the construction of an automatic counter are not available and when available are very expensive. Therefore for a reliable measurement of the concentration of Aitken particles in the atmosphere, a modified form of the Nolan Pollak type of PCNC is chosen for fabrication.

3.1.0 DESIGN AND CONSTRUCTION

The locally constructed counter, the Zaria Condensation Nucleus Counter (ZCNC) shown in fig. 3.1 was fabricated in the physics department workshop. It has four main system components:-

a) The illuminator
b) The condendation chamber
c) The over pressure system
d) The counting system.

To ensure that the counter is of high accuracy and dependability as well as leak-proof, the design was aimed at achieving the following recommendations of Metnicks and Pollak (1971).

i) Greatest rigidity of the whole instruction
ii) Chamber should be of air-column diameter between 2.5cm and 4.0cm.
iii) Use of ceramic lining to ensure uniform surface lining and regular water vapour supply.
iv) Use of '0' rings, sealing glass plates, and vacuum taps to prevent leakages.
v) The illuminator light beam should be well centred and collimated with such a narrow cross-section that the lining of the walls is not struck, leaving a dark annular ring around it.

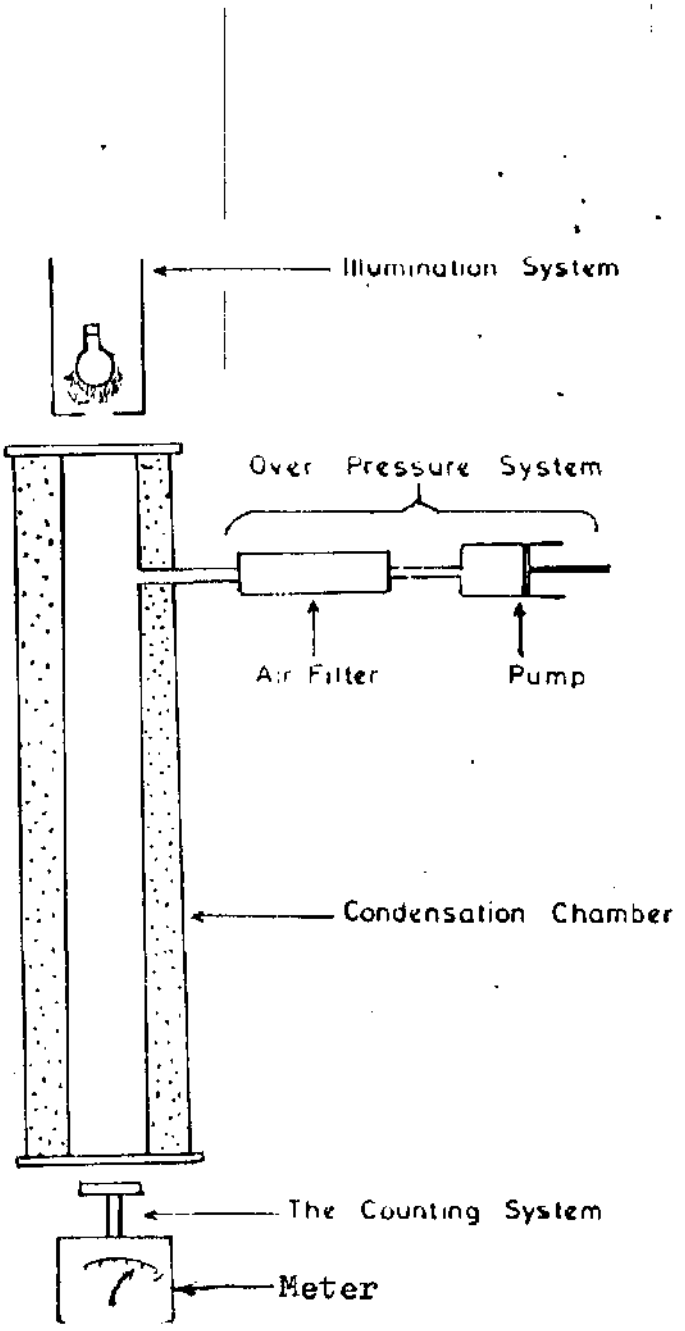


Fig. 3-1 : A Sketch of the ZCNC Showing the four main Components

vi) Uniform illumination of the cross-section of the beam at the sensitive surface of the photo-cell.

vii) Use of heating coils on the sealing glass plated to prevent misting on the plates.

viii) Use of stable and durable photo-cells.

3.1.1 Illuminator System

The illuminator shown in fig. 3.2 consists of two plano-convex lenses of focal length 5cm each, an achromat lens of focal length 18cm, a 6V. 15W point source bulb and a bulb mounting. These are properly arranged in the illuminator housing to produce a parallel beam of diameter 15mm and 17mm at the exits of the illuminator and chamber respectively.

The assembly drawing in fig 3.3 shows the order in which the different components of the illuminator are coupled. The illuminator housing is made of a blackened brass pipe of diameter 3.9cm and length 35cm. Distances between the lenses are maintained by the use of spacers which are blackened brass pipes of external diameters 3.8cm cut to the required lengths. The machining of the brass pipes to the precise dimensions were carried on the lathe machine in the physics department workshop.

The bulb mounting used was the type that ensures rigidity of the point source and allows good centering of the light beam. While diaphragms are used to ensure the required diameters of the beam.

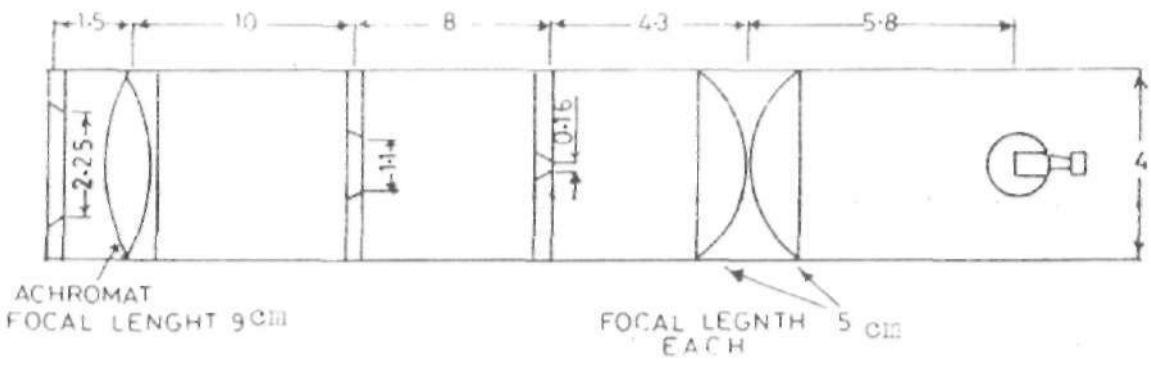
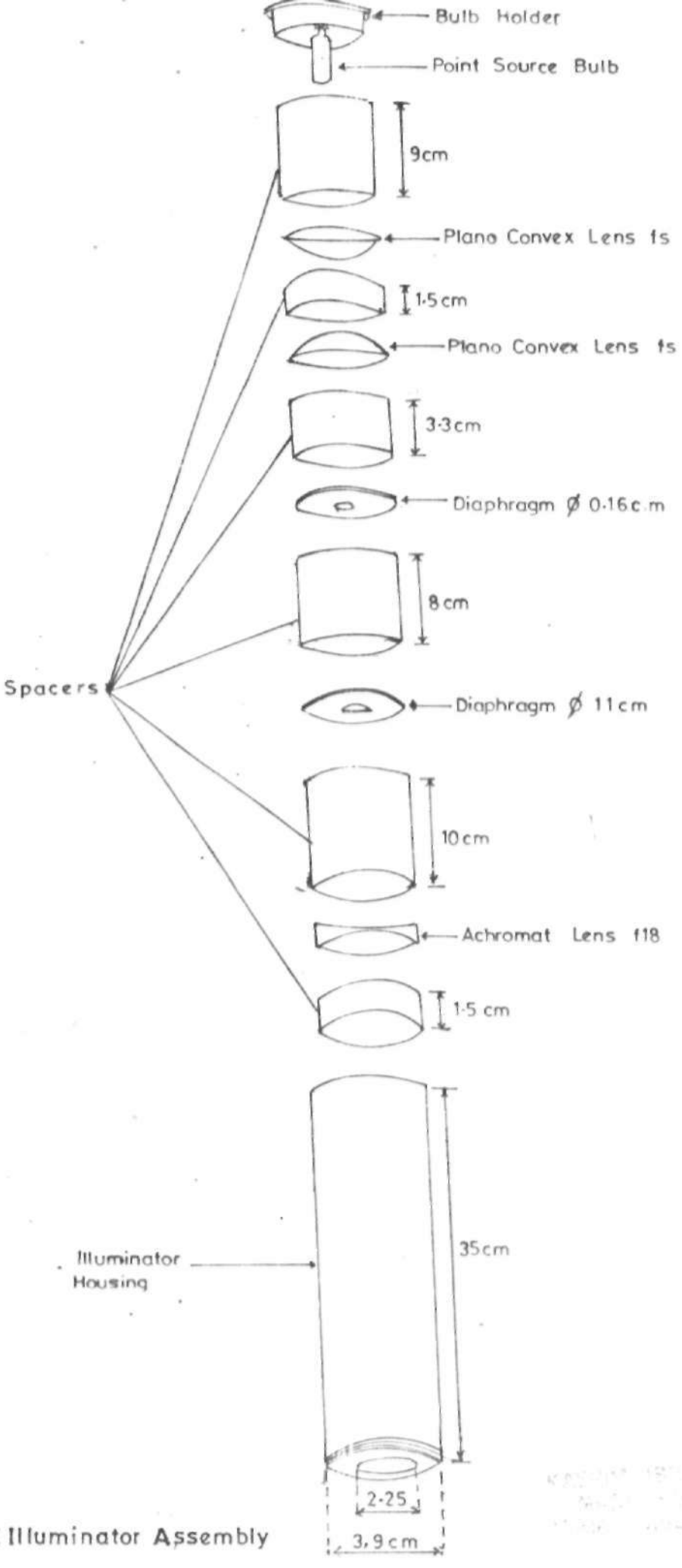


