THE ESTABLISHMENT OF AN ENVIRONMENTAL SCIENCE LABORATORY IN NIGERIA

Ahmadu Bello University

Case Study

A report presented to the

Bartlett School of Architecture,

University College London,

London University as part

submission of an M.Sc. in Architecture

(Environmental Design & Engineering)

by

Olajide Solanke

September 1979

CONTENTS

		Page
	Acknowledgements	2
	Abbreviations	3
	Introduction	4
1.	Historical Background	5
2.	Justifications	7
3.	Location	12
4.	Requirements and Equipment Layout	19
	4.1. Artificial Sky	20
	4.2. Heliodon and Artificial Sun	24
	4.3. Wind Tunnel	24
	4.4. Other Equipment	26
	4.5. Space	29
	4.6. Staff	32
5.	Expansion - Growth and Changes	33
	5.1. Research	36
	5.2. Teaching	36
	5.3. Equipment	38
6.	Services	39
	6.1. Electrical Services	39
	6.2. Lighting	45
	6.3. Acoustics	62
	6.4. Air-Conditioning and Ventilation	73
7.	Cost Analysis	77
	7.1. Building Costs	78
	7.2. Equipment Costs	82
	7.3. Staff Costs	84
	7.4. Architects' Productivity	84
8.	Conclusion	85
	Bibliography	87

ACKNOWLEDGEMENTS

I would like to thank Mr. E. Rowlands for his invaluable guidance in the production of this report.

Thanks to Professor E.A. Adeyemi, Mr. J. Longmore and Mrs. Lucas (NUC Information Secretary London) for the relevant material made available to me during the data collection period.

Finally, I must thank 'Inter-University Council for Higher Education Overseas' (IUC London) who provided the financial support to allow me to undertake the M.Sc. course offered by London University.

ABBREVIATIONS

ABU - Ahmadu Bello University

NEPA - Nigerian Electricity and Power Authorities

NPL - National Physical Laboratory

BSI - British Standard Institution

BRE - British Research Establishment

CSA - Canadian Standard Association

ISI - India Standard Association

DIN - Deutsch Industrie Normung

AFNOR - Association Francaise de Normalisation

ASTM - America Society for Testing Materials

ISO - International Standard Organisation

SRI - Sound Reduction Index

AEC - Annual Equivalent Cost

INTRODUCTION

This report is concerned with the need to set up environmental science laboratories in Nigeria. The establishment of these laboratories is hoped to be a new approach to architectural education and the basis for research work into local environmental conditions. Justifications for the establishment of such laboratories and factors that normally influence their planning decisions are discussed as general principles.

In later parts of the report, specific problems pertaining to the environmental science laboratory of Ahmadu Bello University (ABU) are solved. Perhaps it is pertinent to mention that the ABU laboratory building is under construction. Hence the knowledge gained through the use of a similar laboratory in Bartlett School of Architecture London was employed to solve the specific problems mentioned above. This approach is a demonstration of what Environmental Science Laboratory's set out to achieve.

The final part of this report deals, in detail, with the cost analysis. The attempt here is purely exploratory as economic principles and methods abound for this purpose.

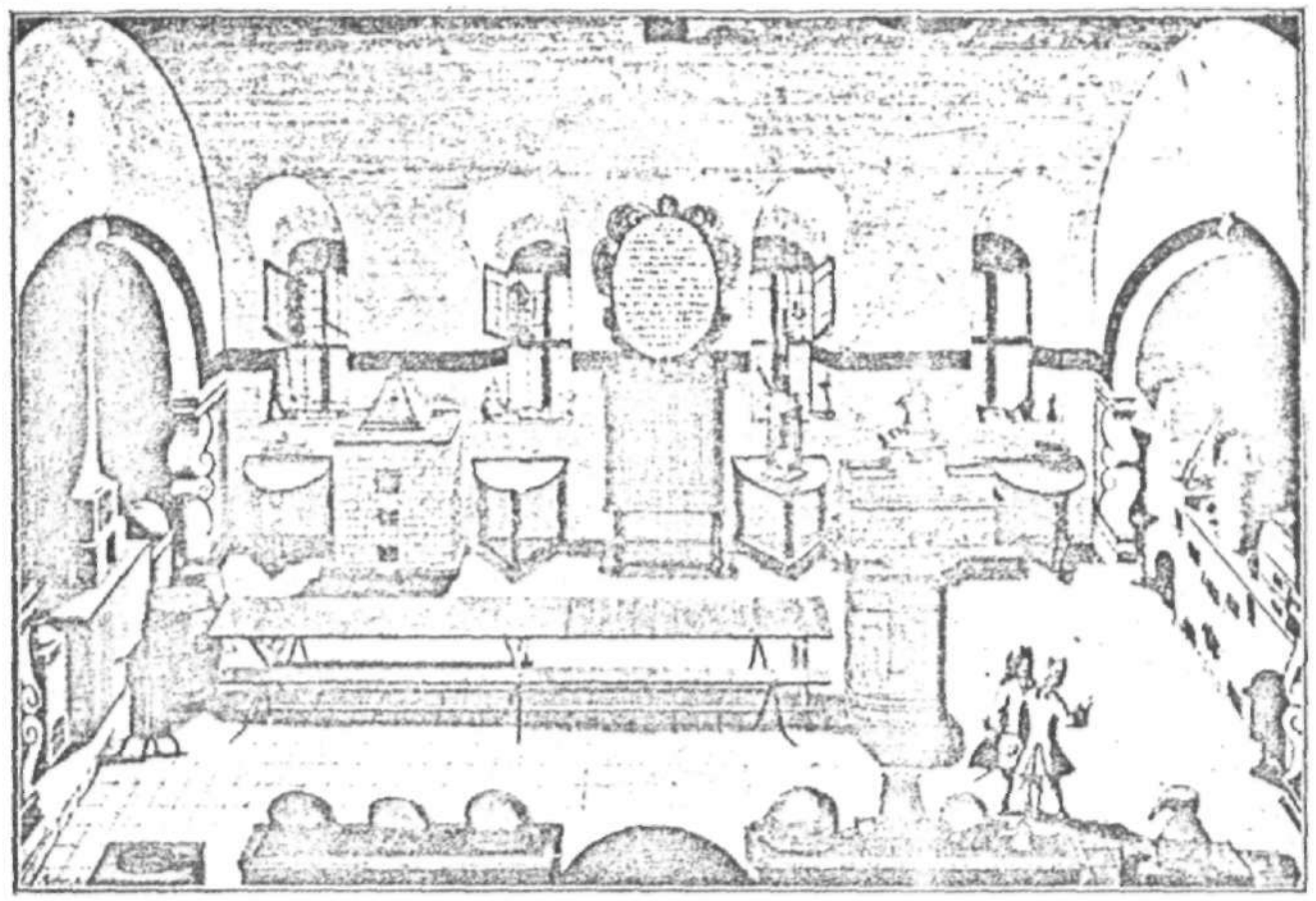
1. HISTORICAL BACKGROUND

If a laboratory can be defined as a place - both building and equipment - used for scientific experiments, then some early organised workshops found around the Mediterranean Sea - A.D. 300 - can only be described as semi-laboratories. In fact laboratories were not formally set up until the publication of Andreas Libavius' project - Alchymia - in the 17th Century, and eventual developments include the early record of laboratory planning in Europe. The tide immediately moved to the Universities and institutions of higher learning. Consequently, in 1682, the earliest laboratory was set up at the University of Altdorf in Germany (fig. 1). In 1799, the British Royal Institution was founded and this marked a mile-stone in laboratory design. The desire to carry out research and to have demonstrative teaching, led to the revolution of laboratory establishment, and a variety of them were set up. But environmental science laboratories were to wait until after the Second World War.

In Nigeria, the first formal establishment of a laboratory was at the beginning of this century, located at Yaba College of Technology in Lagos. The establishment of laboratories was stepped up as the Nigerian College of Arts, Science and Technology was established at Ibadan in 1952. But an Environmental Science laboratory is still to be built after thirty years of existence of Nigeria's first Department of Architecture.

First among Nigerian Schools of Architecture to perceive the need for a new approach to the training of Nigerain architects is the School of Environmental Studies at the University of Lagos. This school set the ball rolling by creating a two-tier degree; the first being B.Sc. environmental Science and the second B.Arch. But it would not be an oversimplification to say that although Lagos University is moving in

FIG. 1



Chemical laboratory at Altdorf University, Germany, 1682.

the right direction, it has not the facilities for the teaching of environmental science and these facilities will not be available until a new building for the School has been constructed. With the arrival of a new Head of Department of Architecture in 1974 at Ahmadu Bello University attitudes to the teaching of environmental science changed. ABU became the second school to perceive the importance of this subject. Hence there is a firm commitment to the training of staff in the field of environmental science and above all to the establishment of an environmental science laboratory.

2. NEED AND JUSTIFICATION

Over much of the world surface, the natural environment does not provide, except for a very short period, satisfactory conditions for human comfort. For comfort and efficiency, the human body requires to be maintained within a limited range of environmental conditions. The apparent human environmental requirements are for light, air and warmth. In addition, sound must be considered since it is indispensable from most activities. But the control of these environmental elements will be difficult if their physical properties, nature and behaviour are unknown.

Professional approaches to the control of environmental conditions in the developing countries vary with the type and complexity of the building under design. Lighting is not often approached in a comprehensive way. The quantity of light is treated as important while the quality aspect is not often mentioned. The lighting engineer in Nigeria is generally the electrical engineer. He bases his design purely on artificial lighting considerations and it is only the quantity of light for tasks and usual performance that concerns him. Daylight is often taken for granted and consequently the electrical engineer applies the lumen method of design

all the time. His design is never threatened by any performance test because of the constant guarantee of high levels of natural light and because human adaptation to varying levels of lighting illumination intensities, particularly to low intensity lighting when there is a 'power cut' at night. It is often discovered that some architects consider the problem of building services as the exclusive job of services consultants and that architects are only to co-ordinate and to make sure that the project is well finished. But it is equally desirable that on minor works, an architect should be able to cope with surveys, estimates structural calculations, services and settlement of accounts.

The rate at which industries are established in Nigeria is high and the attendant consumption of electrical energy is having its effects on the supply of energy for the lighting of buildings. There is, therefore, need to harness all sources of energy - natural and artificial - and make a rational use of them. And the agents of development must be trained to appreciate the need to conserve energy.

There has been a steep rise in the economic growth of Nigeria due to crude oil production and stable government after the civil war. This growth manifests itself in all branches of the national economy but the construction industry appears to carry the lion's share. Consequently, more architects, builders, planners and surveyors with a wealth of experience are in demand. The rate of development and local man-power to cope cannot be divorced from one another. Hence the training methods of the local man-power has to be revolutionized and kept in pace with the development.

It is now conventional that an architect should be able to design appropriate partitions that will reduce background noise levels to a desirable point where speech communication, sleep etcetera are possible. His lighting design should be able to stand the test of performance in quantitative and

qualitative terms. Above all, thermal comfort, which is another yard-stick for measuring the success of a building, should receive adequate consideration. It is necessary to know that unguided penetration of solar radiation into an interior can mar a well-designed building. He - the architect - should know when it is desirable to apply simple sun-shading devices and when air-conditioning must be decided upon. Well, it is rarely possible within the constraints of practical design and finance to achieve the ideal solutions to all environmental problems. Some solutions, indeed, may be mutually opposed; improvement of one resulting inevitably in the deterioration of the other. In spite of dilemmas, a designer must be able to advocate and take part in obtaining optimum overall solutions.

It is pertinent to examine what the postition of the laboratory for the environmental science course will be. There are many ways in which this laboratory can be employed to strengthen the background of the national man-power and standard establishment. But in the case of ABU, it will be expected to play three major roles :

a) It will be used to augment lectures in the form of demonstrative teaching to confirm certain theoretical principles and assumptions,

b) students, probably in groups, will be expected to physically test the performance of buildings, in model form using their designs which are based on theoretical principles and assumptions. This will normally follow the demonstrative teaching.

c) A designer needs design parameters and standards. International standards cannot be employed de-facto without the national reference levels. Hence the laboratory will be the national environmental standard establishment nucleus that looks into local conditions.

The Department of Architecture at ABU Zaria Nigeria has a well developed curriculum for the teaching of building services. It is referred

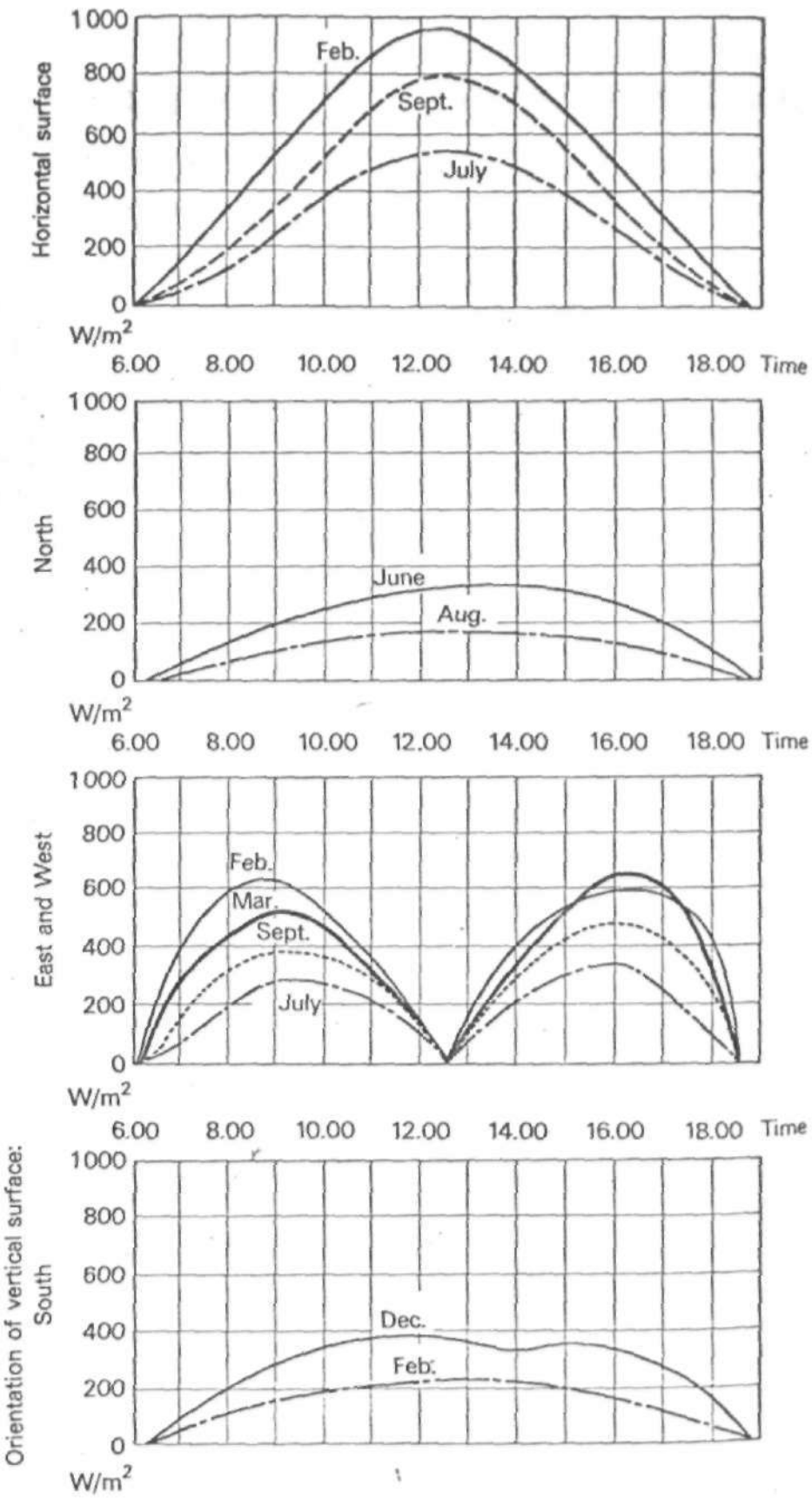
to as 'Environmental Control Systems' in the prospectus of the Faculty of Environmental Design. Lack of qualified staff and facilities make the teaching of the subject difficult. And since it is appreciated that the knowledge of this subject is essential in the training of architects, the Department of Architecture has to depend on other academic Departments. But it is always difficult to obtain exactly what is desirable under this type of arrangement.

Most of the teaching of environmental science is done by referring to foreign publications and researches carried out beyond the boundaries of Nigeria. Consequently, Nigerian students of Architecture digest all they can read in books of environmental science which sometimes may be obsolete and sometimes can contain contradictory facts about the national environment. And when the facts are correct, they are in generalised form, whereas micro-climatic conditions may either contradict or reduce the validity of such facts (fig. 2). The mood now is a justified desire for demonstrative teaching. Theories about environmental factors can, therefore, be confirmed by simple demonstrations on relevant equipment.

There have been investigations into nearly all environmental factors and advanced technology has been introduced to control hostile environmental elements such as sound, heat, light, wind and rain. The harmattan wind known as the North-East trade wind, blows strongly across the northern part of Nigeria. This wind always carries along sand and dust. In fact, there have been cases when strong winds blew off roofs and the dust deposit is a social menace. There is need to look into all aspects of wind and in particular the quality of air we breathe. The quantity and quality of light we receive from the sun should receive no less attention. As a comfortable interior environment hinges primarily on the proper control of the visual, thermal and aural environmental stimuli, it is important to understand

FIG. 2

Solar radiation intensities for latitude 1° South (Nairobi) – measured values



the three types of stimuli and the technique used to control them in interiors. Since many of the solutions to individual environmental problems conflict in performance with each other and since different environments demand different standards, research into all these environmental elements in order to establish standards should be a continuous process. Developed countries have various standards establishment organs. United Kingdom basic standards are those possessed or laid down by national laboratories or institutes such as NPL, BSI, BRE, etcetera. In other parts of the world, standards establishment is the responsibility of AFNO, ASTM, DIN, CSA, ISI, CAA, ISO, etcetera. It is therefore desirable for Nigeria to have some quality laboratories in some institutions where establishment of environmental standards will be one of the objectives of setting up such laboratories.