Fig. 3.2 : A DIAGRAMMATIC REPRESENTATION OF THE ILLUMINATOR



Fig·3·3: Illuminator Assembly

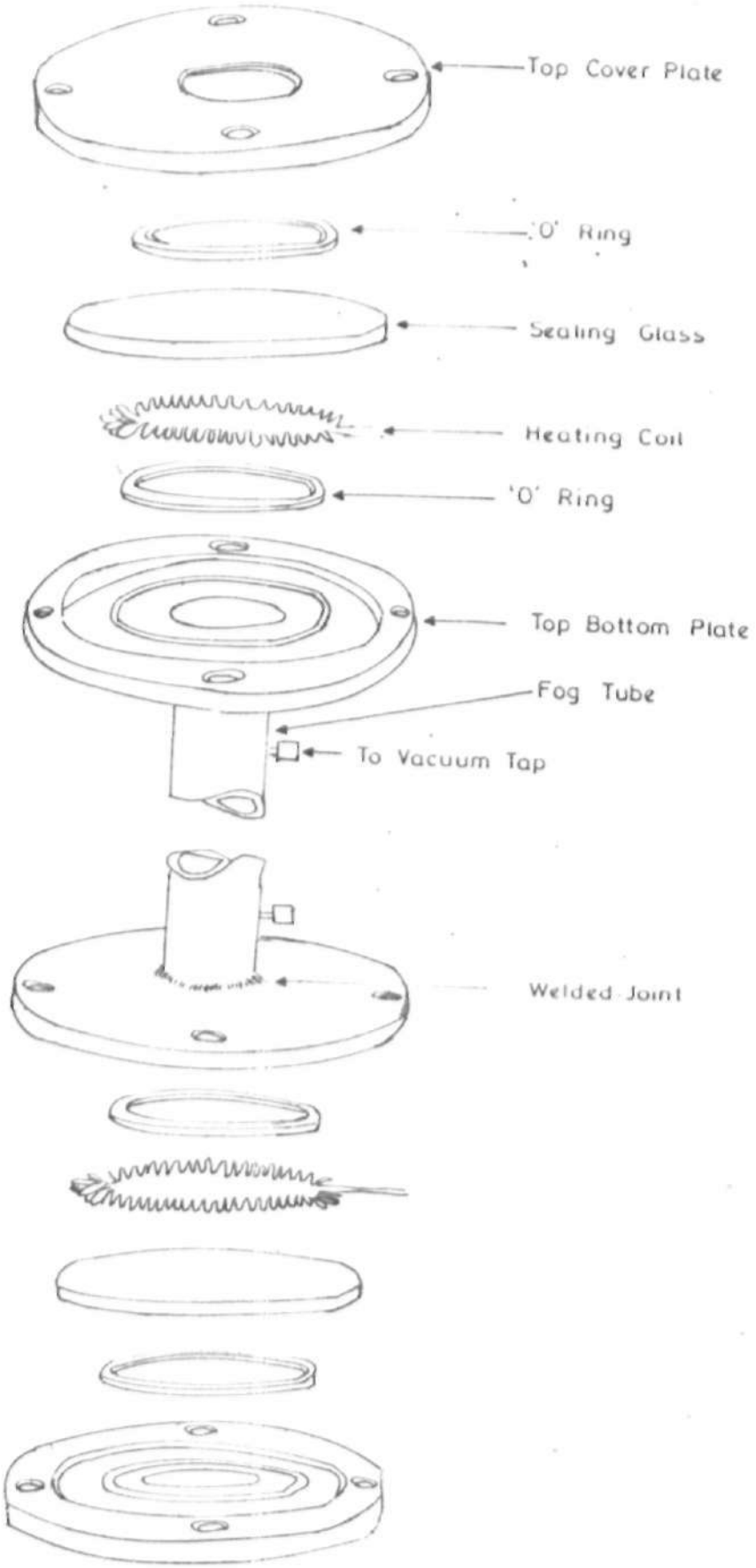
In constructing the illuminator care was taken to ensure that when fitted to the condensation chamber, the light pencil emanating from it is always well aligned with axis of the chamber. To ensure great rigidity, the illuminator is joined to the condensation chamber by threaded joint.

3.1.2 The Condensation Chamber

The inner part of the chamber is a 3cm internal diameter porous ceramic pipe fabricated in the department of Industrial Design, ABU Zaria. This is encased in a steel pipe and the composite tube machined to 60cm in length. To either ends of the tube is brassed a brass flange each. The flanges, together with a cover plate each, form housings for the electrically heated sealing glasses. Each of the glasses is provided with a heating coil made of constantan wire coiled round to the size of the glass plates as shown in fig. 3.4 and provided with leads to the power supply. The heating coils are insulated from the brass flanges by covering them with insulating paper.

To ensure air-tightness, 'O' rings are slotted one each between the brass flanges and the glasses, and one each between the glasses and the cover plates. With the use of bolts and nuts, the cover plates are tightly bolted to the flanges. Fig. 3.4 is an assembly drawing of the seating glass plates.

To the top and bottom of the chamber are fitted one vacuum tap each to form the over-pressure and sample taps respectively. While a metal manometer and



(Not drawn to scale)

Fig. 3.4 : Sealing — Glass Plate Assembly

a copper-nichrome thermocouple are fitted to the middle part.

The top cover plate is internally threaded such that the illuminator can be screwed on while the bottom of the chamber is made attachable to the counting system on the wooden base. Fig. 3.5 shows a cross-section of the condensation chamber after assembly.

All metal parts are machined to the precise dimensions on the lathe machine in the physics department workshop.

3.1.3 The Over-Pressure System

The over pressure system consists of a foot pump and an air filter joined together by a length of rubber tubing. The outlet end of the air filter is provided with a length of rubber tubing through which it can be joined to the condensation chamber through the sample tap.

(a) Air Filter

The locally produced air filter shown in fig. 3.6 is made up of an inner part which is a cylinderical can made of tin, and stuffed with layers of cotton wool. This is separated from the empty outer parts, soldered on to it, by perforated tin lids. To both ends of the filter are soldered brass pipes for the passage of air.

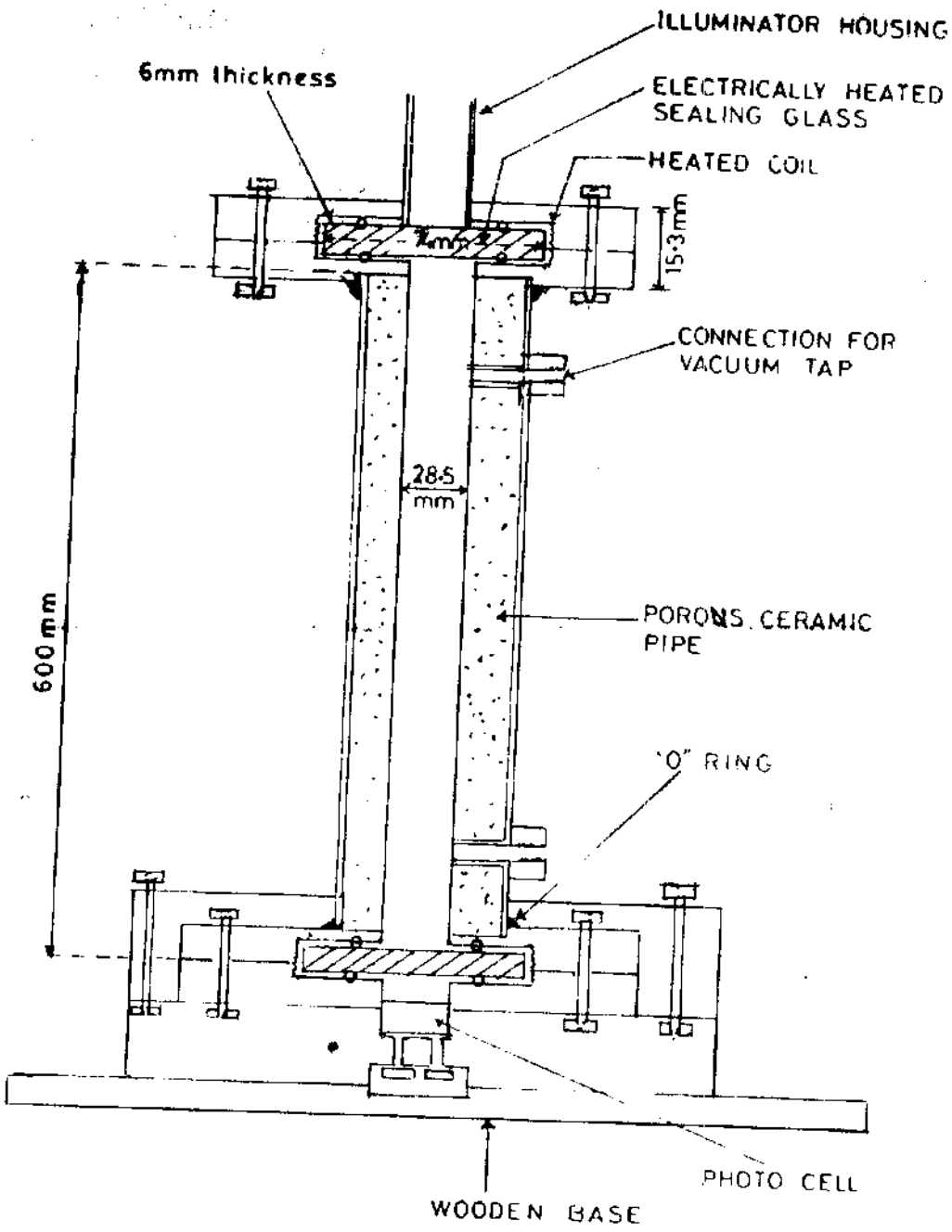
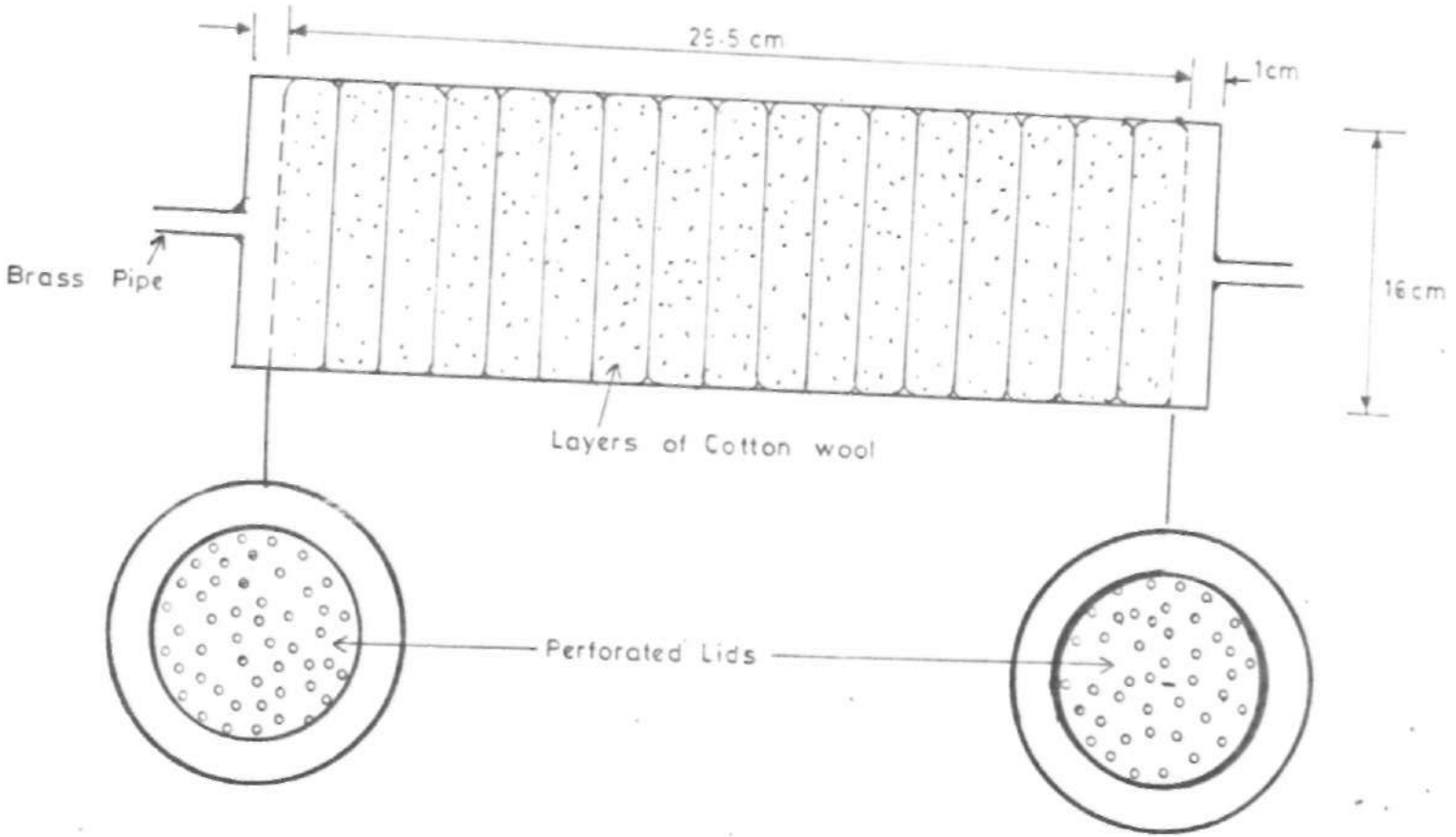


Fig. 3.5: THE ZARIA CONDENSATION NUCLEUS COUNTER (ZCNC) ASSEMBLY.



Fig·3·6: A Sketch of the Air Filter (All Joints Soldered Air tight)

(b) The Foot Pump

For the production of the required over pressure in the chamber as well as for pumping in the air sample a bicycle foot pump is used.