3. LOCATION

It is rational to view the location of environmental science laboratories from many standpoints which hinge basically on national objectives. Hence laboratories of this nature should not necessarily be limited to one site and criteria must be set up to determine the best national locations suitable for the establishment of these laboratories. With reference to Table 1, four Universities at Zaria, Ife, Lagos and Nsuka possess the criteria for the establishment of environmental science laboratories. The fifth Institution at Jos should also set up a similar laboratory to complement the efforts of Ahmadu Bello University in the field of environmental services. Lagos University has the advantage of well established school of environmental studies, the only one in the country that awards the degree 'Bachelor of Environmental Science' - B.Sc.

The location of the five laboratories are as shown in figure 3, and

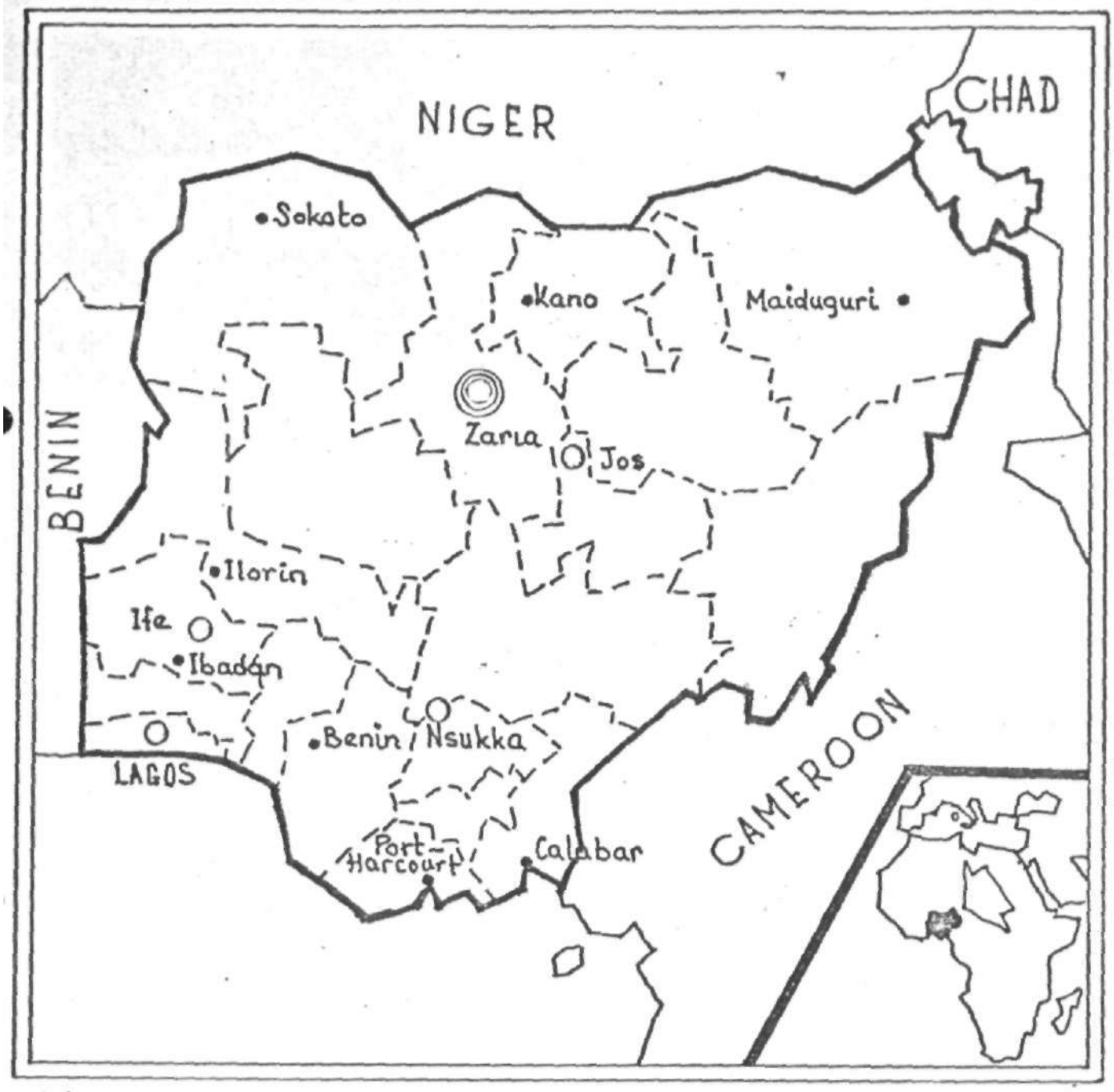


FIG. 3 A Map of Nigeria showing locations of Universities

among them is Ahmadu Bello University which is the proposed site for the first environmental science laboratory in the country.

	NIGERIAN UNIVERSITIES	CRITERIA				
		Geographical	Established School of Architecture	Staff/Facilities Availability	Allied Dept. & Laboratories	CHOICE
1	Ahmadu Bello University - Zaria					
2	Bayero University - Kano					
3	University of Benin					
4	University of Calabar					
5	University of Ibadan					
6	University of Ife					
7	University of Ilorin					
8	University of Jos					
9	University of Lagos					
10	University of Maiduguri					
11	University of Nigeria - Nsuka					
12	University of Port-Harcourt					
13	University of Sokoto					

Table 1. Universities and Criteria

The planning of a university campus has direct influence on the location of any laboratory which is always a part of a Department. There are two planning forms in which Universities are found today all over the world:

a) Some universities developed with the towns in which they are situated and hence the Departments of such universities are scattered all over the town - a consequence of expansion.

b) The other form is that the Universities are built as models of master-plans with all the departments on a single site.

In the first case, it is difficult to talk of proper location of any laboratory. They too develop with their mother-Department. But the location of a laboratory becomes less cumbersome if all the academic

Departments are built on a single site.

Well, ABU is built on a single site and with appropriate planning the Department of Architecture is surrounded by the Departments of Building, Civil Engineering and Fine Arts. Hence the function of the proposed laboratory at ABU will be supplemented by some facilities in the surrounding laboratories, fig. 4.

In considering the functional analysis of all the activities in a Department of Architecture, the place of a laboratory must be properly marked out. Among such activities are those carried out in lecture-theatres, drawing, modelling and photographic studios, staff and administrative offices. For demonstrative teaching, the laboratory must be well-linked with the studios, lecture-theatres and offices of the technician in charge, fig. 5.

The choice between single-storey and multi-storey building is not difficult to make. Functional and site factors are the main criteria that always influence decisions. On functional grounds, single-storey buildings have the merit of lending themselves to easy alteration and extension. Weight and handling equipment can tilt decisions towards single-storey building. On the other hand land availability can make functional considerations a secondary factor. If the site is compact, the laboratory building will have to go up. In environmental laboratories, the weight cannot significantly influence decisions because most of the equipment is light. But other reasons such as expansion may dictate that it should be single-storey or on the ground floor of a multi-storey building. Another approach is for the laboratory to occupy the basement of a building. But this is a rather special approach.

In ABU case studies, this decision has been properly taken when the departmental building was at the design stage. It is on the ground floor of a three-storey building with adequate space for expansion, fig. 6.

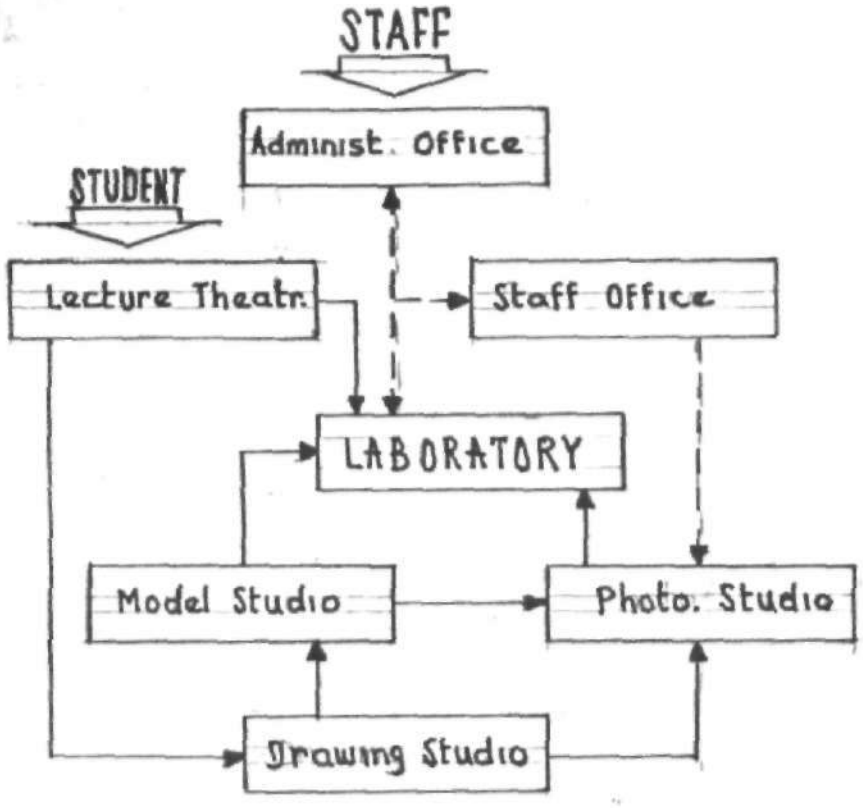


FIG. 5
FUNCTIONAL
DIAGRAM

fig 6

FIG. 6

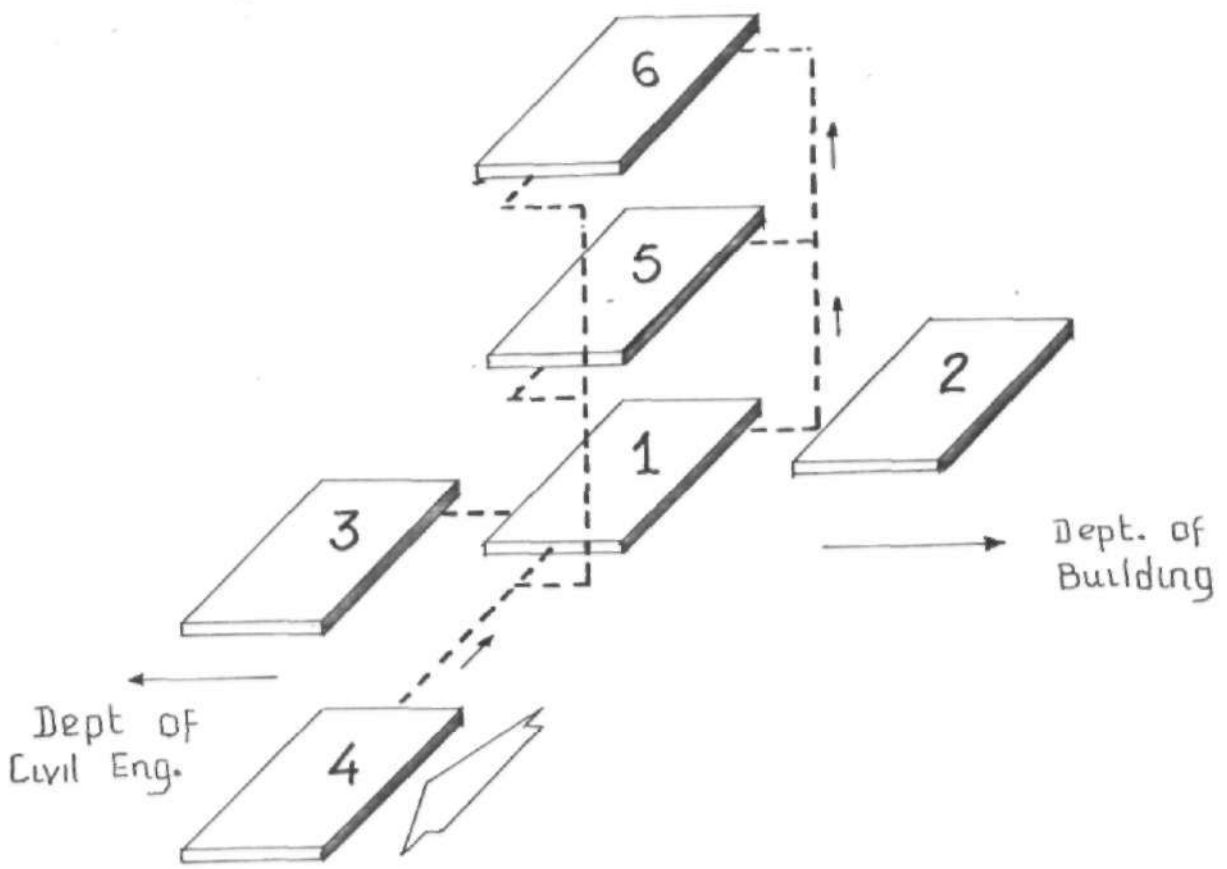


fig 6

1 – Laboratory
2 – Modelling Studio
3 – Photo. Studio
4 – Lecture Theatre
5 – Offices
6 – Drawing Studio

4. REQUIREMENTS AND EQUIPMENT LAYOUT

The Department of Architecture has its requirements in terms of students entry qualifications as well as what the admitted students should learn. The courses are based on the admitted students' background which is reflected in the quotation below from the Ahmadu Bello University 1978/79 Calander :

> 'Candidates will be required to have passed in 5 subjects at G.C.E. with at least 2 subjects at Advanced Level. There is preference for candidates who pass Science subjects (i.e. Mathmematics and Physics etc.) at Advance Level'.

But the establishment of a laboratory will necessitate reappraisal of the relevant section of the departmental curriculum. All subjects on environmental science are grouped together under a single title - Environmental Control System. Curriculum reappraisal will have to take into consideration discontinuity and repetitions apparent in the teaching of the subjects. All the basic principles should be introduced to the students at the beginning of the architectural studies. The course should then advance in complexity as the students progress in years. This approach will equip the students with decision taking parameters right from the early years of studies. Any reappraisal should be carried out locally although it should necessarily include the following subjects to qualify for the term 'Integrated Approach' :

a) Climatology

b) Building Science

c) Water Supply and Sanitation

d) Electrical Installations

e) Natural and Artificial Lighting

f) Acoustics

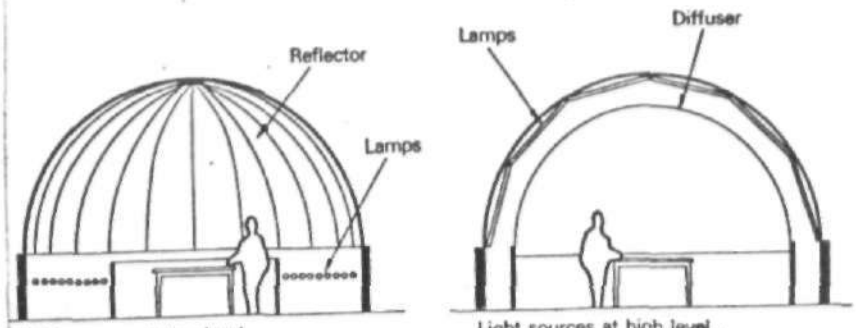
g) Ventilation and Air-conditioning

h) Practice and Standards

Now, the quantity and variety of equipment in any laboratory depends upon the nature of its usage and the function for which it is to be built. Obviously the research laboratory calls for a greater degree of equipment than an instructional or control unit. Whichever is the type of laboratory one has in mind, availability of funds is one of the major factors that can influence decisions on equipment requirements. Therefore these requirements must be tailored to suit the available funds. This is the case in the ABU case study which had initially seventeen items on the plan but when global inflation overtook the project, the equipment requirements had to be cut down to what the available money could buy. It is the initial equipment that is quoted in this exercise.

4.1. ARTIFICIAL SKY: This is built to simulate the luminance pattern which has a close approximation to a standard C.I.E. overcast sky, and this is employed for daylight studies. The artificial sky is a model of space with the ceiling of the model as the sky and its floor as the ground. Building models, in appropriate scale, must therefore be made and placed on the floor of the 'sky' for the necessary studies. There are two basic types of Artificial Sky: the hemispherical and rectangular types, fig.7. The hemispherical one has the advantage of close visual resemblance to the real sky. This makes it a useful tool for teaching and demonstrative purposes. Its shortcomings make it less appropriate for research purposes than the rectangular type. There are two fundamental faults with the hemispherical type of Artificial Sky. The size of the dome determines the scale of the model to be used for studies. And since this hemisphere cannot be too large, the scale of the model is bound to be small and visual observation of the environment-building relationshio will be difficult.

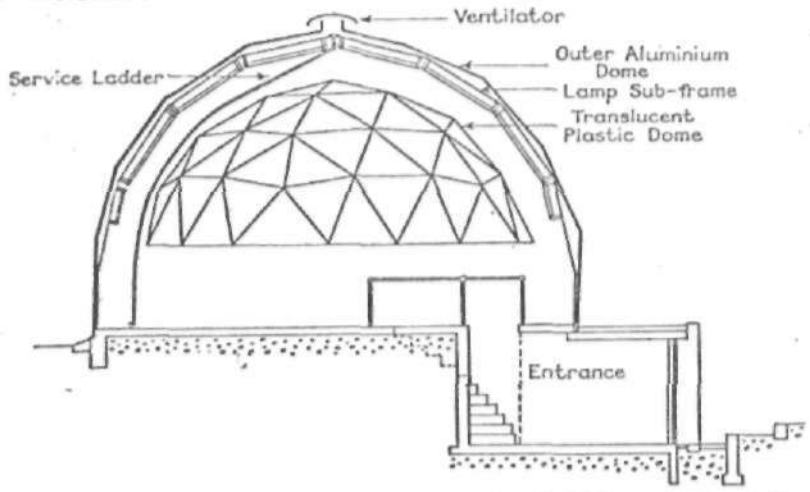
FIG. 7a



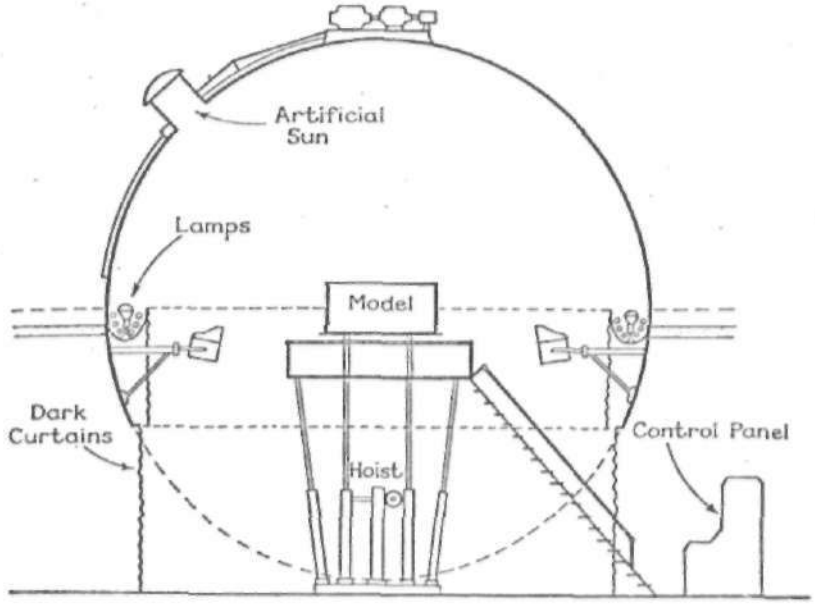
Light sources at low level inside of dome reflective

Light sources at high level, behind diffusing inner dome

Hemispherical artifical skies

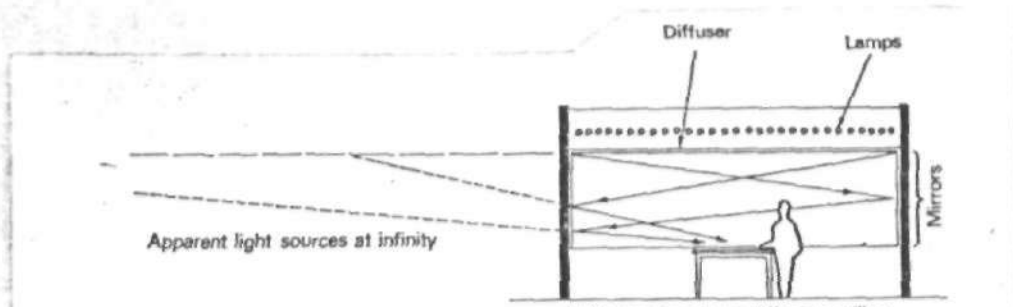


The transilluminated hemispherical artificial sky at the Cambridge School of Architecture.

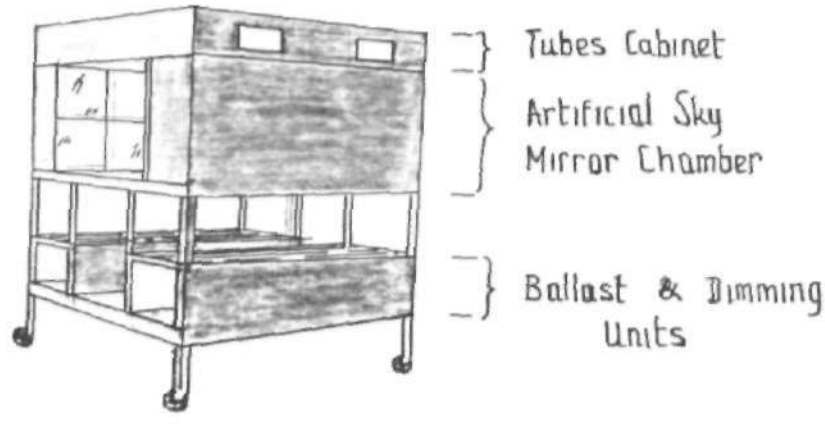


The artificial sky at the Academy of Building and Architecture in Moscow is 9 metres in diameter and incorporates an artificial sun.

FIG. 7b



Rectangular (mirror-type) artificial sky



Mobile Artificial Sky

The other shortcoming is the position of the horizon. When the luminous surface of the artificial sky extends below the window-head of the model room, light will reach the ceiling of the room from the sky. This does not happen in nature and consequently, accuracy will suffer. And when the horizon is at the window-head of the model room, part of the sky will be obstructed and another form of error is introduced. The rectangular sky has all lamps above a diffusing ceiling and three walls are lined with mirrors. This creates an advantage over the hemispherical one: an apparent horizon is developed at infinity and hence it is more precise. The rectangular sky is of two types:

a) The fixed artificial sky and

b) The mobile type of sky.

The choice between these two types depends mainly on availability of funds and space. When the fixed artificial sky is chosen, its position in the laboratory layout must be selected at the early design stage. Hence the details of its structure, services, etcetera, will be easy to work out. The mobile artificial sky is a 'package unit' which can be moved and placed in a space deemed fit for it. It has less problems to confront the designer. This type is the ABU choice.

The mobile artificial sky is approximately 1.7m square by 2 metres tall. It comes complete with a model trolley. The two lower compartments contain the eighteen special ballast units and the Thyristor dimming unit. On top of one is the master switch and potentiometer for controlling the level of light of the eighteen fluorescent reflector tubes housed in the top unit. These tubes are so arranged that the luminance pattern gives a close approximation to a standard C.I.E. overcats sky. Two fans are incorporated in the lamp box. An opal diffuser is mounted below the tubes. The central section has mirrors on three sides and five removeable reflective

panels on the front which gives an infinite horizon inside the sky. Connections to the lamps are by multi-way cables, plugs and sockets so that the various sections may be easily dismantled to enable the sky to be moved from one laboratory to another through a normal doorway.

4.2. HELIODON AND ARTIFICIAL SUN : Both heliodon and artificial sun belong to a group of equipment known as the solarscope. A solarscope is built to simulate the sun-building realtionship and to facilitate shading studies on models. Such studies include :

a) Shadow casting either of buildings on one another or of interior shadowing.

b) Sunlight as an interior illuminant; it may be either direct sunlight or reflected from exterior and interior surfaces.

c) Subjective effects of the play of sunlight in relation to interior light and colour.

A Heliodon is a simple piece of equipment and this is illustrated in fig. 8. The lamp represents the sun, and the mid-day attitude at various months of the year is set by the vertical scale on which the lamp can slide. A model of a building is placed on a turntable which can be rotated round a vertical and horizontal axis. By rotating about the vertical azis, the the building can be sited with respect to its sited direction on the ground. The horizontal axis allows the building to be turned with respect to the time of day. These three adjustments make it possible to study either the shadows or sunlight penetration through the day and the year. The artificial sun is more delicate that the heliodon and it requires more space for its installation and operation. Its accuracy is an advantage over the heliodon.

7.3. WIND TUNNEL : Satisfactory and complete theory about air-flow patterns is not available. The only way this can be obtained is through predictions based on empirical rules derived from measurements in actual buildings or

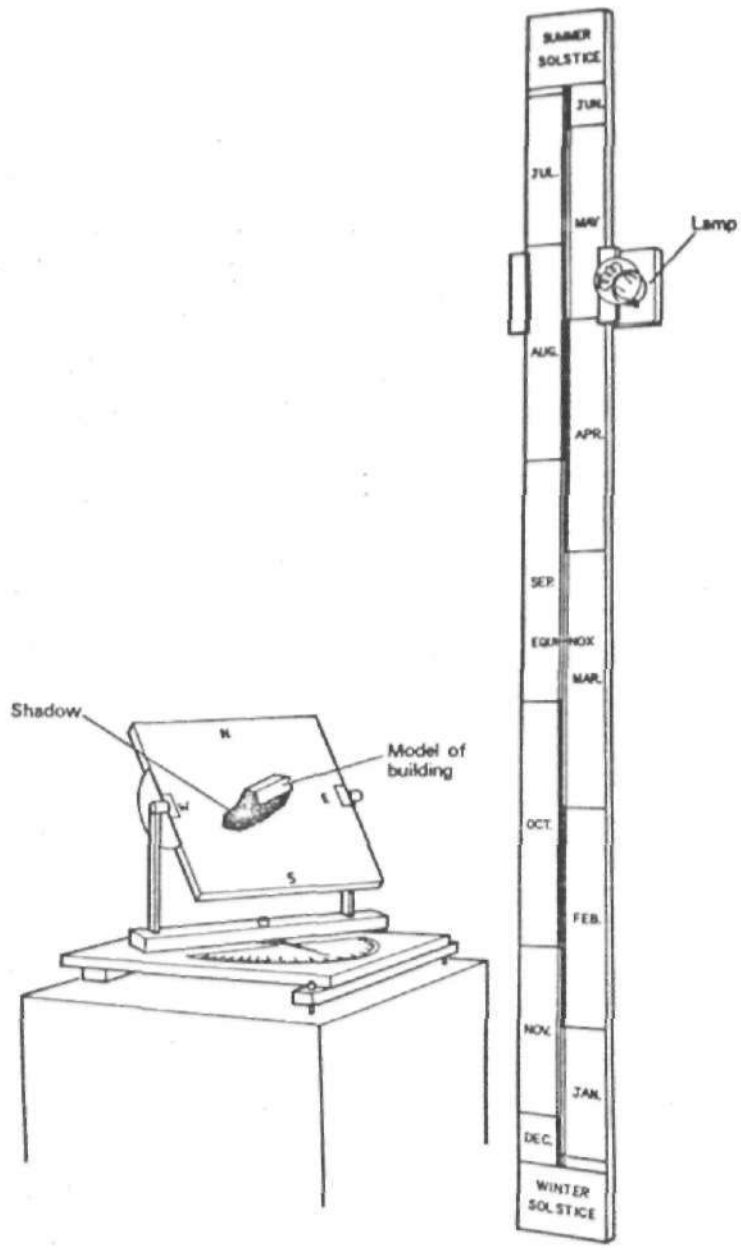


Diagram of Heliodon (based on an illustration supplied by G. Cussons Ltd.)

3 8

FIG. 8

in Wind Tunnel studies. These rules can only be employed as guiding principles but if a disigner is faced with critical situations, models must be built and tested on a wind simulator. There are two types of wind simulators that are employed for the study of wind-building relationships :

a) Open-jet simulator

b) Wind tunnel.

Open jet simulator built at the University of Liverpool is in use with the London Architectural Association School. The other type - wind tunnel - was developed by the Building Research Station (BRS) and it is more accurate than the other type of wind simulator, fig. 9.

For qualitative studies, a smoke generator is used and the smoke is photographed to give a convincing picture of flow patterns, position of laminar flow and turbulences. With experience, it is possible to estimate velocity ratios from smoke traces with some accuracy. On the other hand, if the air velocity analysis is to be quantitative, air pressure measurements must be taken with instruments at predetermined grid points.

The wind tunnel has three sections which are :

a) the fan box

b) the model room

c) the air inlet tube.

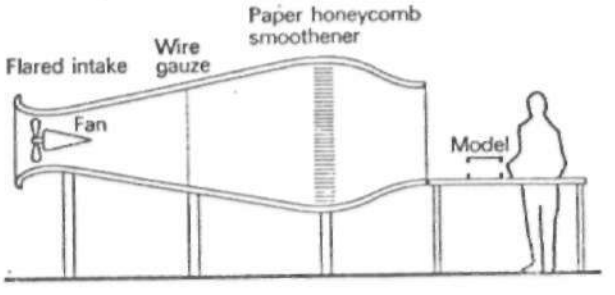
The fan box and the air inlet tube are on either side of the model room. When the fan is switched on, it draws in wind through the 'jar opening' flow control tube across the model room. The lower sides of these three sections are joined together and form a horizontal surface; thus simulating the surface of the earth in the model room. The model to be tested is placed on the horizontal surface in the model room and a study of wind behaviour around a building can begin by setting the fan into motion.

4.4. OTHER EQUIPMENT : The remaining fixed equipment in ABU laboratory consists

FIG. 9

a)

An open-jet wind simulator



b)

wind tunnel

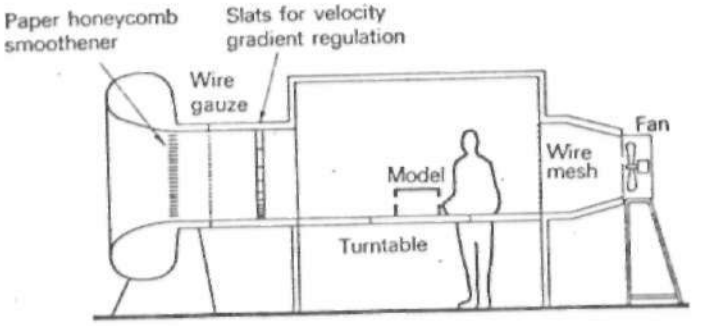
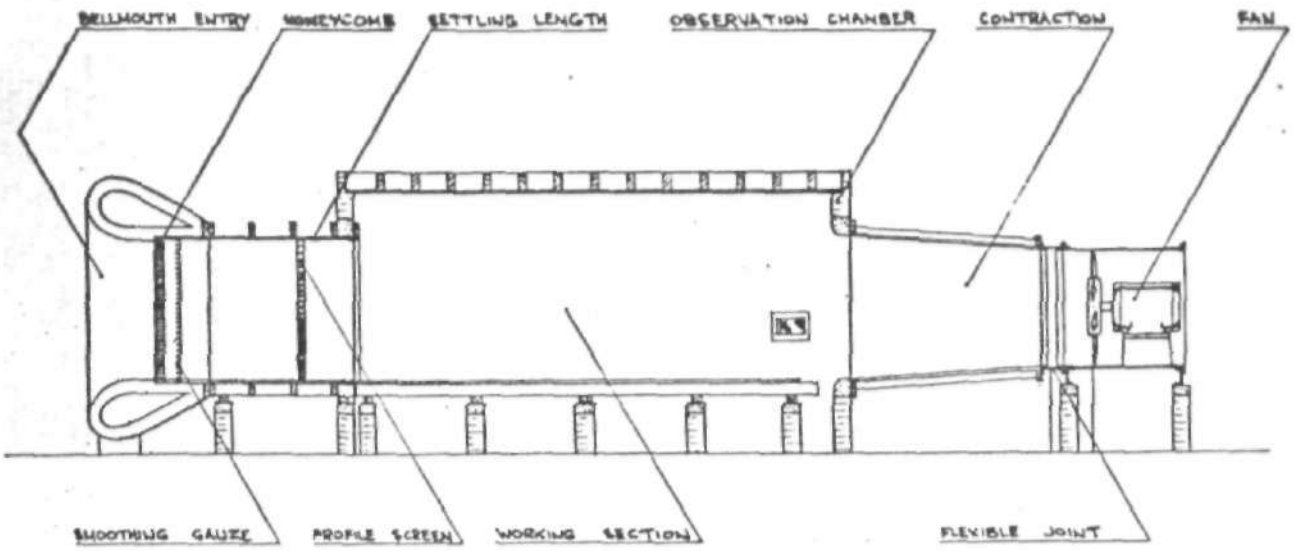


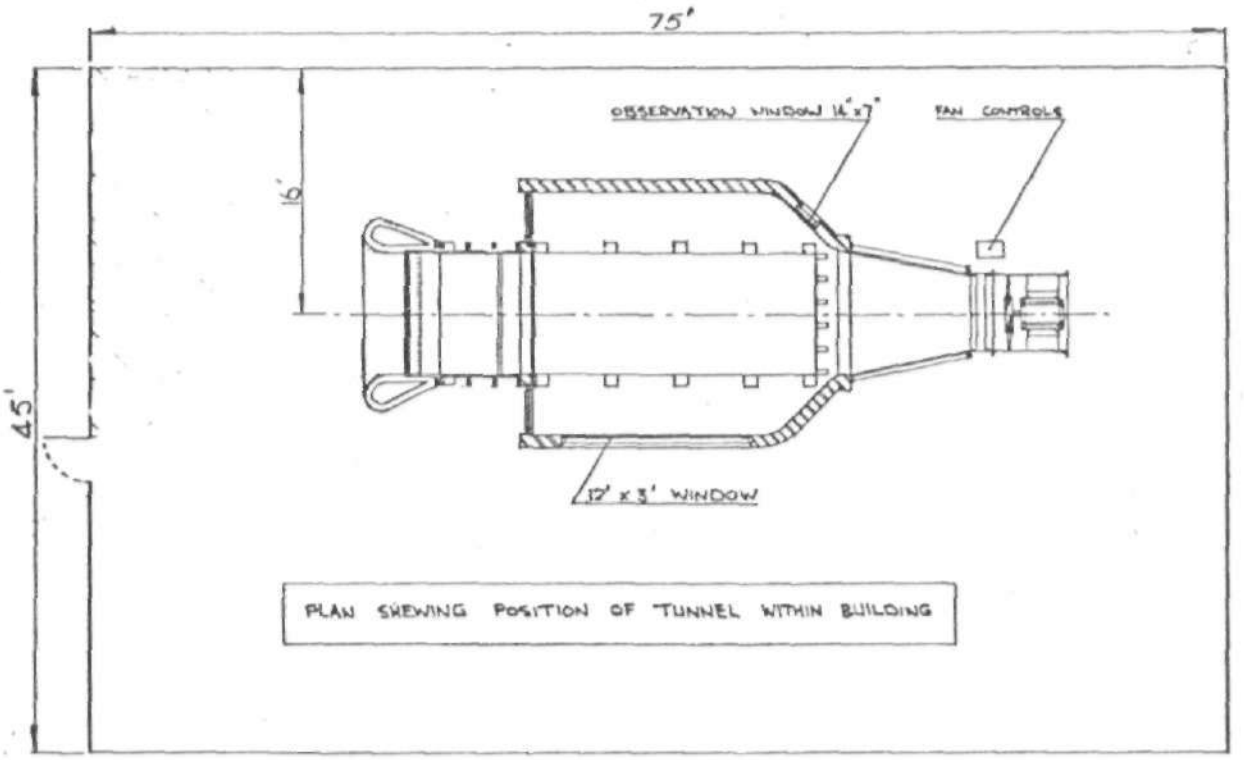
fig 9

c) Section



B.R.S. LOW-SPEED WIND TUNNEL

d) Plan



PLAN SHEWING POSITION OF TUNNEL WITHIN BUILDING

fig 9

B.R.S. LOW-SPEED WIND TUNNEL

FIG. 9

of lighting demonstrations and they include a colour rendering apparatus and a light control unit. The portable equipment required for the proposed laboratory is :

a) Daylight photometer

b) Architectural illuminance meter

c) Hagner luminence meter

d) Illuminance meter

e) Daylight factor meter

f) Sound level meter

g) Tape recorder

h) Whirling hygrometer

i) Air-velocity meter

j) Smoke generator

k) Velocity measuring equipment.