3.1.4 The Counting System

The counting system consists of a selenium photocell connected to a very sensitive microammeter (0-10μA). The photocell is fixed to the wooden base, produced in the carpentry workshop of the physics department ABU, Zaria, in such a way that its centre is aligned with the light beam emmerging from the chamber. To increase the sensitivity of the photocell, the sensitive area is reduced by placing a diaphragm of 15mm diameter above the sensitive surface.

3.15 SUMMARY OF PARTS

PART	QTY	MATERIAL	DIMENSIONS	COMMENT/SOURCE
ILLUMINATOR Housing	1	Brass pipe painted black	Diameter - 3.9cm, Length - 35cm	Produced in Physics Workshop ABU Zaria
Spacers	6	Brass pipe painted black	Diameter - 3.8cm; lengths - 10cm, 9cm, 8cm, 3.3cm and 1.6cm (2).	" " "
Diaphragms	3	Brass plates painted black	Diameters - 2.3cm 1.10cm and 0.16cm	" " "
Plano convex lens	2	Glass (focal length 5cm)	Diameter - 3.8cm	-
Achromat lens	1	Glass (focal length 18cm)	Diameter - 3.8cm	-
Point source bulb	1	Glass and tin	length - 5cm Type: Phillips 13347, 6V 15W	-
Bulb Mounting	1	Tin with Ceramic casing, (pin type)	Casing diameter - 4cm	Obtained from the Physics Department

Summary of Parts (Cont'd)

PART	QTY	MATERIAL	DIMENSIONS	COMMENT/SOURCE
CONDENSATION CHAMBER				
Ceramic lining	1	Ceramic	Diameter - 3cm, length - 60cm	Fabricated in the industrial design department ABU, Zaria
Steel pipe	1	Galvanized steel	Diameter - 4cm, Length - 60cm	Produced in Physics Department Workshop ABU Zaria.
Vacuum taps	2	Aluminium, plastic and rubber		
Metal manometer	1			
Thermocouple	1	Copper and constantan		Produced in Physics department electronic workshop, ABU Zaria
Flanges	2	Brass	Diameter - 12cm, thickness - 0.5cm	Machined in the mechanical workshop Physics Department, ABU Zaria
Cover plates	2	Brass	Diameter - 12cm, thickness - 0.5cm	" " "
Sealing glass	2	Glass	Diameter - 4cm, thickness - 0.64cm	Machined to size in Geology workshop ABU Zaria.
'O' rings	4	Rubber	Diameter - 3cm, thickness - 0.4cm	
Bolts and nuts	8	Steel		

Summary of Parts (Cont'd)

PARTS	QTY	MATERIAL	DIMENSIONS	COMMENTS
OVER PRESSURE SYSTEM Air Filter				
Inner part	1	2in can stuffed with cotton wool	Diameter 16cm, Length 29.5cm	Fabricated in
Outer parts	2	Tin	Diameter 16cm, length 1cm	The Physics
Pipes	2	Brass pipe	Diameter 0.7cm, length 5cm	Department workshop ABU Zaria.
Foot pump	1			
COUNTING SYSTEM Photo cell	1	Selenium photosensitive cell	Diameter - 2.5cm	
Microammeter	1	0 - 10uA range		
Wooden base	2	Circular pieces of wood	Diameter 14cm, thickness 2.5cm	Produced in the Physics department carpentary workshop.
Diaphragm	1	Blackened cardboard	Diameter 1.5cm	

3.1.6 Other Accessories

The other accessories of note required for the use of the counter include 6y d.c power supplies for the illuminator as well as the heating coils, a rheostat, two variable resistors, an ammeter, two milliammeters, a galvanometer and a wooden platform 1.5m above the ground level.

The rhestat and the two variables resistor are used in the illuminator and the heating coil circuits respectively. For setting the required currents while the ammeter (0-5A) and the milliammeters (0-100 mA and 0-200mA) are for monitoring these currents.

The galvanometer is required for the thermo-couple if the temperature within the chamber is required.

To ensure that only airborne particles are measured, the counter needs to be raised above the ground level. For this purpose the wooden platform 1.5m high is used.

3.2.0 COUNTER ASSEMBLY

To assemble the counter, the components of the sealing glass plates are first assembled as shown in fig 3.4 and the cover plates bolted tightly. However if the counter isto be used, the ceramic lining has to be soaked in distilled water before assembling the glass plates. This is done by covering the lower end of the condensation chamber with a metal plate and then pouring the distilled water into the chamber of

the ceramic lining thereby soaking it. The metal plate is then removed and the excess water allowed to drain off. The cover plates are then assembled and plate tightly bolted after which the counting system with the wooden base is coupled to the bottom sealing glass and photo cell leads appropriately connected to the microammeter.

After proper greasing, the inlet and the over pressure values as well as the metal manometer are tightly screwed onto the condensation chamber.

The illuminator is then assembled as shown in fig. 3.3; the exit end screwed onto the top cover plate of the chamber. One end of the air filter is then connected through a rubber tubbing to the inlet value on the chamber and the other end connected through another tubbing to the foot pump.

The free ends of the thermocouple are then connected to the galvanometer and the heating coils as well as the illuminator leads appropriately connected through the variable resistors and the rheostat respectively to the 6V d.c power supply.

Whenever the counter is to be used the heating coils and the illuminator power supplies have to be switched on for 5 minutes before measurements are commenced. This is to ensure that the glass plates are warm enough and the intensity of light from the illuminator is steady.

CHAPTER FOUR

TEST MEASUREMENTS AND CALIBRATIONS

4.1.0 COUNTER TESTS AND CHECKS

To ascertain that the locally constracted condensation Nucleus counter, conforms with the desired requirements, the following test and checks were carried out.

4.1.1 Shape and alignment of the Light beam

The illuminator was assembled as shown in fig. 3.3 and connected through a rheostat and an ammeter to a 6V d.c source as shown in the circuit diagram of fig 4.1. With a supply current of 2.3A a circular light beam of diameter 1.5cm as expected was observed at the exist of the illuminator.

The illuminator was then coupled with the condensation chamber and the emerging beam through the chamber directed on a graph paper on which a circle, with a diameter the same as the internal diameter of the chamber (i.e 3cm), has been drawn. With the axis of the chamber aligned with the centre of this circle, the emerging circular beam was found to be aligned with the chamber and the diameter was measured to be 1.7cm. Thus leaving an annular dark ring of about 0.65cm, as shown in fig. 4.2, between the walls of the chamber and the light pencil.

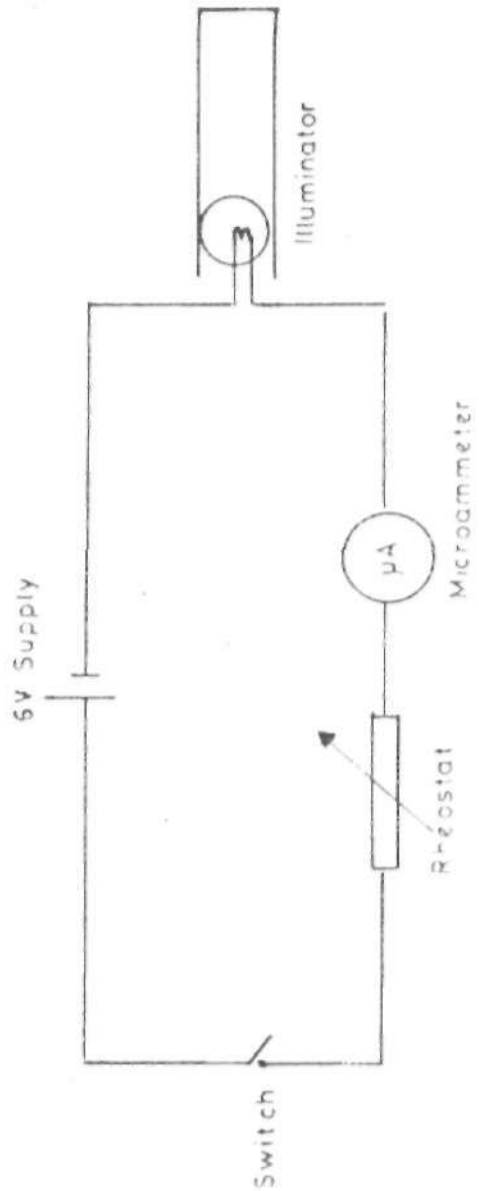


Fig. 4.1: Illuminator Circuit

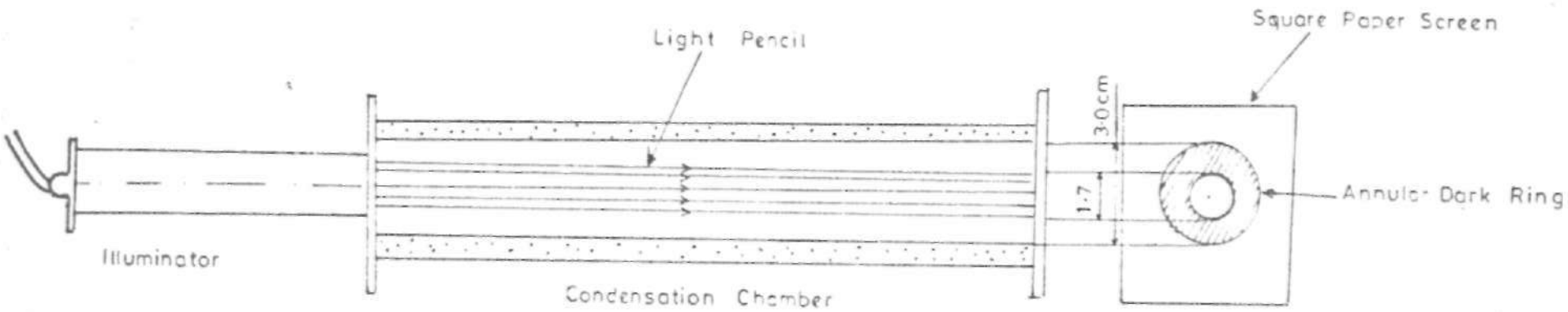


Fig. 4·2 : Diagram of the Light Pencil Traversing the Condensation Chamber

This is a clear indication that whenever the illuminator is properly assembled and coupled to the chamber the light pencil is of the required size and is centrally aligned with the axis of the chamber.

4.1.2 Heating Coil effectiveness

As suggested by Pollak and Metrieks (1956). to prevent misting on the top sealing glass it should be kept at a temp 0.5°C above the ambient temperature while the bottom sealing glass should be kept at a temperature about 0.9°C above the surrounding to prevent misting as well as reduce fogging on the bottom plate.

It was found that these temperatures could be achieved by feeding the top heating coil with a current of 70mA and the bottom coil with a current of 150mA when both are supplied by 6V d.c. sources.

It is therefore assumed that with the heating coils working, no misting will take place on the cover glasses and fogging on the bottom glass is minimized.

4.1.3 Chamber Leakage Test

To carry out the leakage test, the taps as well as the 'O' rings were properly greased with Apiezin grease and the condensation chamber properly assembled. Then with the overpressure tap closed

air was pumped into the chamber to a pressure of 200mmHg as recommended by Metrieks and Pollak (1971). The inlet tap was then closed and counter left for some time. After one hour no noticeable drop in pressure was observed. This shows that no appreciable drop in pressure will occur when using the counter.

A drop of about 1mmHg per minute would have been intolerable as reported by Metrieks and Pollak (1971) since more than one minute is spent when taking measurement with the counter.

4.1.4 Photocell Reception

To check the photocell reception, the cell was mounted on its housing in the wooden base and connected to the microammeter. The cell diaphragm was then put in place and the wooden base coupled to the condensation chamber.

The illuminator was then screwed onto the chamber and the microammeter set to the 0-10uA range. When the illuminator supply was switched on, an almost full deflection of the microammeter was noticed. When left for about 15 minutes and with zero setting it was possible to adjust the pointer to the full scale reading. Thus normal reception of the photocell and the ease of taking readings are assured.

4.1.5 Air Filter efficiency

To test for the efficiency of the air filter, it was connected, through rubber tubings, to the inlet valve of the chamber and the foot pump.

The ceramic lining was then properly soaked and the counter properly assembled as described in section 3.2. With the two valves on the chamber opened, filtered air was then pumped in through the inlet valve until the chamber is completely flushed. This is to ensure that the air in the chamber is entirely, that from the air filter, which is to be tested for being particle free.

The over pressure valve was then closed the chamber pumped to an over-pressure of 160mmHg, still with the particle free air from the air filter. With the illuminator and the heating coils switched on, the inlet valve was turned off and the micro-ammeter pointer set to full scale. After one minute, the over pressure valve was opened to release the pressure and the microammeter reading still showed a full scale deflection.

This means that no appreciable condensation process took place during the test, as the microammeter reading would have fallen had there been any appreciable condensation. The air pumped into the chamber from the air filter can thus be said to be trully particle free and it can therefore be concluded that the air filter works effectively.

4.2.0 TEST MEASUREMENTS

After the positive tests and checks of the different components of the counter, some test measurements were carried out with the instrument in March, 1988.

The procedure for taking measurements with the counter is the same as that described in the last section, the difference being that the chamber is now flushed with the sample air instead of the particle free air from the air filter. This is done by pumping the sample air, in this case the Harmattan air, directly into the chamber instead of pumping through the air filter. However, the over-pressure of 160mmHg still has to be attained by pumping in the particle-free-air from the filter. When this pressure is attained, the over-pressure valve value closed and the microammeter reading, Io adjusted to 10 uA. After the waiting period of one minute, the pressure is released and the final microammeter reading, I noted. The illuminator and the heating coil supplies are always switched off after every measurement to be switched on again 15 minutes before the next.

The over-pressure of 160mmHg was chosen so that when the pressure is released to atmospheric an expansion ratio of approximately 1.21 is achieved. Of the three types of particles activated due to this expansion ratio, the large and giant

particles fall out during the waiting period of one minute leaving only Aitken particles as explained in section 2.1. Hence the resulting extinction of the light beam is due only to the water droplets formed by these particles.

Measurements were made hourly from 7.00a.m. to 7.00p.m., local time, daily for two weeks in March 1988. On each day the chamber is always first dismantled, so that the sealing glasses could be cleaned and all valves and 'O' rings greased. However, soaking of the ceramic pipe was only done once every four days as a single soak is enough for about fifty measurements.

4.2.1. Readings

The initial meter readings, Io are always set to 10 u_A and the extinction, E obtained from the final readings, I of the microammeter using equation 2.6. Tables 4.1 and 4.2 show the readings as obtained for a typical clear day and a typical dusty day in March, 1988 respectively.

4.3.0 CALIBRATION

Using a calibration table prepared by Metnieks and Pollak (1959), a calibration curve was prepared for the ZCNC. The table of Metnieks and Pollak (1959) has values of extinction ranging from 0% to 93.9%, corresponding to concentrations of 0.000 to 440.038x 10^9 particles per m^3 of sample air. Due to this wide

range of particle concentration, a semi-logarithmic curve, with particle concentration on the vertical axis and the extinction, E on the horizontal axis, had to be used. This is shown in fig. 4.3

4.4.0 RESULTS AND DISCUSSIONS

As shown in Tables 4.1 and 4.2, the extinctions measured during the two weeks of March range from 79% to 92.5%. Using the calibration curve of fig. 4.3, the corresponding concentrations of the Aitken particles are 104,712 and 275.422 x 10^9 particles per metre cube.

This same method was used for the rest of the readings obtained for the two weeks of measurement and the results are as tabulated in Table 4.5. Tables 4.3 and 4.4 are the results as obtained a typical clear day (March, 15) and a typical dusty day.

Table 4.1: Readings of Extinction as measured for a typical clear day in March, 1988, using the ZCNC.