4.5. SPACE : The space required to accomodate the above enumerated equipment can also be divided into two. While spaces are needed for fixed equipment, the portable items will be kept in the storage areas such as benches and cupboards. The fixed spaces are therefore determined by :

a) The size of the equipment

b) Required operational space

c) Observation space for students and

d) expansion predictions.

As for the portable equipment, the bench size is not only dictated by the size of the equipment but also by the amount of work students and researchers are expected to carry out on them. Future acquisition of additional portable equipment must not be neglected or forgotten in the provision of space because they are obtained and brought in without any attention to space. Consequently the designed size of the laboratory benches must be larger than

the present need. Apart from the factors mentioned above, circulation is another main consideration in a teaching laboratory. The movement of large numbers of students demands easy ingress, egress and flow. The circulation space is complicated by the fact that students need specific space when observing demonstrative experiments.

A research conducted applying a 'multiple regression method' and 'standard significance tests' led to the conclusion that there is a correlation between subjective judgments and free floor area per person. A modification of the results so obtained will lend a solution to the problem of floor area for students observing demonstrative experiments. With reference to fig. 10 and if it is assumed that ten students' space need is equal to a scientist's need, the floor area needed for 80 students is equal to $29.76m^2$. This condition is not obtainable at ABU laboratory. Another avenue must be explored for a solution. It might appear simple to split up large classes of students into small groups which do their practical work in relays and so to economise laboratory space. This, in fact, is what is done in the United States of America. A class of, say, 250 students is split up into ten groups of 25 and so the laboratory does not need to hold 250 : a capacity of 25 is enough and the 'Plant Utilisation Efficiency' in percentage is high.

In ABU, some factors will influence the way space is used and among such factors are :

a) effective teaching

b) limited space

c) laboratory environments

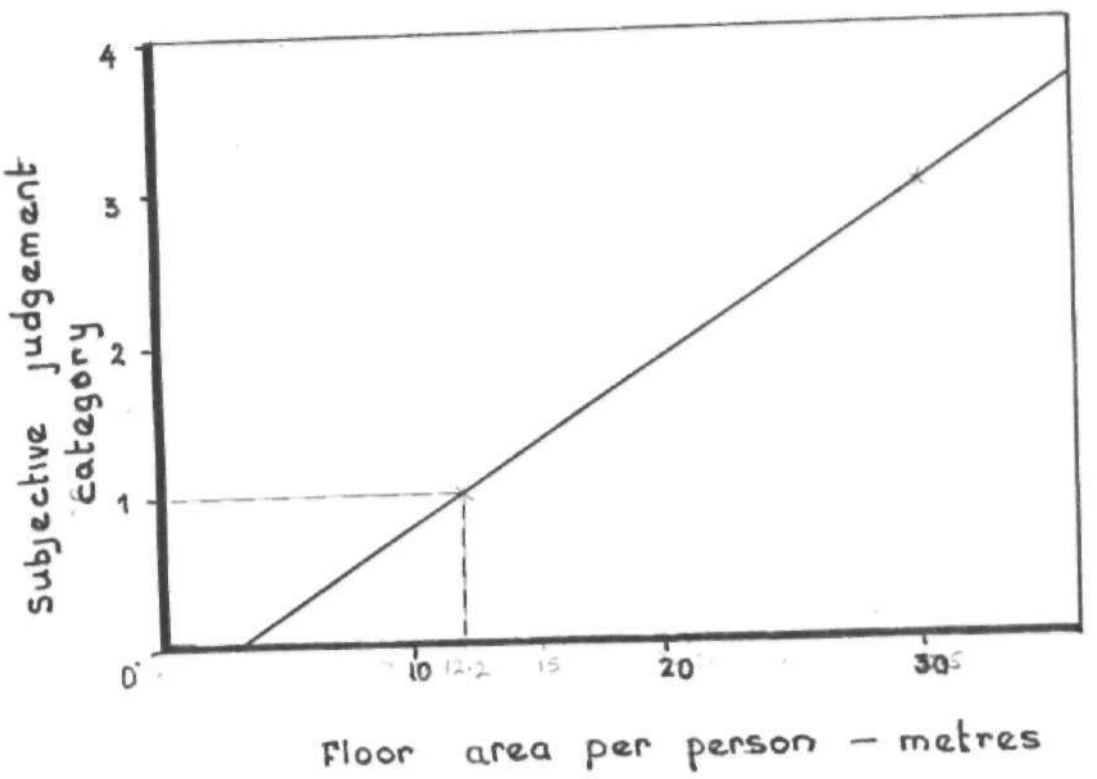
d) safety risks.

Considering these factors, it can be observed that an average student population of 80 cannot be admitted into the laboratory at once, fig.

FIG. 10

Judgement	Category
0	Crowded
1	medium to crowded
2	Medium
3	Medium to roomy
4	Roomy

Relationship between subjective judgements and floor area.



This is why the students will have to be divided into groups and be allowed into the laboratory in turns. This exercise cannot be discussed here because other factors will creep in at the moment of implementation.

4.6. STAFF : Staff requirements depend on the way the laboratory is to be established. And the type of staff - lecturers, technicians, etcetera, - depends largley on whether lighting, air-conditioning or acoustic units are established first. An expert will be required for each of the three units. In exceptional cases and when the funds are available, all necessary units of the laboratory may be established at the same time. Hence the appointment of experts should be considered at the planning stage and the training of the local environmental scientists should simultaneously be considered. Technician offices must be very near the laboratory while those of the lecturers may or may not be as close to the laboratory as that of the technician.

In ABU's case study, the staff requirements are based on the following :

a) number of students

b) size of the laboratory

c) lighting unit being established.

And the staff of the laboratory were limited to four :

1 Lecturer

1 Technician

2 Technical assistants.

There are no statistics to support the staff needed for the laboratory but the list given above is rational enough to run the laboratory efficiently. What is implied here is that a statistically-backed analysis may produce a different list.

LAYOUT

In principle, the laboratory should be treated as a special factory with less rigid lines of production where equipments function and relationship are scrutinized so that a rational layout can be achieved. Apart form the equipment, it is obvious that the layout of benches can radically affect plan forms and even the dimensions of the laboratory room.

Fig. 11 shows the arrangement of the equipment of the ABU laboratory. The ingress and egress into the laboratory is through a single door. The other door will always remain closed, open only for emergency purposes. This will facilitate the proper usage of all the space around the artificial sun. This equipment is more delicate than the heliodon and the Artificial Sky and therefore should be kept away from the entrance which is in frequent use. The heliodon is placed nearest the ingress because it is the least delicate and it is likely to be used more frequently than any other equipment.

On the other side of the corridor is a space assigned to the Wind Tunnel. The positioning of this equipment depends on the direction from which the wind will be drawn into the tunnel. But dust-laden North-East Trade Wind, blowing across the Sahara over Nigeria, will increase the Wind Tunnel dust and dirt menace. It is therefore logical not to orientate the opening of the Tunnel to North-East Trade Winds - fig. 12. In addition to good orientation of the Wind Tunnel, the North East Trade Wind should be blocked and diverted from the position of the Wind Tunnel. These precautions will reduce the dust deposits in this equipment and efficiency as well as the well-being of the research fellow or the Wind Tunnel operator will be enhanced.

5. EXPANSION

Growth and changes are natural parts of life and in laboratory design they are important factors that must never be overlooked. Laboratory trends of expansion varies from one establishment to the other. Anyway, when

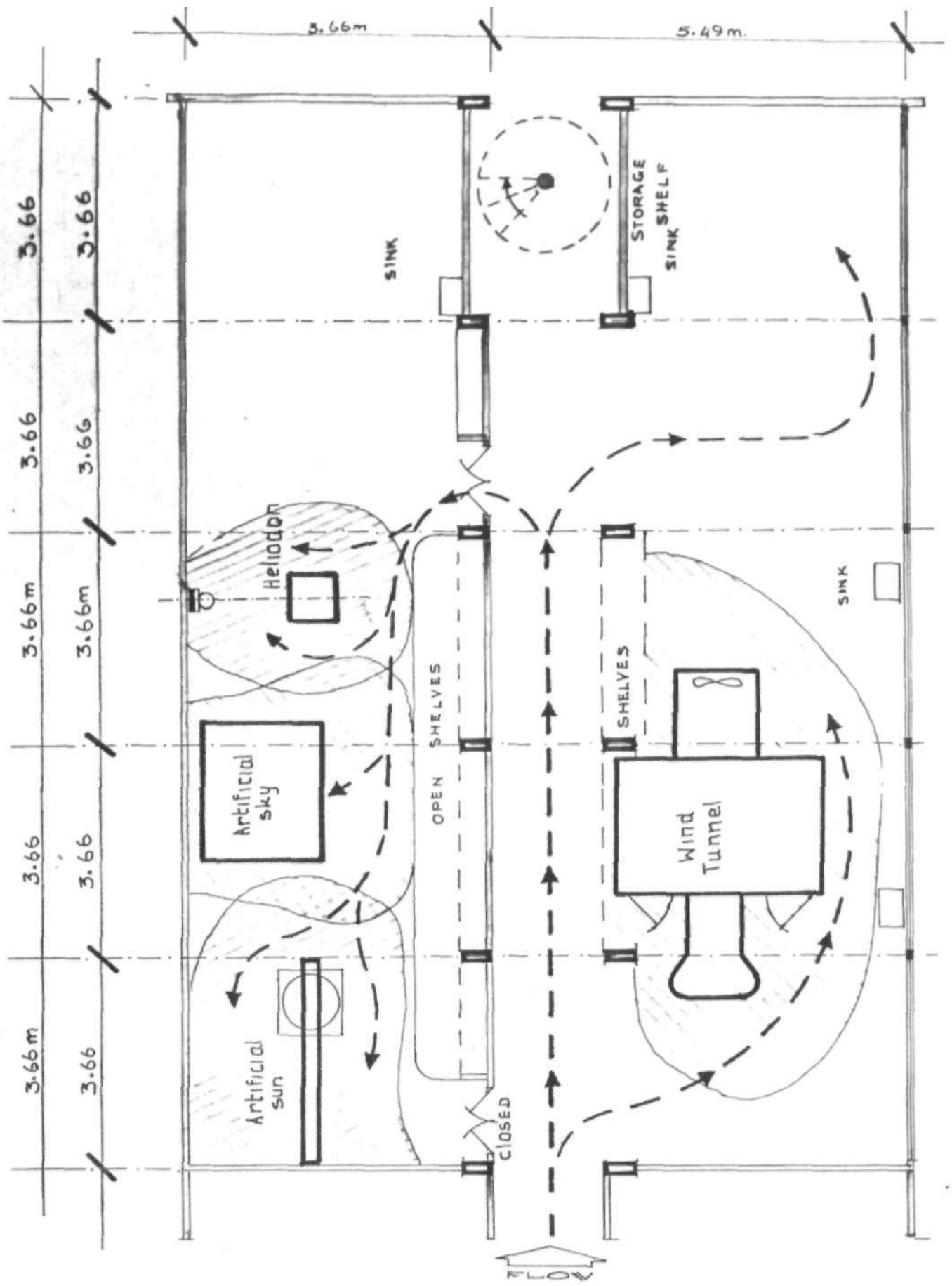
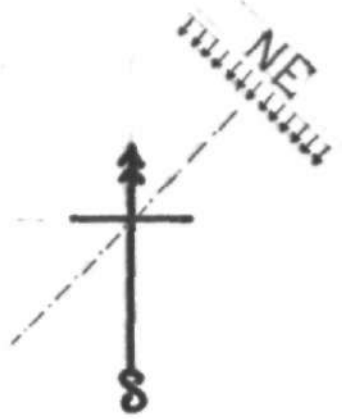
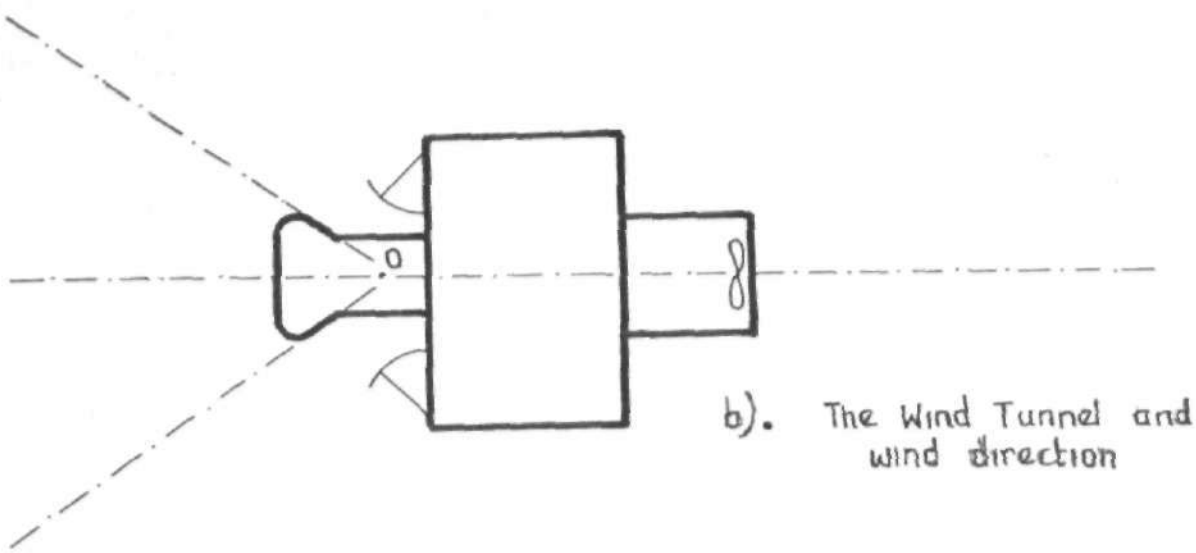


FIG 11 ABU LABORATORY PLAN

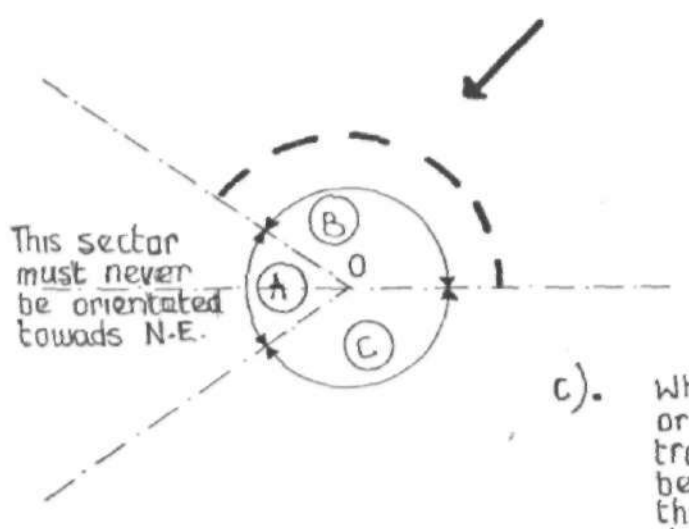
FIG. 12



a). The North - East Trade - Wind



b). The Wind Tunnel and wind direction



c). When sector B or C is orientated towards N.E. trade wind, point O may be protected against the dust menance of this wind by using building to block its path. This is achieved in ABU design.

form and character of basic structures are to be considered, there are two ways in which expansion may be approached. These approaches are determined according to a limited range of criteria, such as the overall area, range of ceiling height, and floor area as well as the proportion of total area likely to need natural illumination. Predictions based on these criteria can be in favour of complete repetition of the laboratory building, fig. 13, or of a less wholesome additive structure. But building parameters are means of effecting laboratory expansion whereas the basic cause are increased activities resulting from teaching, research or both.

5.1. RESEARCH: The scientist in search of the ultimate laws of nature always applies experiments as instruments of empirism. He soon discovers that one natural law often leads to another. Thus a developing experiment is characterised not only by change but also by growth: growth in the quantity and complexity of the apparatus in use, and growth by the accumulation of the apparatus standing by. This is why it can happen that a research laboratory sometimes resembles a junk shop and why after a time all available free space is used to a point where efficiency starts to suffer.

5.2. TEACHING: In higher eductation, changes in science teaching appear to be less volatile than changes in scientific research. But when changes occur in teaching, they can be just as far reaching in their effect on the way in which the laboratory building is used. And immediate causes of such expansion are as follow:

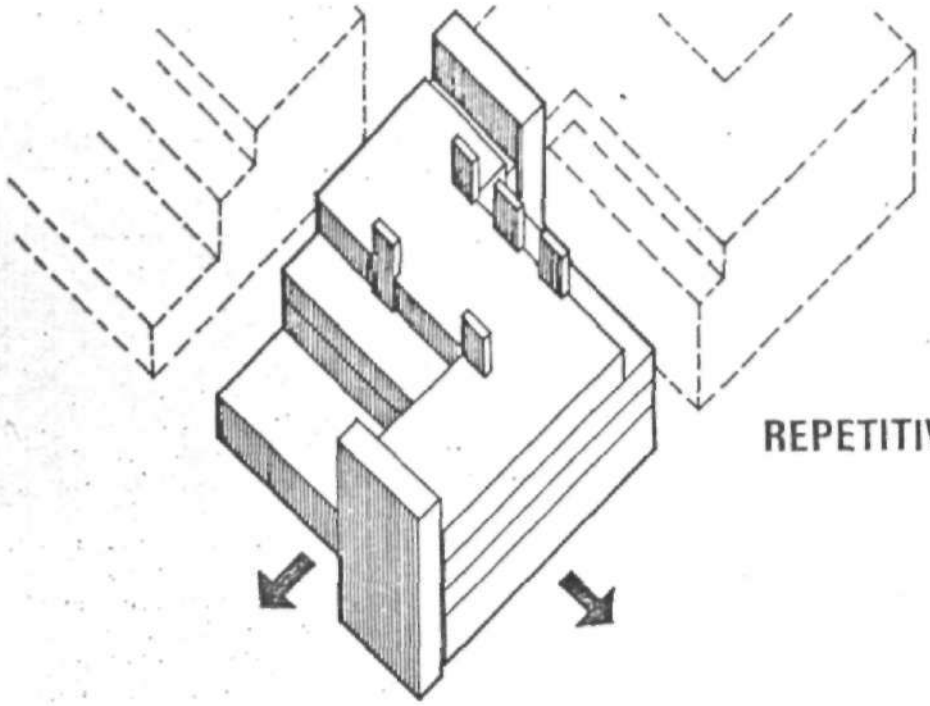
a) growth in the number of students

b) changes in curricula

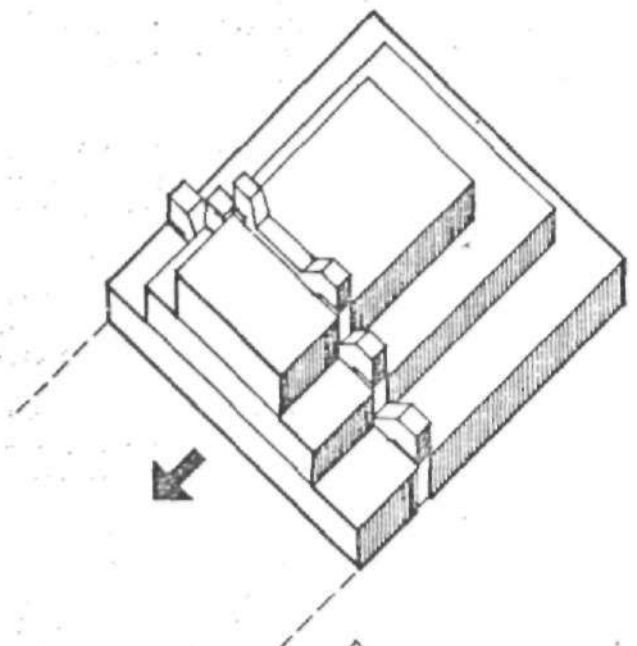
c) developments in teaching methods.