Local Time (hrs)	Microammeter Readings, I(u_A)	Io-I(u_A)	Extinction $E = \frac{Io-I}{I} \times 100\%$
7.00	2.00	8.00	80.0
8.00	1.95	8.05	80.5
9.00	2.00	8.00	80.0
10.00	2.05	7.95	79.5
11.00	2.05	7.95	79.5
12.00	2.05	7.95	79.5
1.00	2.10	7.90	79.0
2.00	2.10	7.90	79.0
3.00	2.10	7.90	79.0
4.00	2.05	7.95	79.5
5.00	2.05	7.95	79.5
6.00	2.05	7.95	79.5
7.00	2.05	7.95	79.5

Table 4.2: Readings of Extinction as measured for a typical dusty day in March 1988 using the ZCNC.

Local Time (hrs)	Microammeter Readings, I (u_A)	Io-I(u_A)	Extinction $E = \frac{Io-I}{I} \times 100\%$
7.00	0.75	9.25	92.5
8.00	0.75	9.25	92.5
9.00	0.80	9.20	92.0
10.00	0.85	9.15	91.5
11.00	0.85	9.15	91.5
12.00	0.85	9.15	91.5
1.00	0.90	9.10	91.0
2.00	0.85	9.15	91.5
3.00	0.90	9.10	91.0
4.00	0.90	9.10	91.0
5.00	0.90	9.10	91.0
6.00	0.85	9.15	91.5
7.00	0.85	9.15	91.5

Table 4.3: Concentrations of Aitken particles for a typical clear day in March 1988 as obtained using the calibration curve of fig. 4.3.

Local Time (hrs)	Extinction, E(%)	logZ	Concentration Zx10^{-9} particles m^{3}
7.00	80.0	11.060	114.815
8.00	80.5	11.075	118.850
9.00	80.0	11.060	114.815
10.00	79.5	11.040	109.648
11.00	79.5	11.040	109.648
12.00	79.5	11.040	109.648
1.00	79.0	11.025	105.925
2.00	79.00	11.025	105.925
3.00	79.0	11.025	105.925
4.00	79.5	11.040	109.648
5.00	79.5	11.040	109.648
6.00	79.5	11.040	109.648
7.00	79.5	11.040	109.648

Table 4.4: Concentrations of Aitken particles for a typical dusty day in March 1988 as obtained using the calibration curve of fig. 4.3

Local Time (hrs)	Extinction, E (%)	LogZ	Concentration, Zx10^{-9} particles/m^{3}
7.00am	92.5	11.445	278.612
8.00am	92.5	11.445	278.612
9.00am	92.0	11.420	263.027
10.00am	91.5	11.395	248.313
11.00am	91.5	11.395	248.313
12.00noon	91.5	11.395	248.313
1.00p.m	91.0	11.380	239.883
2.00p.m	91.5	11.395	248.313
3.00p.m	91.0	11.380	239.883
4.00p.m	91.0	11.380	239.883
5.00p.m	91.0	11.380	239.883
6.00p.m	91.5	11.395	248.313
7.00p.m	91.5	11.395	248.313

TABLE - 4.5

DAILY, HOURLY-CONCENTRATION OF AITKEN PARTICLES AS OBTAINED FROM 2ND TO 15TH MARCH, 1988 USING THE ZCNC

Local Time	2/3/88 E%	2/3/88 Zx10^{-9}/n^2	3/3/88 E%	3/3/88 Zx10^{-9}/n^2	4/3/88 E%	4/3/88 Zx10^{-9}/n^2	5/3/88 E%	5/3/88 Zx10^{-9}	6/3/88 E%	6/3/88 Zx10^{-9}	7/3/88 E%	7/3/88 Zx10^{-9}/n^2
7.00am	92.5	278.612	92.5	278.612	92.0	263.027	92.0	263.027	90.0	221.165	89.0	205.966
8.00am	92.5	278.612	92.0	263.027	92.0	263.027	92.0	263.027	90.5	229.253	88.0	194.091
9.00	92.0	263.027	92.0	263.027	91.5	248.313	91.5	248.313	90.0	221.165	87.5	188.337
10.00am	91.5	248.313	91.5	248.313	91.5	248.313	91.5	248.313	89.5	213.565	87.0	182.583
11.00am	91.5	248.313	91.5	248.313	91.5	248.313	91.5	248.313	89.5	213.565	87.0	182.583
12.00nc	91.5	248.313	91.5	248.313	91.0	239.883	91.5	248.313	89.0	225.966	87.0	182.583
1.00p.m	91.0	239.883	91.0	239.883	91.0	239.883	91.0	239.883	89.0	225.966	87.5	188.337
2.00p.m	91.5	248.313	91.0	239.883	91.0	239.883	91.0	239.883	89.0	225.966	87.0	182.583
3.00p.m	91.0	239.883	91.0	239.883	90.5	229.253	91.0	239.883	89.0	225.966	87.0	182.583
4.00p.m	91.0	239.883	91.0	239.883	91.0	239.883	91.5	248.313	89.5	213.565	87.0	182.583
5.00p.m	91.0	239.883	91.5	248.313	91.0	239.883	91.5	248.313	89.5	213.565	87.5	188.337
6.00p.m	91.5	248.313	91.5	248.313	91.5	248.313	91.5	248.313	89.0	225.966	87.5	188.337
7.00p.m	91.5	248.313	91.5	248.313	91.5	248.313	91.5	248.313	89.5	213.565	87.5	188.337

Table 4.5 (Cont'd)

Local Time	8/3/88 E%	8/3/88 Zx10^{-9}	9/3/88 E%	9/3/88 Zx10^{-9}	10/3/88 E%	10/3/88 Zx10^{-9}/m^3	11/3/88 E%	11/3/88 Zx10^{-9}/m^3	12/3/88 E%	12/3/88 Zx10^{-9}	13/3/88 E%	13/3/88 Zx10^{-9}
7.00am	86.5	177.140	87.0	182.583	85.5	166.460	84.0	151.292	84.0	151.292	82.5	137.655
8.00am	86.5	177.140	87.0	182.583	85.0	161.222	83.5	146.734	83.0	142.175	82.0	133.136
9.00am	86.0	171.698	86.5	177.140	85.0	161.222	83.5	146.734	83.0	142.175	81.5	128.772
10.00am	86.0	171.698	86.5	177.140	84.5	156.257	83.5	146.734	83.5	146.734	81.5	128.772
11.00am	86.5	177.140	86.0	171.698	84.5	156.257	83.0	142.175	83.0	142.175	81.0	124.407
12noon	86.0	171.698	86.0	171.698	84.0	151.292	83.5	146.734	82.5	137.655	81.5	128.772
1.00pm	85.5	166.460	86.0	171.698	84.0	151.292	83.5	146.734	82.5	137.655	81.5	128.772
2.00pm	85.5	166.640	86.5	177.140	83.5	146.734	83.0	142.175	82.0	133.136	81.0	124.407
3.00pm	85.5	166.640	86.0	171.698	83.5	146.734	83.0	142.175	82.0	133.136	81.0	124.407
4.00pm	86.0	171.698	85.5	166.460	83.5	146.734	82.5	137.655	82.0	133.136	81.5	128.772
5.00pm	86.0	171.698	85.5	166.460	83.0	142.175	82.5	137.655	82.5	137.655	81.5	128.772
6.00pm	86.0	171.698	85.5	166.460	83.5	146.734	83.0	142.175	82.5	137.655	82.0	133.136
7.00pm	86.0	171.698	85.5	166.460	83.5	146.734	83.0	142.175	82.5	137.655	82.0	133.136

Table 4.5 (Cont'd)

Local Time	14/3/88 E%	14/3/88 Zx10^{-9}	15/3/88 E%	15/3/88 Zx10^{-9}
7.00am	81.0	124.407	80.0	115.822
8.00am	81.5	128.772	80.0	115.822
9.00am	81.0	124.407	80.5	120.114
10.00am	81.0	124.407	80.0	115.822
11.00am	80.5	120.114	79.5	111.822
12noon	80.5	120.114	79.5	111.822
1.00pm	80.0	115.822	79.5	111.822
2.00pm	80.0	115.822	79.0	107.822
3.00pm	80.5	120.114	79.0	107.822
4.00pm	80.5	120.114	79.0	107.822
5.00pm	81.0	124.407	79.5	111.822
6.00pm	81.0	124.407	79.5	111.822
7.00pm	81.0	124.407	79.5	111.822

Table 4.6; Daily, 7.00a.m - Concentration of Aitken Particles during the two weeks of Measurement.