Furthermore, remote causes can also influence the demand for more space but such causes are always within the control of the institution.

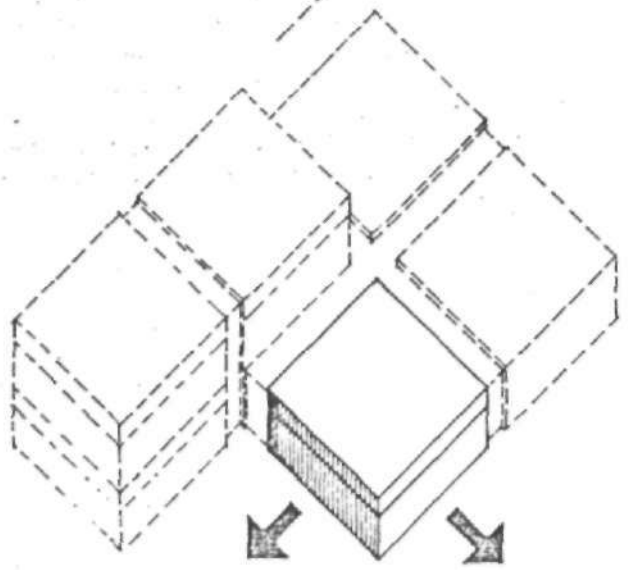
FIG. 13



REPETITIVE BUILDING FORM



REPETITIVE CROSS SECTION



REPETITIVE STRUCTURAL FORM

BASIC SHELLS

5.3. EQUIPMENT: Equipment life expectation does affect the expansion of the laboratory. The life expectation of some large equipment may not normally exceed 15 to 25 years and after that time it will sterilise space if not dismantled and removed or reassembled in a different form. The obvious solution is to look round for more room.

It is, of course, necessary to be sure that valuable laboratory space and storage is being fully and properly used to justify an extension of the laboratory. When eventually the decision is in favour of expansion, a rational approach must be adopted towards its implementation. However, it is encouraging to observe that scientists commissioning new laboratories today recognise the drawbacks of tailoring the building too closely to one set of conditions only. They now appreciate these conditions are bound to change and that flexibility must be included in the brief. Consequently, the designer is free to adopt the principles of flexibility and thus employ the following in his design concept:

a) Moveable and non-load bearing partitions

b) Modular or regular bay principle of laboratory layout

c) Laboratory furniture design on a unit principle - benches, shelves etc.

d) Adaptable service extensions - outlets etc.

But the best approach is not to leave the problem of expansion until it presents itself; rather it should be predicted and its direction controlled right from the initial design stage. There are many ways in which the expansion of a laboratory can be predicted and controlled. The chosen path will depend largely on the type of laboratory being designed. In the case of environmental science laboratories where there are three units - lighting, acoustics and air-conditioning - planning for expansion can take two forms :

a) A mixture of equipment without emphasis on any of the three units and

expansion will be dictated by needs.

b) A mixture of equipment with emphasis on a unit - e.g. lighting - as the first stage of laboratory establishment; other units coming as subsequent stages of expansion, as in fig. 14.

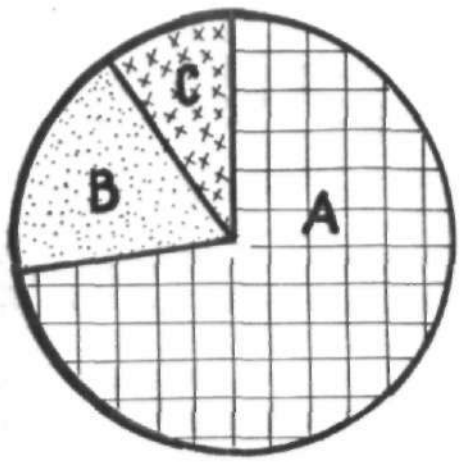
The second form is the one adopted for ABU. On the ABU plan it can be observed that only three of the five bays are utilised leaving the remaining two bays for minor expansion purposes. And the free space in the 'blind box' is particularly meant for lighting unit expansion. Major expansion which will normally be any of the other units - acoustics and air-conditioning - and may demand more accommodation is to be effected as the repetition of the bays and in the direction of Kashim Ibrahim Library. The last stage of expansion will be in the direction of the Fine Arts Department, terminating at the Building Science laboratory of the Department of Building, ABU, fig. 15.

Decisions as to the Staff requirements, number of floors, type of equipment and building parameters which may be the consequence of expansion should be left until the situation confronts the ABU authority because other factors may creep in and any analysis carried out now will have to be reviewed. This recommendation may seem a negative one. But this is the best option in view of the fact that the building of this laboratory has been designed and has been constructed before this exercise.

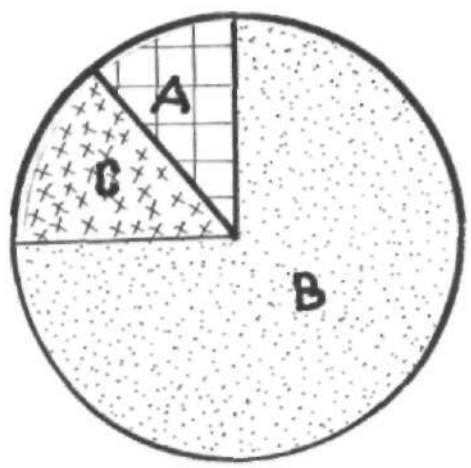
6. SERVICES

6.1. ELECTRICAL : In modern laboratories, a wide variety of services is required to be available at laboratory benches, fume-hoods or walls. The required services depend on the type of laboratory and physics laboratories, under which environmental science laboratories are classified, may have to be supplied with gas, water, steam, air, electricity, etcetera or any combination of these. The distribution of services is an important aspect of laboratory

FIG. 14 ESTABLISHMENT & EXPANSION

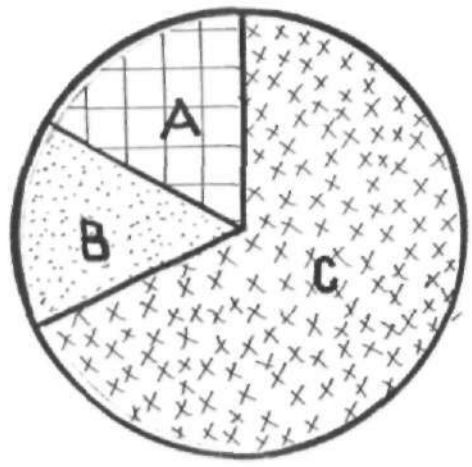


I



II

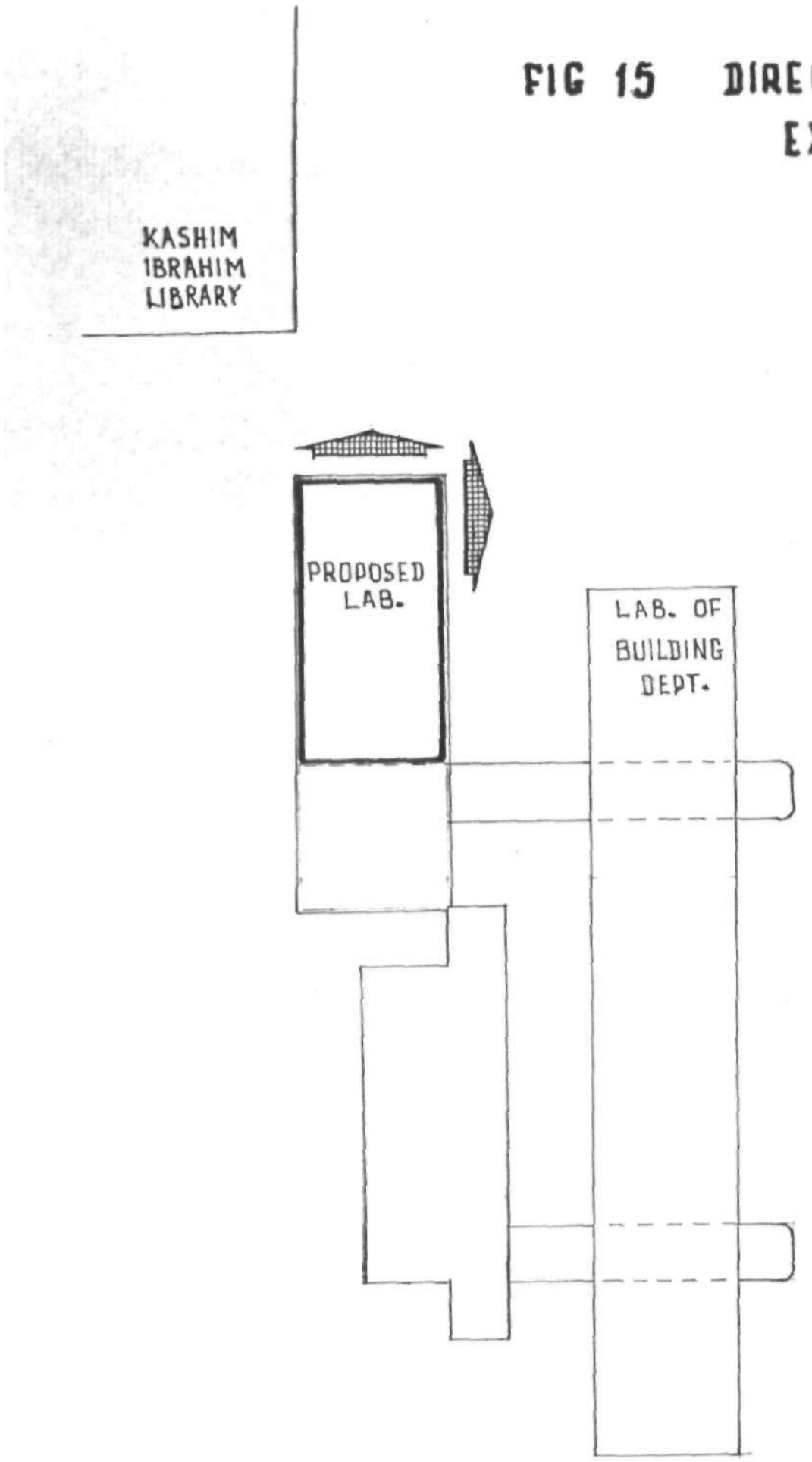
In each case the sector is proportional to the capital cost of the equipment



III

A – Lighting **B** – Ventilation & Air-conditioning
C – Acoustics

FIG 15 DIRECTIONS OF EXPANSION



planning. An improper distribution of services can mar a good laboratory design. Hence planning of services layout is necessary to maximise efficiency, flexibility and adaptability. Foresight should always be exercised during the design period. Distribution lines are separated into two categories: the main supply and the sub-mains. When the mains are vertical, the submains are horizontal and vice versa, fig. 16. The horizontal services are usually run above the false ceilings of corridors, basements, below the raised floors and along the laboratory walls, fig.17. Electrical power supplies are the main requirement of any environmental science laboratory and in ABU laboratory, electrical power will be required for lighting, portable and fixed equipment as well as for plug-in devices. For the use of portable equipment, flexibility of power facilities and convenient locations of power outlets are of primary importance. The main supply (AC) will be from NEPA high tension main, the voltage of which will be reduced by the transformer provided by the same authority. The switch-board is generally installed in the premises of the customers buying the power from the electricity authority. But the main problems with the NEPA power supply are the fluctuation of current and constant power cuts. These problems may reduce the life-expectation of the equipment by 70 to 90 percent. It is therefore necessary to recommend the provision of the following items with other equipment for the ABU laboratory:

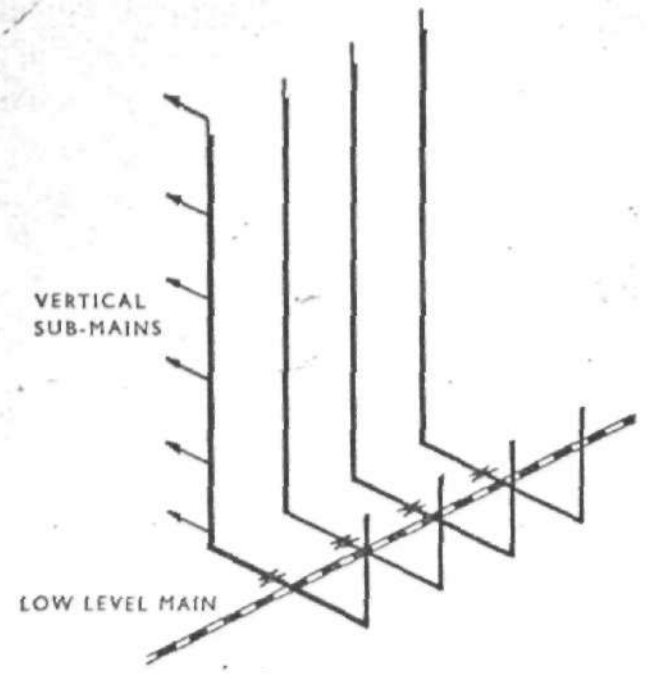
a) Current stabilizers

b) A power generator with automatic on and off switch.

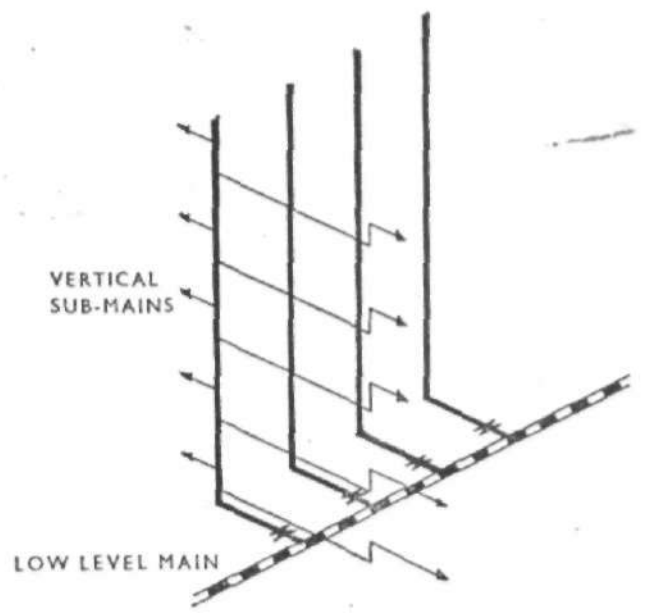
Now, power outlets must be clearly identified in accordance with the current to which they are connected and they may have to be vapour-proof, explosion-proof and dust-proof depending on the laboratory requirements. And since the electrical requirements of laboratories increase continually, there should be facilities for additional connections.

The power outlets for ABU Artificial Sky and the Wind Tunnel should

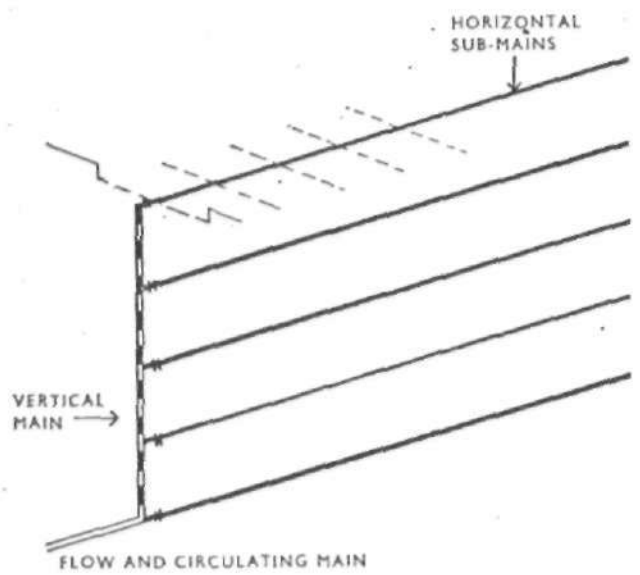
FIG. 16



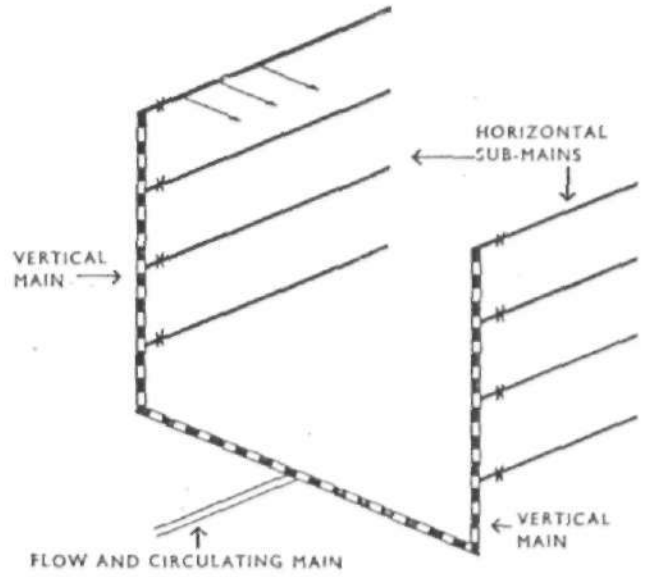
Vertical sub-mains fed from a main at low level using one vertical riser for each cell.



Vertical sub-mains fed from a main at low level using one vertical riser for each pair of cells, one on either side of the corridor.



Horizontal sub-mains at each floor level fed from one vertical main.



Perimeter sub-mains at bench level fed from two vertical mains.

g16

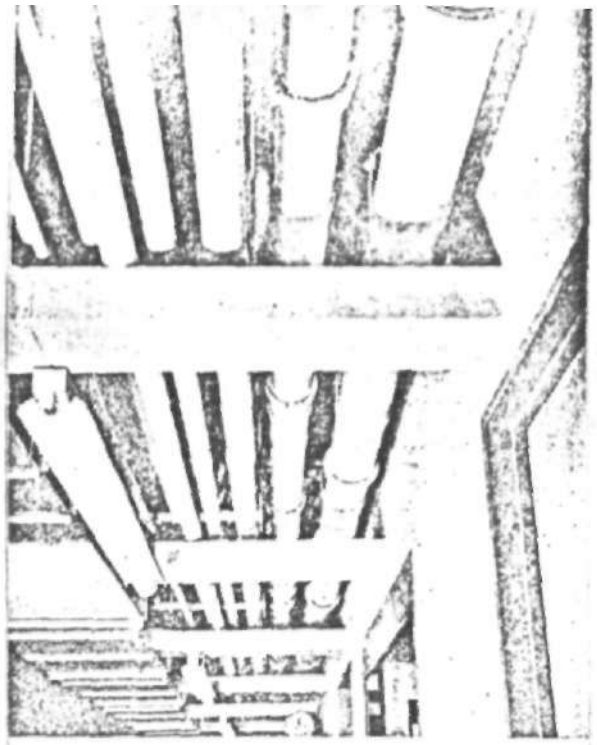
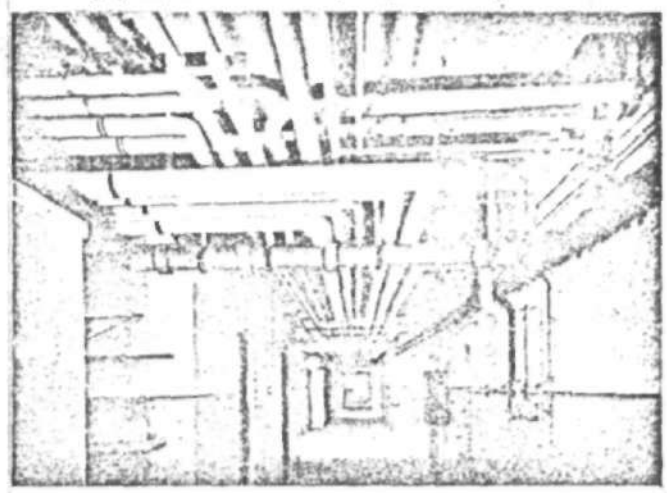
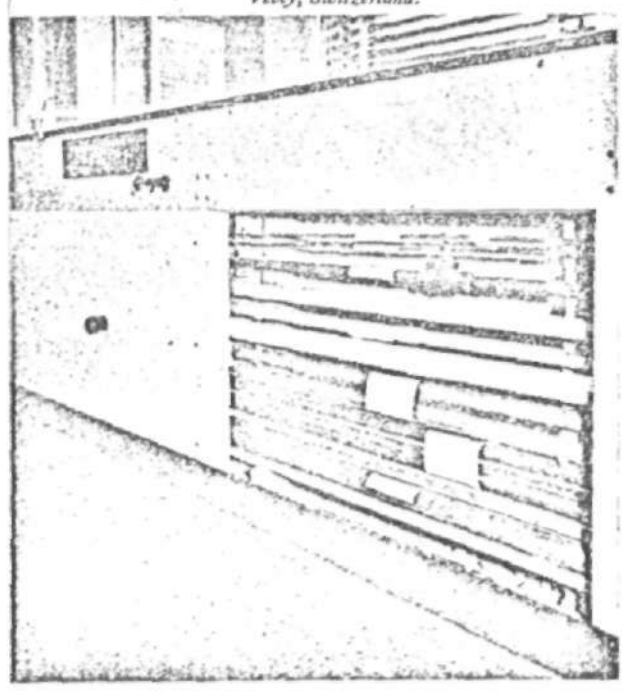


FIG. 17

Laboratory services detail (overhead). (By courtesy of the architects: Grassold-Johnson and Associates, and the photographers, Gottscho-Schleisner, Inc., New York.)



Distribution of services (basement); Nestlés research laboratory, Vevey, Switzerland.



Distribution of services, showing access to pipes and conduit; Sylvania-Thorn television laboratories, Enfield, Middlesex. (By courtesy of the Editor, Architects' Journal, and the architect: G. A. Jellicoe.)

be installed with non-standard outlet fittings to ensure that no apparatus is inadvertently connected to the supply of the wrong frequency. Perhaps it is pertinent to mention that the Artificial Sky requires a single phase 30 ampere outlet while the outlet of the Wind Tunnel should have 3-phase 30 ampere. Some two more non-standard outlets may be provided in anticipation of expansion. All other outlets may be of ordinary single phase supply at domestic voltage. These normal outlets will serve all the portable equipment as well as the Artificial Sun and Heliodon which has a lamp wattage of 250.

6.2. LIGHTING : Adequate quantities and correct quality of lighting are very important in any interior environment. And as with the majority of services in the laboratory, the particular lighting requirements of each laboratory must be studied. In general, if design success is to be achieved, the lighting system in ABU must fulfil the following objectives :

a) Sufficient quantity of light on any task

b) Good quality of light with regards to brightness grading or brightness contrast in different parts of the laboratory.

c) Quality lighting with respect to the absence of glare, flickers etc.

d) Optimum general lighting to expell corners of gloom.

Daylight, artificial light or a combination of the two may be employed to achieve these ends. The lighting of the ABU laboratory is considered section by section because it consists of two parts.

The Windowless Area - The lighting of this room has to be designed with artificial light in mind. The whole lighting system must take the following factors into consideration :

i) Calculation for the quantity of light necessary for task lighting

ii) Quality lighting in terms of brightness grading and avoidance of discomfort glare.

iii) Supply of artificial light simulating the supply of daylight.

The first factor is taken care of by the lamps which are the integral parts of each of the three pieces of equipment - Heliodon, Artificial Sun and Sky. It is the last factor that dictates the choice of the light source. In Nigeria, the psychological reaction towards interior lighting is more positive for the white fluorescent lamps than for the filament lamps. The reason is not far-fetched; the fluorescent lamps do not possess the strong characteristics of sun emission of light which is inherent in the filament lamps. This characteristic of fluorescent lamps offers a desired break in the monotonous supply of sunlight. In view of the above reasons and of the fact that comprehensive information is needed for design purposes, the luminaire chosen is a coffer-light cell, manufactured by Thorn Lighting Limited, with PPC twin batten fittings. The following data are taken from the manufacturers catalogue :

a) Max. spacing/Height ratio = 1.63

b) DLOR = 53%, ULOR = %, Total = 53%

c) Luminous Area = 0.96 m^2

d) Wattage = 2 x 65 W

e) B.Z. Classification = 3

f) Light Source : i) Thorn Fluorescent Tube - Plus White

ii) Length = 1500 mm

iii) Wattage = 65 W

iv) LDL = 4500 lumen

v) Colour rendering quality - good

vi) Colour appearance - medium

Room Data :

a) Ceiling height = 3 m

b) Mounting height = 2.15 m

c) Dimensions = 18 x 3.66 x 3.00 m^2

d) Area to be lit = 18 x 3.66 m^2 = 65.88 m^2

e) Standard Service Illuminance = 750 lux (fig. 18a)

f) Reflectances : Ceiling = 70%

Walls = 50%

Floor = 20%

The Standard Service Illuminance is obtained from fig.18 which is taken from the IES code.

Lighting Quantity and Lamps :

Again form the Lamp manufacturers information –

U.F. = 50%

M.F. = 90%

$$\therefore \text{Installed Flux} = \frac{750 \times 18 \times 3.66}{0.9 \times 0.52}$$

$$= \frac{49410}{0.468}$$

= 105577 lumens

$$\text{Required number of tubes} = \frac{105577}{4500} \text{ tubes}$$

= 23.46 tubes

≅ 24 tubes.

This gives 12 luminaires – fig. 18b.

Lighting Quality and Glare :

The glare index is examined in the direction of view indicated on fig. 19.

Light mounting height above 1.2 m eye level = 1.8 m (H)

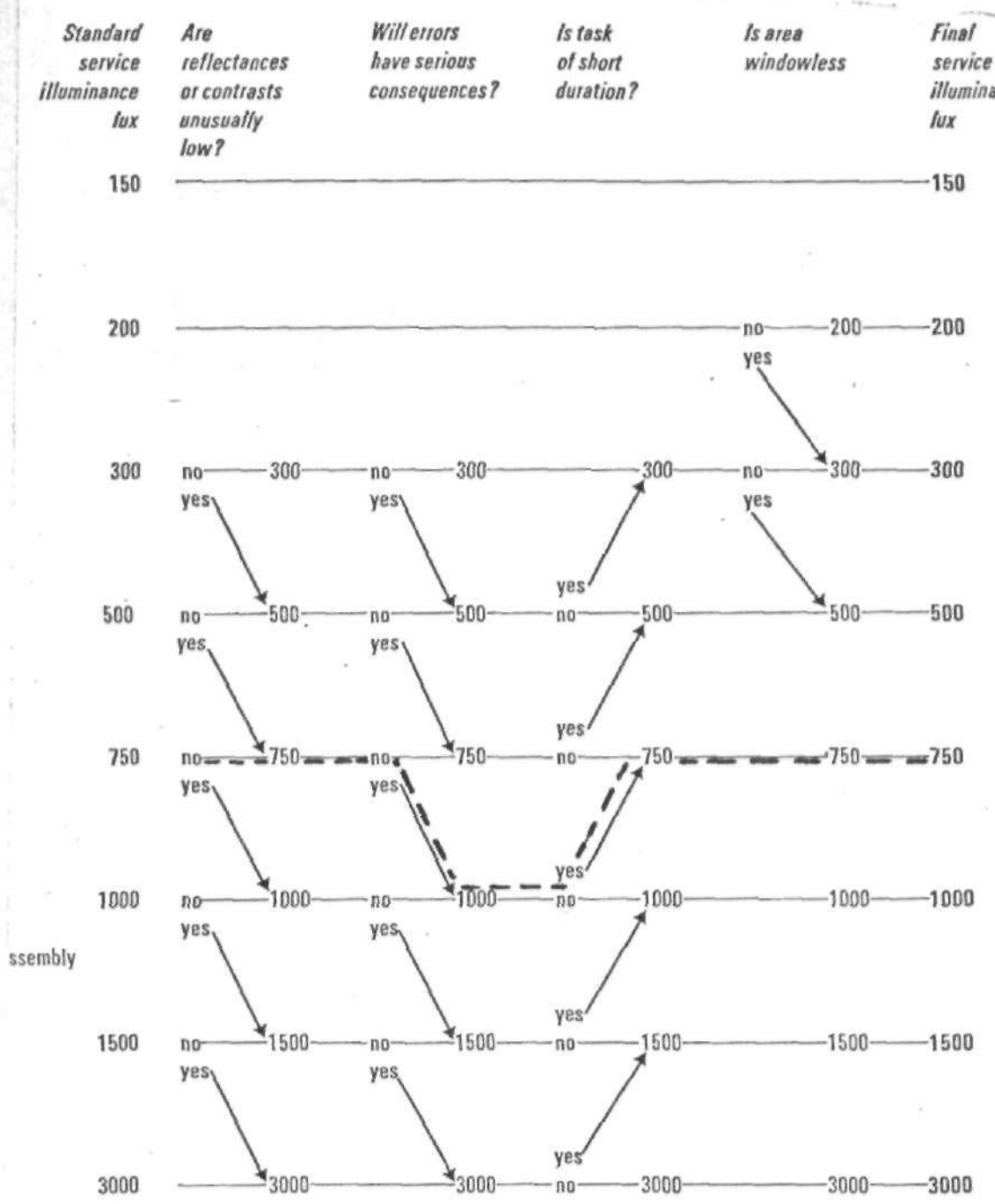
$\therefore$ Dimension X = 3.66 = 2.03H

Y = 18.0 = 10.0H

Interpolating these values in Table 1a of Appendix 4, 'Interior Lighting Design' by the Electricity Council, initial glare index is GI where

GI = 13.92

FIG. 18a



ssembly

Using local lighting, if necessary supplemented by use of optical aids, *e.g. binocular loupes, magnifiers, profile projectors etc (see Fig 33).*

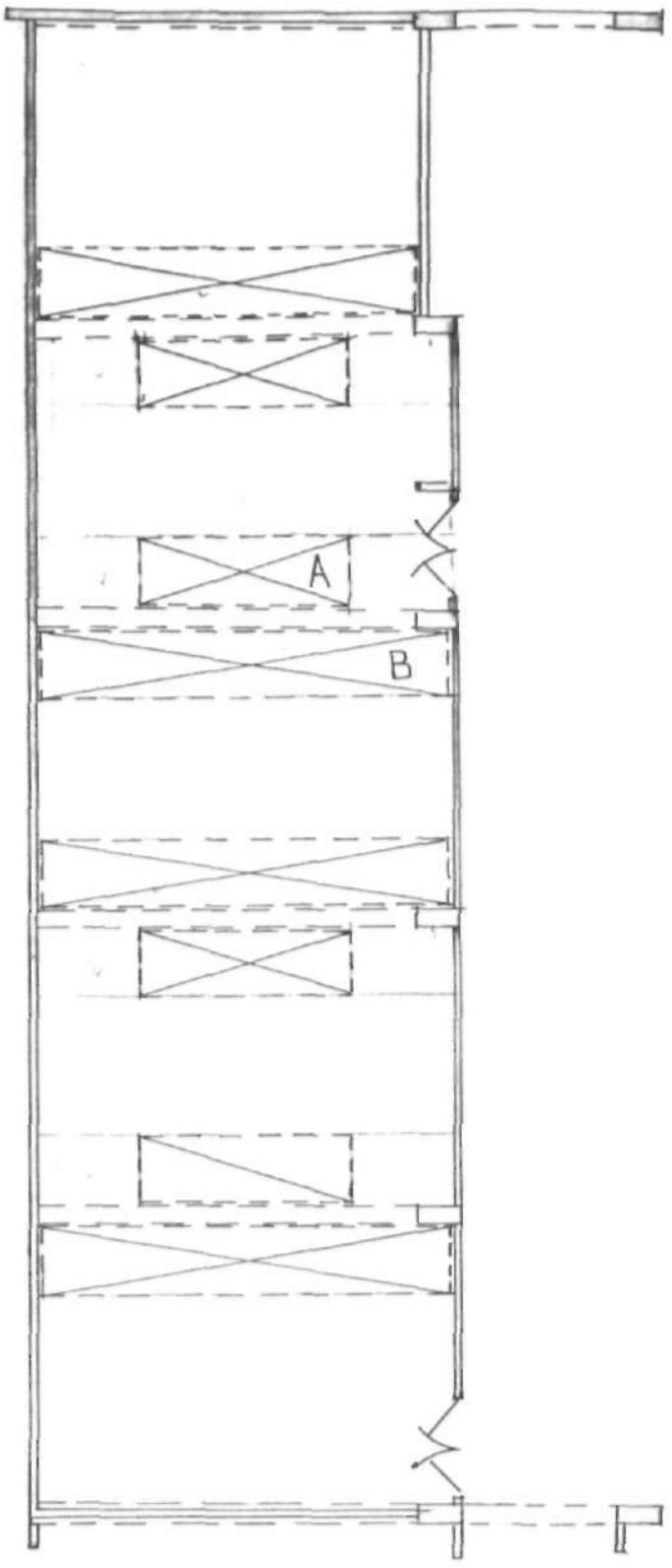


FIG. 18b LUMINAIRE ARRANGEMENTS

A = 1
B = 2
} Luminaires

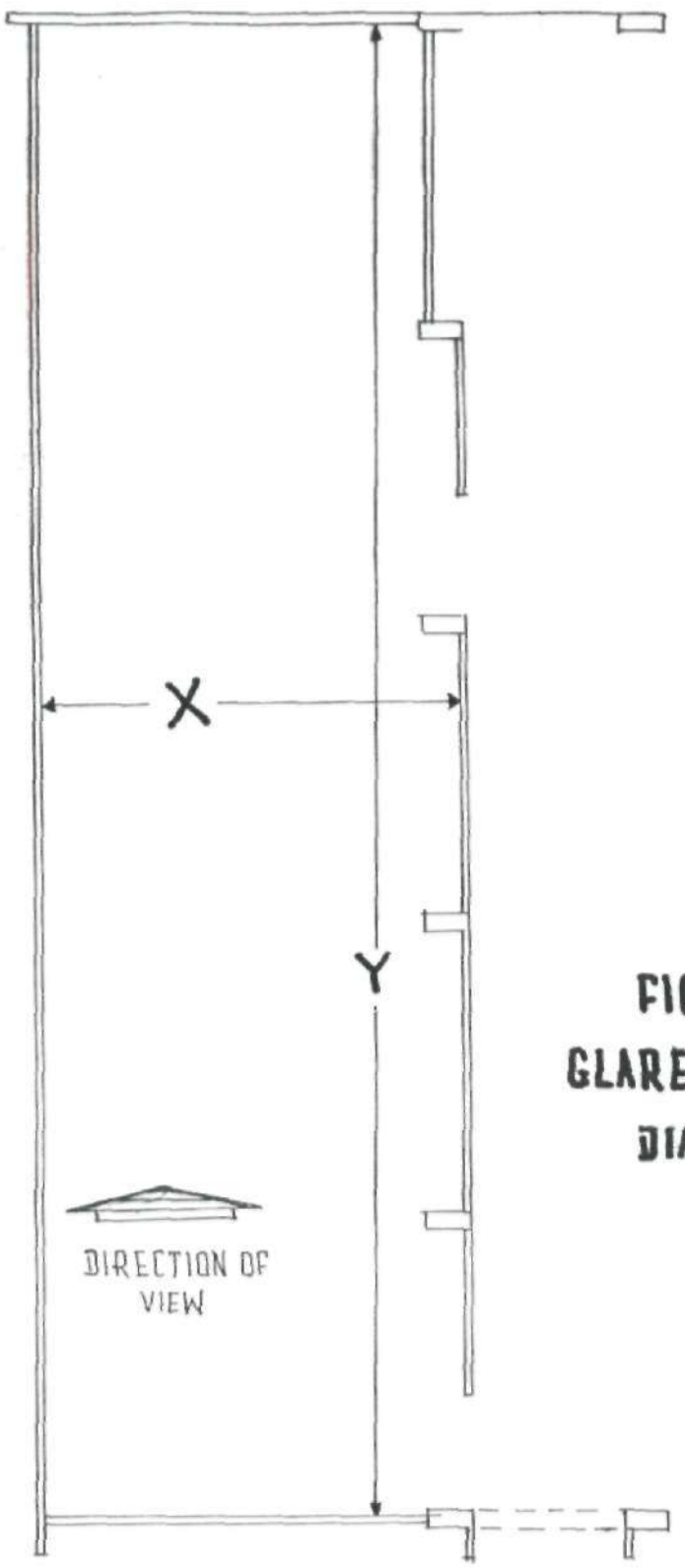


FIG. 19
GLARE INDEX
DIAGRAM

Corrections :

Height (1.8 m) = -0.6
Luminous area (9600 cm^2) = -9.5
Downward flux (2385/m) = +2.2
Flux fratcion ratio (0.0) = +4.6
Sum = -0.6 - 9.5 + 2.2 + 4.6
= -3.3
∴ Final Glare Index = 13.92 - 3.3
= 10.6

Since 10.6 < 19.0, there is no threat of discomfort glare.