Date	Extinction, E %	Concentration, $Zx10^{-9}$ (Particles (m^3)
2/3/88	92.5	278.612
3/3/88	92.5	278.612
4/3/88	92.0	263.027
5/3/88	92.0	263.027
6/3/88	90.0	221.165
7/3/88	89.0	205.966
8/3/88	86.5	177.140
9/3/88	87.0	182.583
10/3/88	85.5	166.460
11/3/88	84.0	151.292
12/3/88	84.0	151.292
13/3/88	82.5	137.655
14/3/88	81.0	124.407
15/3/88	80.0	115.822

A number of interesting observations can be made on the results obtained, Table 4.3 shows how the particle concentration varies with time of day. To investigate the variations of particle concentration during the two weeks of measurement, the concentrations at 7.00am which are mostly the highest daily concentrations, were chosen. This is shown in table 4.6,

4.4.1 Variation of particle concentration with time of day. Fig. 4.4 is a plot of the particle concentration with time for 2nd March which is a typical dusty day of the month. From this graph it can be observed that the readings in the morning are generally the highest. While the lowest readings are usually between 3p.m and 4p.m.

This suggests a lowering of the particle concentration as the solar insolation increases. However, thorough investigation of the relationship between the insolation and particle concentration needs to be carried out before any conclusive statement can be made on this.

4.4.2 Variation of daily particle concentrations during the two weeks of March.

From the results of Table 4.5 it can be observed that the highest concentration of Aitken particles as measured by the instrument was 278.612 x 10^9 particles per metre cube while the lowest was 107.822 x 10^9 particles per metre cube. The highest value was recorded on the first and second days of measurement (2nd and 3rd March) while the lowest was recorded on the last day, 15th day of March. This suggests a gradual reduction of the particle concentration as the day increases. For a clearer observation, the particle concentrations at 7.00 am during the period of measurement were compared (Table 4.6). This is as plotted in fig. 4.5. The plot shows a gradual