Lamps Arrangement

The lamps are arranged in two series, A & B, and they will be operated by separate switches, A & B. The decision to select any of these series of lamps will depend on the type of equipment being used and both may be switched on if none of the equipment is being operated or if there should be a discussion period before a demonstrative experiment. The lighting system is designed in this way to satisfy the condition of selected lighting for task purposes on the equipment :

a) The Artificial Sun and Heliodon will need enough quantity of lighting whenever they are being set up. But when the stage of model observation is reached, only the light from any of the equipment is required on the model. At this stage, too strong secondary lighting will affect the ability of the equipment primary lighting to cast strong shadows of the model being observed. Hence the secondary light should either be reduced or switched off.

b) On the other hand, the Artificial Sky possesses the quantity of light needed for its operation. But since the one chosen for ABU is the mobile type, the photometer readings will be undertaken outside the luminous ceiling of the Artificial Sky. Hence light will be needed to carry out this task and therefore the secondary light cannot be

completely switched off but reduced by applying switch A or B.

Area With Windows : This area is expected to be daylit by reflected sunlight only, because Zaria is in the tropics and because the first phase of the faculty building is parallel to the window of this room. This faculty building is high enough to provide the needed reflected sunlight to the exclusion of direct sunlight.

Now a series of nomograms have been developed by Mr C. Plant, J. Longmore and R. Hopkinson in 'A Study of Interior Illumination Due To Skylight Under Tropical Conditions', published in the Netherlands in 1967. In order to build these nomograms many factors were taken into consideration : factors such as interior illumination, internal surface area, window area and interior reflectances. These nomograms are employed here to design the daylighting for the Wind Tunnel section of the laboratory.

$$\frac{W}{A} = \frac{\text{Window Area}}{\text{Total Internal Area}}$$

$$= \frac{1.6 \times 17.5}{3 \times 56.98 + 2 \times 18 \times 5.49}$$

$$= \frac{28}{338.58}$$

$$\cong 0.08$$

$$R = \frac{\sum AiRi}{\sum Ai}$$

$$= \frac{5.49 \times 18(0.2+0.7) + 3 \times 0.5 \times 28.98 + 18(1.4 \times 0.5 + 1.6 \times 0.15)}{46.98 \times 3 + 10.98 \times 18}$$

$$= \frac{136.728}{338.58}$$

$$\cong 0.40$$

The values of $\frac{W}{A} = 0.08$ and $R = 0.40$ are plotted on the three nomograms in fig. 20 and the results obtained are tabulated in Table 2.

	Distance from Window in 'm'	Illumination E in lux
1	1.22 m	721
2	4.42	312
3	8.23	124
	A	B

Table 2

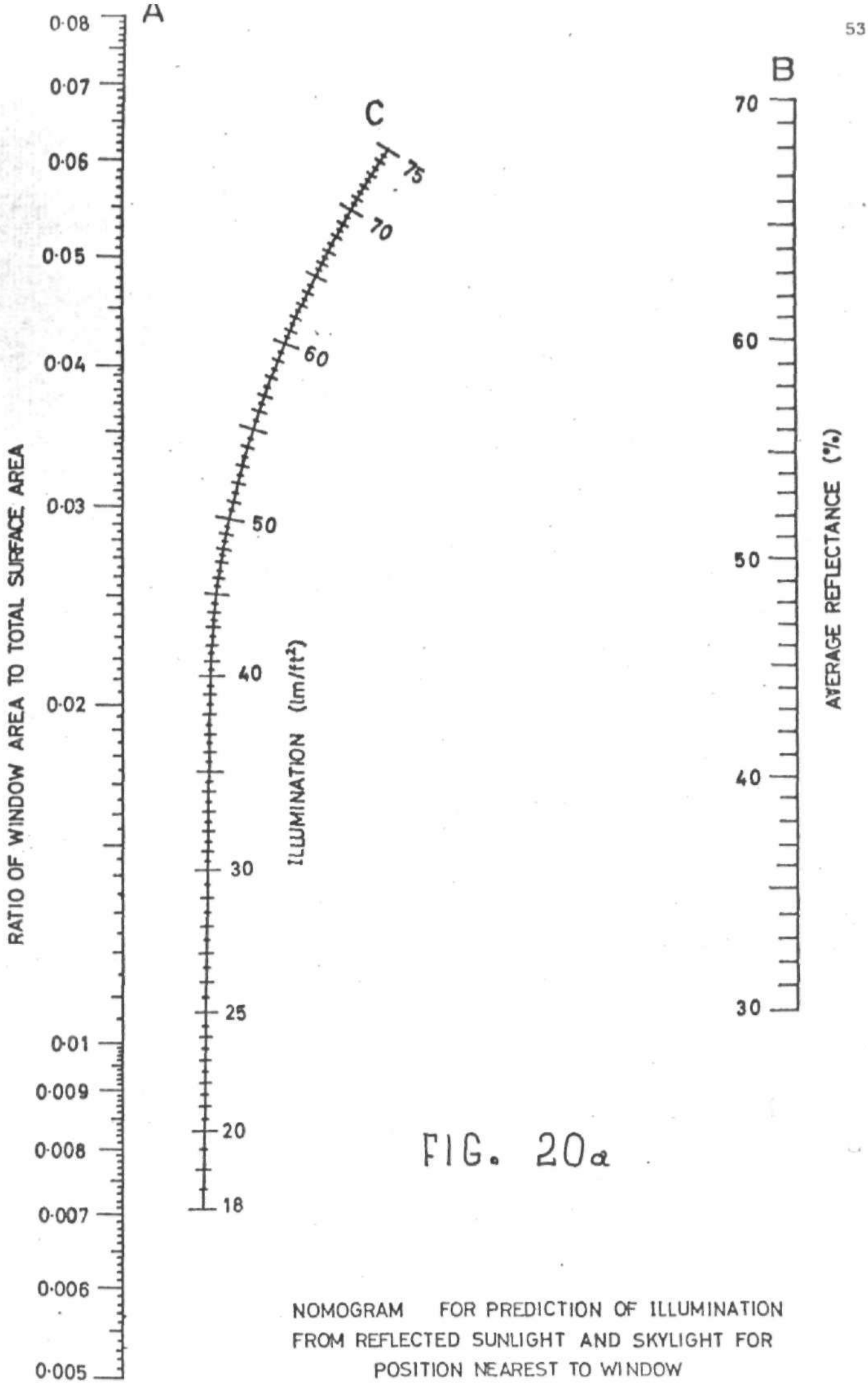


FIG. 20a

NOMOGRAM FOR PREDICTION OF ILLUMINATION FROM REFLECTED SUNLIGHT AND SKYLIGHT FOR POSITION NEAREST TO WINDOW

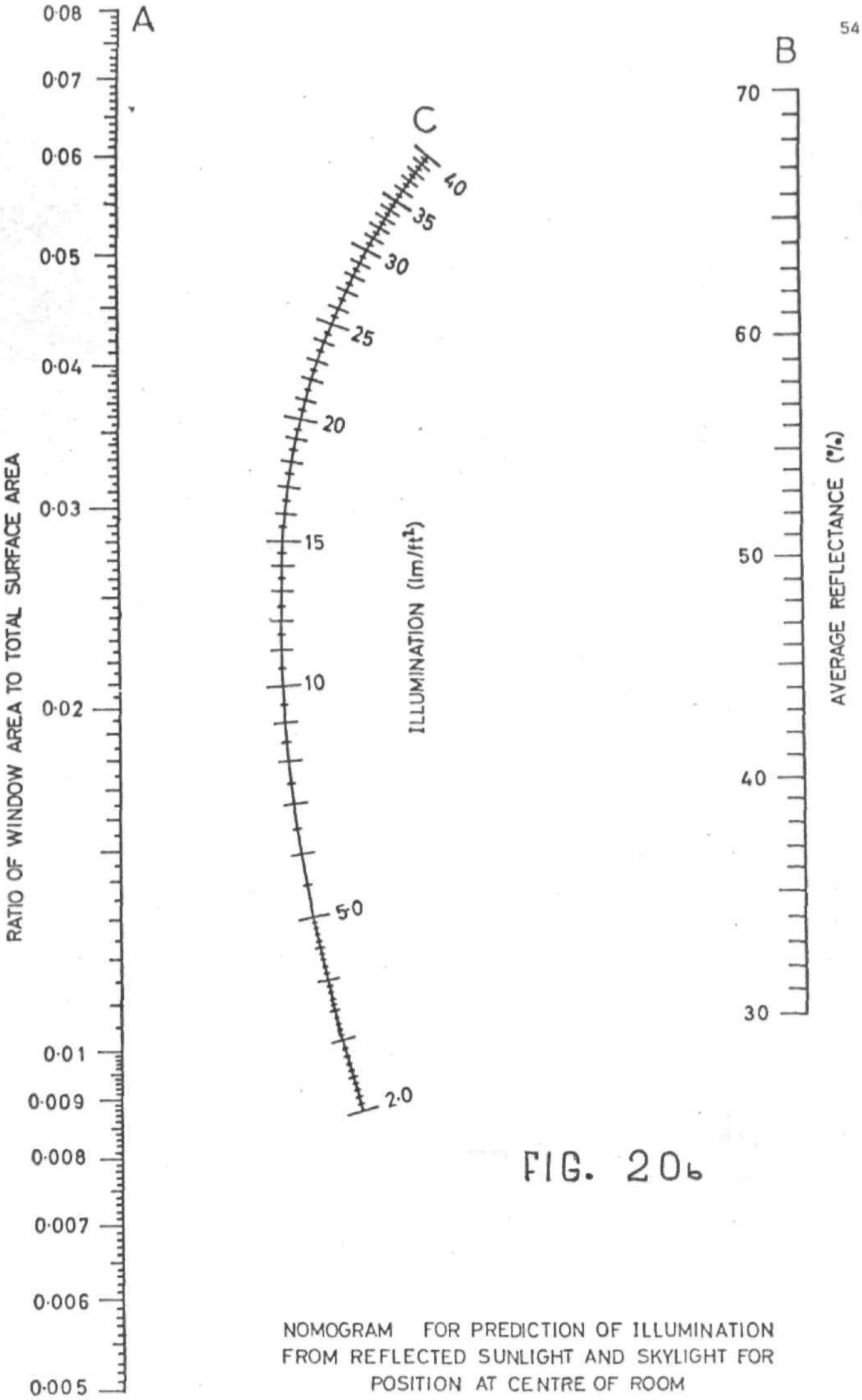


FIG. 20b

NOMOGRAM FOR PREDICTION OF ILLUMINATION FROM REFLECTED SUNLIGHT AND SKYLIGHT FOR POSITION AT CENTRE OF ROOM

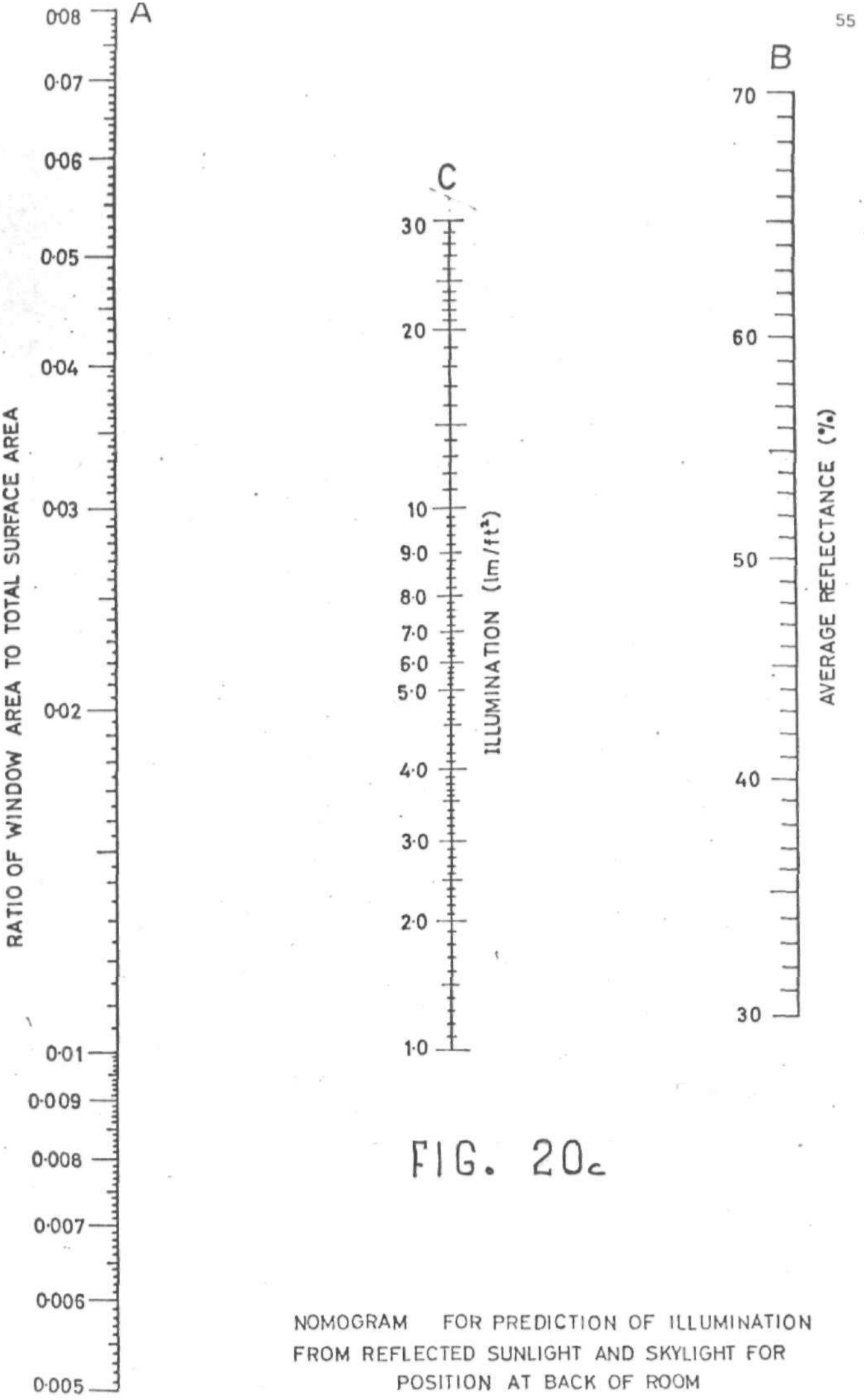


FIG. 20c

NOMOGRAM FOR PREDICTION OF ILLUMINATION FROM REFLECTED SUNLIGHT AND SKYLIGHT FOR POSITION AT BACK OF ROOM

The figures in Column A of Table 2 is plotted against those in Column B to obtain fig. 21. And thus we can observe the daylight distribution in the Wind Tunnel room. The level of illumination at the back of the room under consideration is 235 lux which is less than the 750 lux recommended for laboratory lighting. Therefore, the light in this room needs to be 'topped up'.