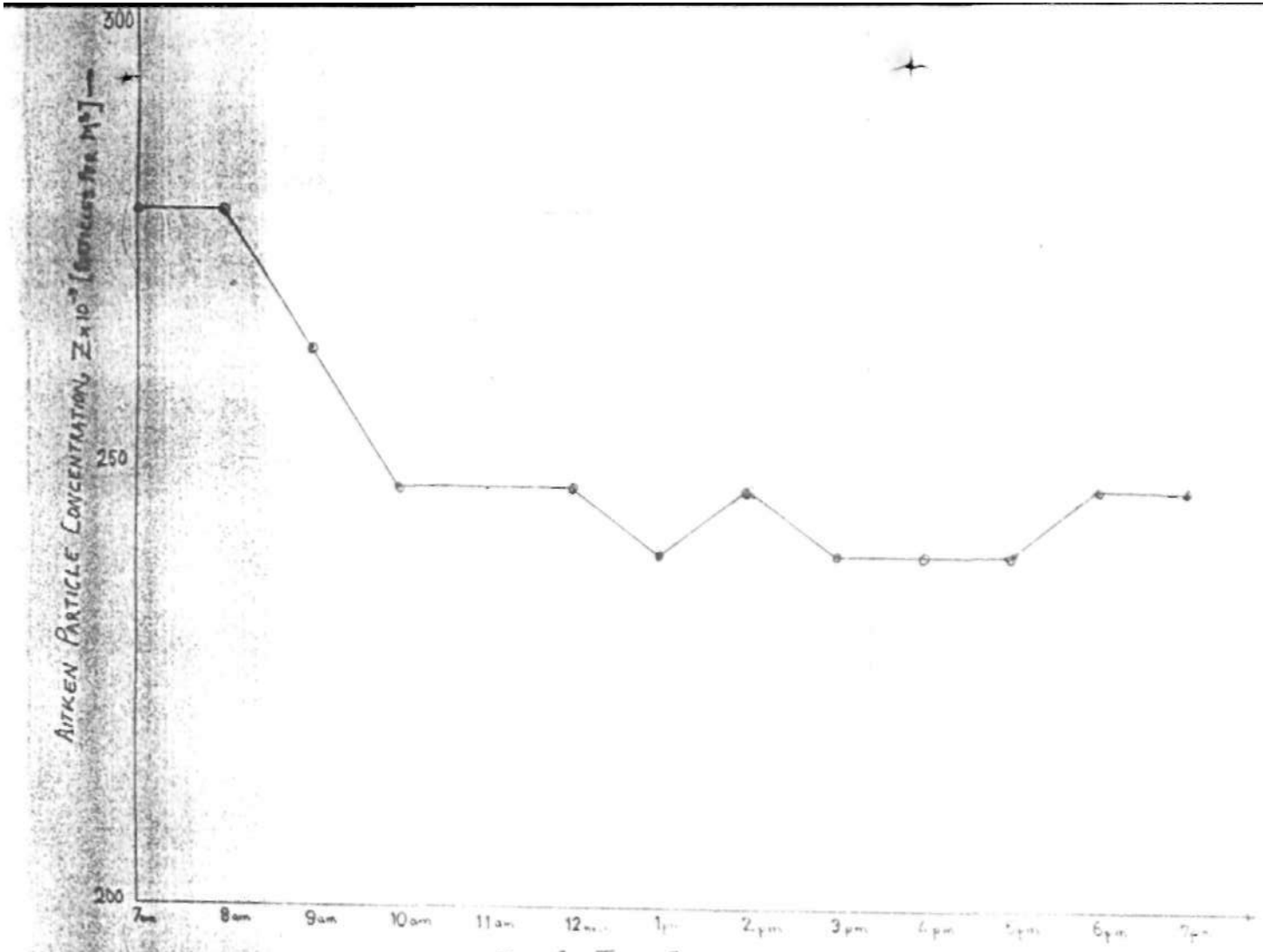


Fig 4.4: Variation Of Aitken Particle Concention With Time Of The Day

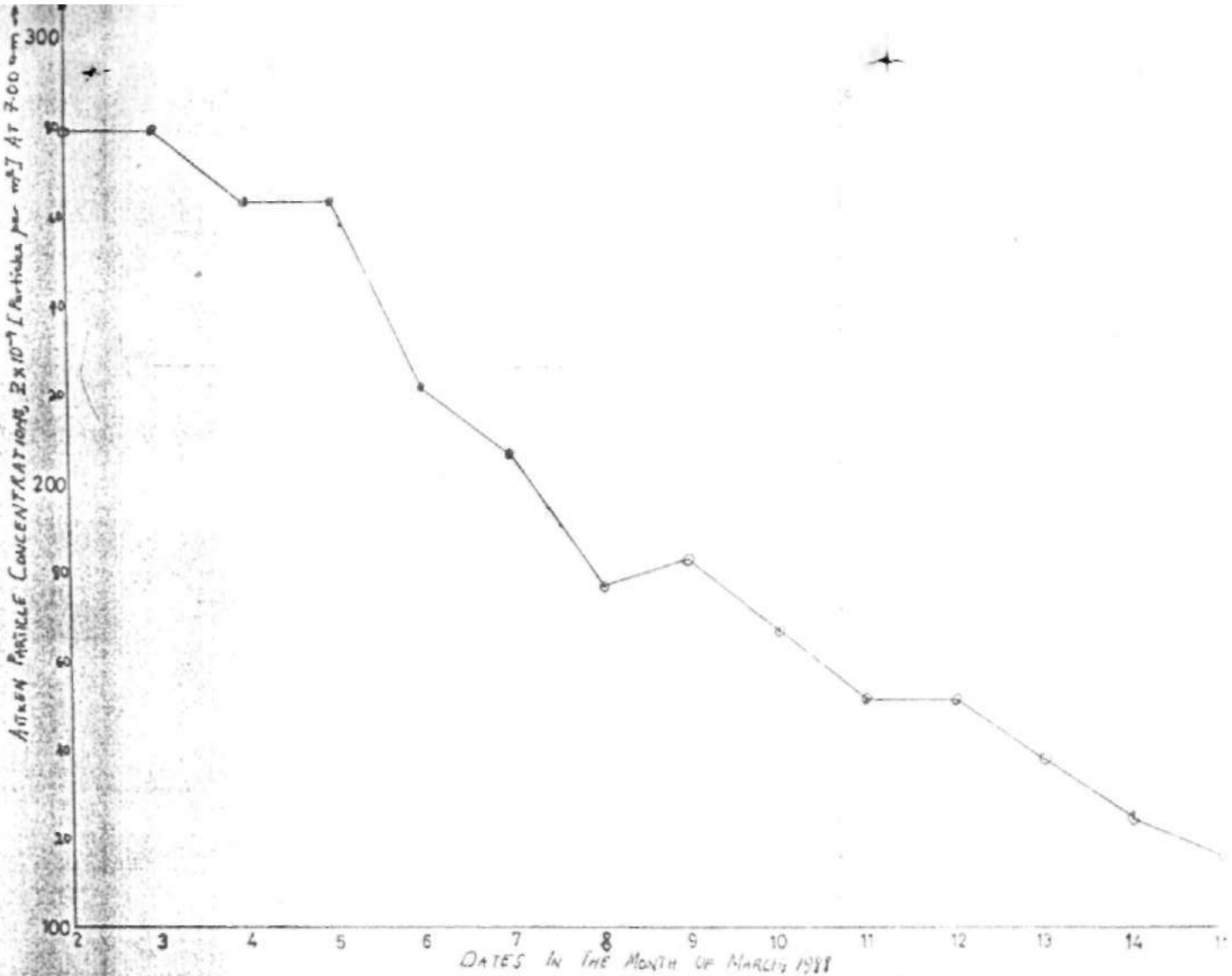


Fig 4.5: GRAPH OF VARIATION OF AITKEN PARTICLE CONCENTRATION AT 7.00 A.M. IN MARCH

decrease in the particle concentrations towards the middle of March. This is understandable since the Harmattan haze is usually more noticeable at the beginning of March than at the end.

CHAPTER FIVE

5.0. COMMENTS, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

5.1.0 COMMENTS

As discussed in the last chapter, the locally fabricated counts, the Zaria condendation Nucleus counter worked satisfactorily without any apparent difficulty or problem when subjected to the performance tests of section 4.1. It therefore satisfies all the recommendations of Metnieks and Pollak (1971) as listed in section 3.1. The counter can therefore be said to be of high accuracy and dependability.

In addition, the test measurements made with the counter as reported in section 4.2 gave reasonable results of the concentration of Aitken particles in the Harmattan haze during the two weeks of March for which the measurements were made. This further confirms the reliability of the counter.

However, there was no previous data with which the results could be compared. This together with other limitations militated against a thorough accessment and wider use of the counter.

5.1.1 Limitations

i) Lack of an Absolute counter:- Since there is no previous data on the local concentration of Aitken particles in the Harmattan haze, an absolute counter would have been handy in ascertaining the reliability of

the results obtained with the counter hence the efficiency of the counter could not be determined due lack of an absolute counter.

ii) Insufficient Measurements:- Due to the cumbersome nature of the procedure of taking measurements with the counter, only hourly measurements can conveniently be carried out with one single unit. However, more frequest measurements, say quarter - hourly are required for a more thorough investigation of the variation of particle concentration with time of day.

iii) Qualitative analysis:- For a better understanding of the nature of the Aitken particles in the air, both quantitative and qualitative analysis of the particles are required. However, the counter as constructed can only be used to determine the concentration of the particles in air but unsuitable for use in determining the composition of the particles.

5.2.0 CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

In the work reported, it is clear that a condensation nucleus counter, such as the one described can be used to measure the concentration of Aitken particles in the Harmattan haze. The locally constructed equipment, the Zaria condensation Nucleus counter proved completely adequate for the task, at only a small fraction of the cost

of a commercial equipment. When used simultaneously with a four stage cascade impactor, the particle size distribution of the Harmattan haze at any time can be determined over a broader size spectrum than hitherto reported.

Already, the ZCNC system has been operated for several hours with no apparent difficulty or problems. Test measurements with the counter indicate that the concentration of Aitken particles in the Harmattan haze can be as high as $3 \times 10^{"}$ particles per cubic meter.

To broaden the use of the counter and to make it less cumbersome to operate, the following improvements aimed at eliminating the difficulties associated with the limitations of the counter are suggested.

i) Acquisition of an absolute counter

For the purpose of determing the efficiency of the counter under various concentrations, an absolute condensation nucleus counter should be acquired. This can be operated simultaneously with the counter for different concentrations and the results compared. From the results, the efficiency of the counter can be found and always quoted to show the reliability of the counter.

ii) Fabrication of more counters including automatic counters

To eliminate the problem of infrequent measurement automatic counters have to be fabricated. In addition, more counters need to be fabricated so that measurements can be made simultaneously at different locations and altitudes. Thus more comprehensive data on the concentrations of the particles in the air at any particular time can be obtained.

iii) Possibility of nuclear technique in qualitative analysis

The problem of the qualitative analysis of the Aitken particles may be solved by nuclear techniques using Neutron Activation Analysis (NAA) on X-ray fluorescence analysis (XRF). However, to use these methods, the particles should be collected.

As observed in section 1.3, none of the established collection techniques is suitable for the Aitken particles. However, there is a possibility of collecting the particles using a modified form of the condensation nucleus counter. Since only the droplets of water formed by the Aitken particles are left after the 'one minute' waiting period during the operation of the counter, the particles can be collected by filling a small container, say the 'rabbit' of

a neutron generator, with these droplets. This may be done just at the end of the expansion process. The rabbit can then be sent into the neutron generator for irradiation. On the return of the rabbit, the parten and level of activity can be analysed for the composition of the particles.

Hence by modifying the counter it can be used for the collection of the Aitken particles for subsequent analysis using neutron activation technique.

With the aforementioned improvements on the counter it can be used effectively for the following purposes.

1. Harmattan haze study

The counter can be used for the determination of the concentration of the Aitken particles in the Harmattan dust. To do this, hourly or quarter-hourly measurements have to be made daily for at least one year. From the resulting data, a comparison of the number concentrations of the particles during the Harmattan season (November-March) may be made with the other seasons.

Hence when the counter is used together with a four stage cascade impactor, a broad spectrum ofthe Harmattan haze can be obtained.

2. Meteorological Studies

In addition to its possible use in Harmattan studies, the counter can be used in local and national meterological studies in general. A number of the counters can be used for observations at different places and different altitudes for extensive measurements of condensation nuclei concentrations. The data so collected can be of emmence use in weather study and in weather forecasting.

3. Industrial Uses

The counter can be used to detect the presence as well as determine the concentration of Aitken particles which are the most numerous of any aerosol sample. Therefore when connected to suitable devices, the counter can be used to control the level of dust in an enclosure. This could be very useful in the electronic industries where the dust level has to be reduced to the barest minimum.

The counter can also be used in industrial test laboratories to investigate some properties of metals. For this purpose, the material under test is used as arcing electrodes to produce nuclei. The concentration and size of the nuclei produced, which can be measured with the counter, depends on the quality of the metal electrode.

4. Medical Uses

The counter can also be used in medical studies. Some diseases are associated with the presence of some aerosol particles in the air. Since some of these particles will be in the form of Aitken particles, the counter can be used in the study of these diseases.

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Chartwell Graph Data Ref. 5241 Log 4 Cycles x mm, ½ and 1 cm

AITKEN PARTICLE CONCENTRATION, $N \times 10^{-6}$ [PARTICLES PER m^3] →

100 200 300 1000 10000 100000

EXTENSION, E (%) →

10 20 30 40 50 60 70 80 90 100

H5