The artificial lighting calculation for the Wind Tunnel room is carried out with the same data employed for the calculation of the blind box lighting. The only change in the data is the difference in the floor area which in this case is $5.49 \times 18.00\ m^2$. Since most of the experiments with the Wind Tunnel will be carried out during the day, the level of supplementary lighting when there is daylight and general lighting level at night will be (750 - 235) lux. Therefore,

$$\text{Installed flux} = \frac{(750 - 235) \times 18 \times 5.49}{0.9 \times 0.52} \text{ lumen}$$

$$= \frac{515 \times 18 \times 5.49}{0.468} \text{ lumen}$$

$$= 108744.23 \text{ lumen}$$

Required number of tubes

$$= \frac{108744.23}{4500} \text{ tubes}$$

$$= 24.17 \text{ tubes}$$

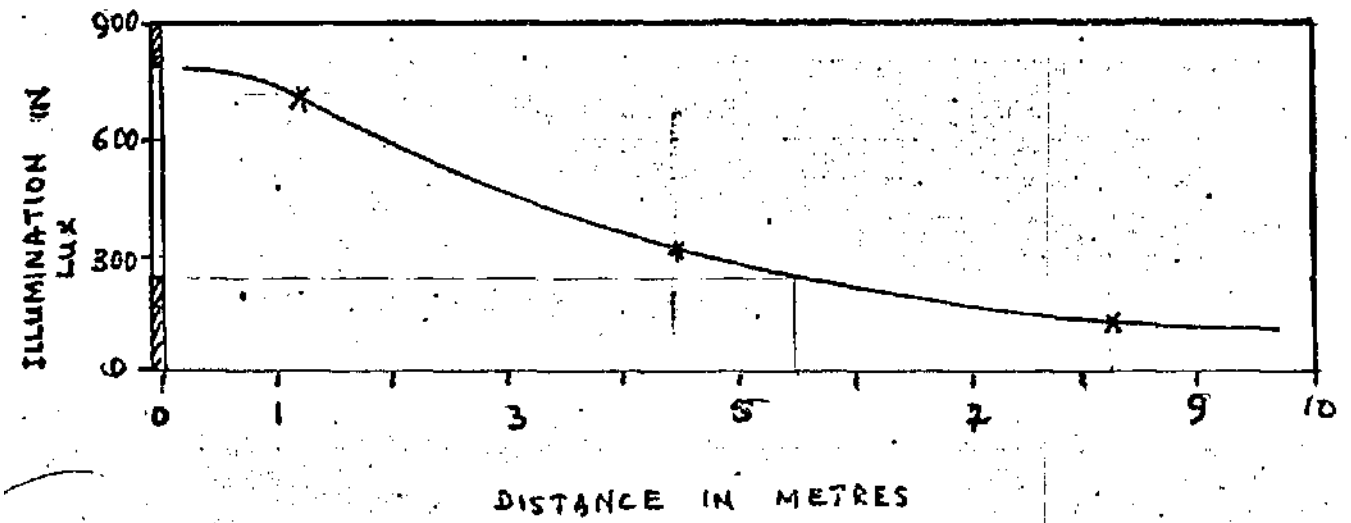
$$\cong 24 \text{ tubes}$$

This gives 12 luminaires - fig.22.

The luminaires are arranged as shown if fig. 22. The method of operation of these luminaires will be the application of a 'day-night' change-over switch. Luminaires in row A will be operated by the day switch and all luminaires - A, B, & C - will be operated by the night switch.

Checking : There is need to check or examine the rationale behind the recommendation and conclusion made above. This exercise is particularly necessary to make sure that the above lighting design lies within the range

FIG. 21


ILLUMINATION IN LUX
900
600
300
0
0
1
3
5
7
9
10
DISTANCE IN METRES

of standards.

I) Spacing / Height ratio $\leqslant$ 1.63 m (Manufacturer)

Mounting Height = 2.15 m (above work plane)

Spacing A = 0.915 m

Spacing B = 2.16 m

Ratio A = $\frac{0.915}{2.15}$

= 0.43 $<$ 1.63

Ratio B = $\frac{2.16}{2.15}$

$\cong$ 1.0 $<$ 1.63

Since the spacing/height ratios in both cases are less than the stipulated 1.63 meters, the arrangement of the luminaires can be described as good.

II) Area Source

The effectiveness of the supplementary artificial lighting is checked at points X, Y, and Z, fig.22, taking into consideration only the luminaires in row 'A' and applying $\frac{E}{L}$ method. With this method, the amount of artificial light that falls on each point is calculated:

Point X

$\frac{Ex}{L}$ = 0.07 (at 4.58 m from the window)

$Ex = 0.07 \times \frac{2 \times 4500}{0.96}$

= 0.07 x 9375

= 656.0 lux.

Point Y

$\frac{Ey}{L}$ = 0.046 (at 3.08 m from window)

$Ey = 0.046 \times \frac{2 \times 4500}{0.96}$

= 0.046 x 9375

= 431.0 lux.

Point Z

$\frac{Ez}{L}$ = 0.0149 (at 1.58 m from window)

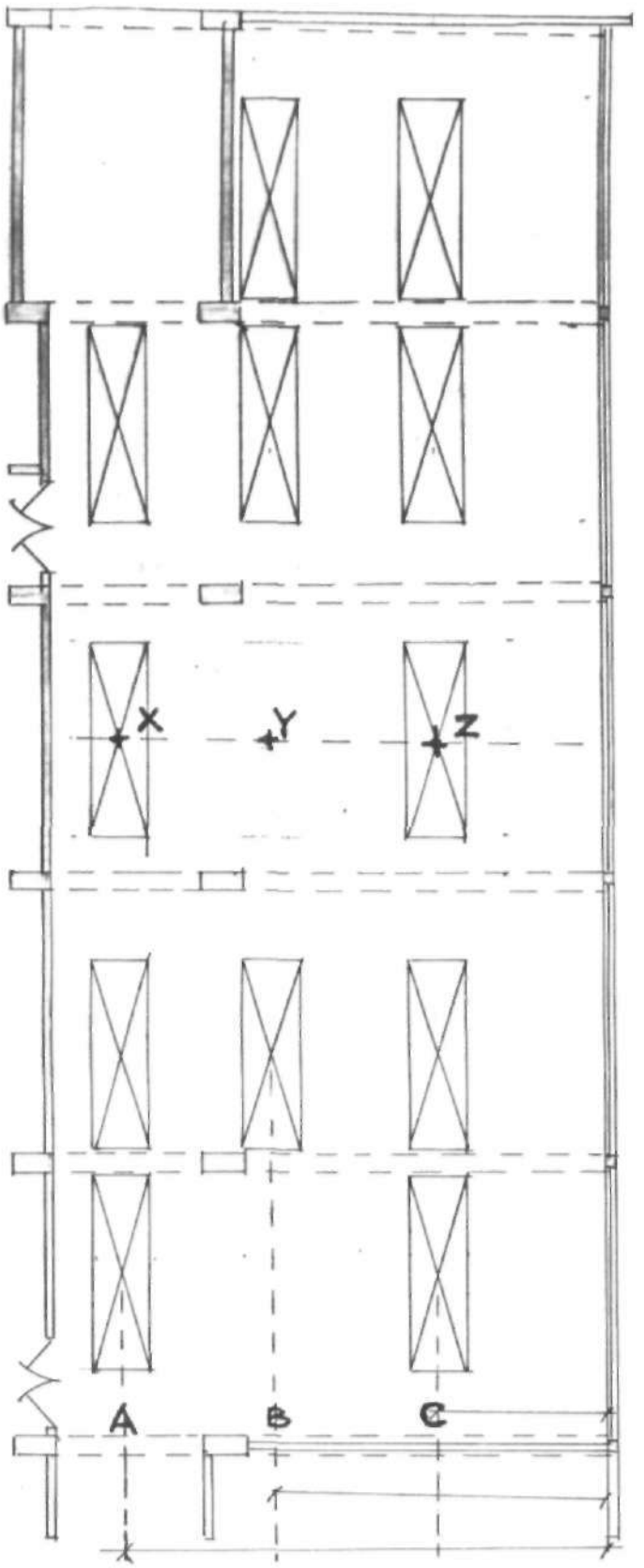


FIG. 22 LUMINAIRE ARRANGEMENT

$$Ez = 0.0149 \times \frac{2 \times 4500}{0.96}$$

$$= 0.0149 \times 9375$$

$$= 140.0 \text{ lux}$$

The quantity of artificial light at points X, Y, and Z are plotted against distance in fig. 23. Consequently Table 3 was built from the values obtained from the mentioned figure. Now the diagrams of figures 21 and 23 are drawn together to form figure 24.

The illumination level of artificial lighting appears to be higher than that necessary for supplementation when the two lamps of luminaires in row 'A' are switched on. In fact the lighting level at the back of the room is higher than that of the points near the window. This result will reduce the role of daylight in interior lighting of this room to a secondary one. This situation is not acceptable in lighting design practice. Hence the 'Day/Night' switch must be wired to switch on a row of lamps in the mentioned luminaires and not the two lamps as earlier recommended. Again, when only one lamp in each luminaire of two lamps is switched on, the supplementary lighting level drops by half and the total lighting level fails to hit the target of 750 lux except near the window. At night when 'night switch' is operated, the lighting level is uniform and equal to 515 lux. This is good enough for general lighting. But if tasks are to be performed at night, lighting calculations must be repeated to obtain 750 lux instead of 515 lux. Anyway, this design is good as supplementary artificial lighting.

Distance from window.	Illumination E (lux)
1 m	50
2 m	260
3 m	450
4 m	600
5 m	610

Table 3

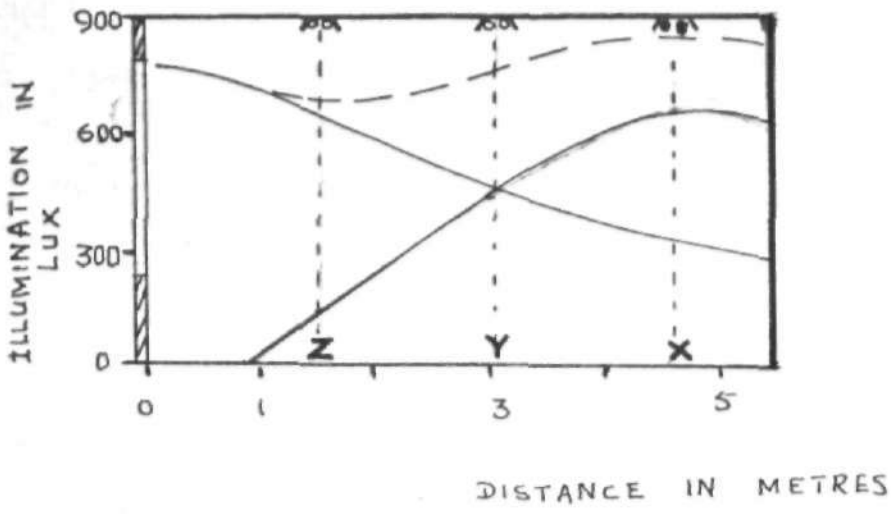

900
600
300
0
ILLUMINATION IN LUX
Z
Y
X
0
1
3
5
DISTANCE IN METRES

FIG. 23

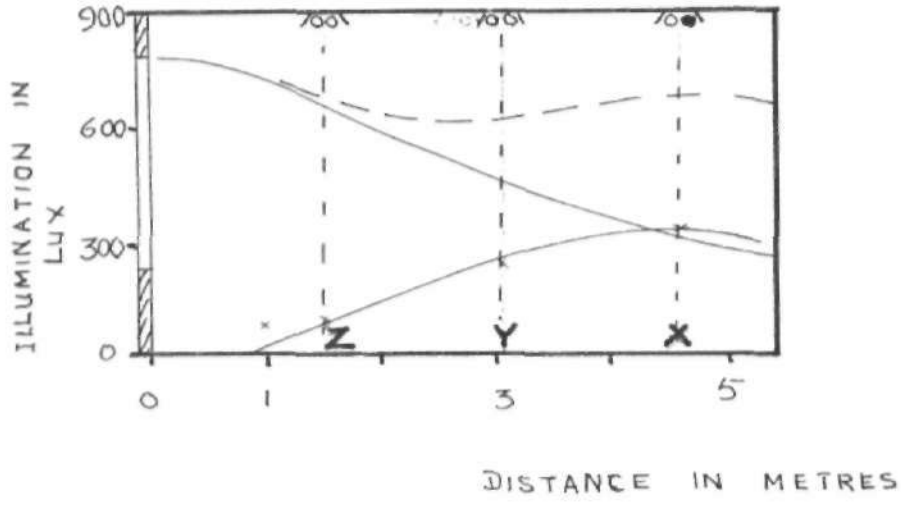

900
600
300
0
ILLUMINATION IN LUX
Z
Y
X
0
1
3
5
DISTANCE IN METRES

FIG 24

6.3.ACOUSTICS : The whole of ABU environment is quiet. The only source of noise is the electricity generator which is about 500 meters away. Apart from distance there are many buildings between the generator and the Department, and hence there are no negative acoustic effects on the site of the laboratory. But there is a car servicing depot close to the laboratory and it is about 10 meters away on the side of the windowless wall. This may occasionally have undesirable effects of the accuracy of the equipment and on the communication between the lecturer and the students during demonstrative experiments. There are two probable acoustical problems which are :

i) Vibration form the noise generating depot

ii) Background noise levels and Sound Reduction Index of the relevant external walls.

i) The frequency of vibration is unknown and since the noise source is a car servicing depot, the probable noise generator is the air-compressor. The compressor fan vibration frequency is likely to be between 5 and 50Hz. The energy of such vibration is not large enough to vibrate the earth surface area that has a width of 10 metres. The ground is assumed to have the ability of absorbing completely the vibration energy. Apart from the mentioned assumption, the equipment in the laboratory are not very sensitive to low frequencies of the compressor. In the case where this vibration is large enough to threaten task accuracy, the laboratory building may be isolated by applying resilent at a distance of 1.5 metres away from the laboratory walls and to a depth of about 50 centimetres when the depth of the laboratory foundations are not greater than 50 cm. This situation is a very extreme case and ABU laboratory does not demand this.

ii) Speech intelligibility is very essential in this laboratory and the only threat to communication is likely to come from the sound of the cars being tested. The frequency range within which this sound can interfere with

speech is 100Hz to 3150Hz. Therefore the investigation of this sound will be limited to this range 100 - 3150Hz. If speech communication is to be achieved in this laboratory, the noise problem must be approached via investigation of

a) External noise levels

b) Internal permissible background noise level

c) Noise control

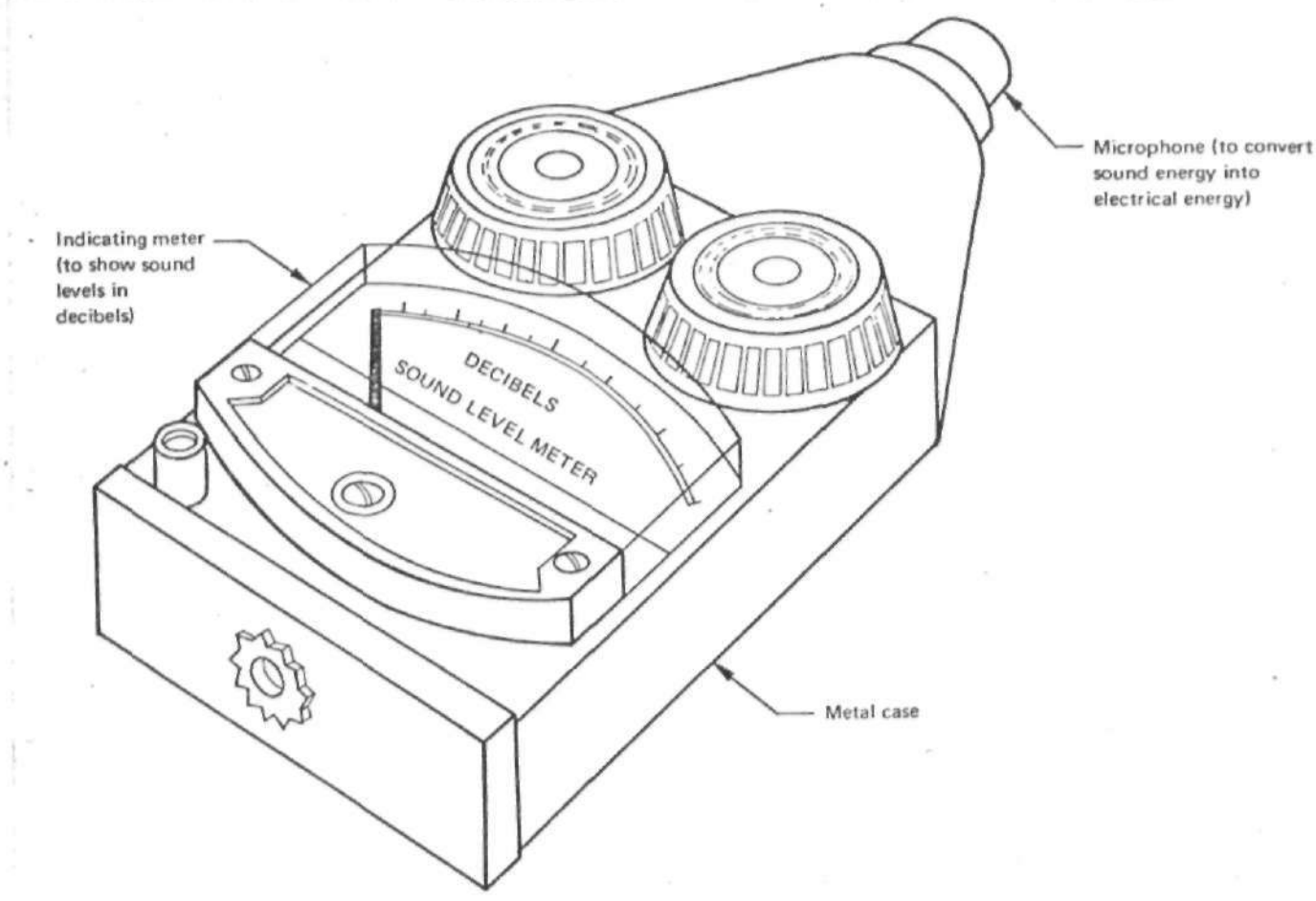
External Noise Levels : The car depot is treated as a point noise source at 10 metres away from the external wall of the laboratory. A similar noise is measured with a sound level meter and then recorded, fig. 25a. The recording was done after the sound level meter had been calibrated. The same recording was later fed into the frequency analyser which gave the results in figure 25b. Since this is not the actual sound, a lot of corrections must be carried out on the results of the analysis. Such corrections will be for temperature, humidity, distance, room absorption and external wall area. Temperature and humidity data are not available and therefore corrections cannot be made for them.

Now measurements were made at the kerb of the busy Euston Road, London. All the measured noises were analysed and 3 graph analyses of the selected noises are given in fig. 26a. Graph B in the same figure is chosen for the purpose of this exercise because it intrudes more into the subjective range of 100 - 3150Hz. Now fig. 26b gives the sound pressure level at 500Hz as 96dB. At 10 metres away it will have sound power level of Wx where

$$96 = 10 \log_{10} \frac{Wx}{W_0}$$

$$9.6 = \log_{10} \frac{Wx}{10^{-12}}$$

$$10^{9.6} = \frac{Wx}{10^{-12}}$$

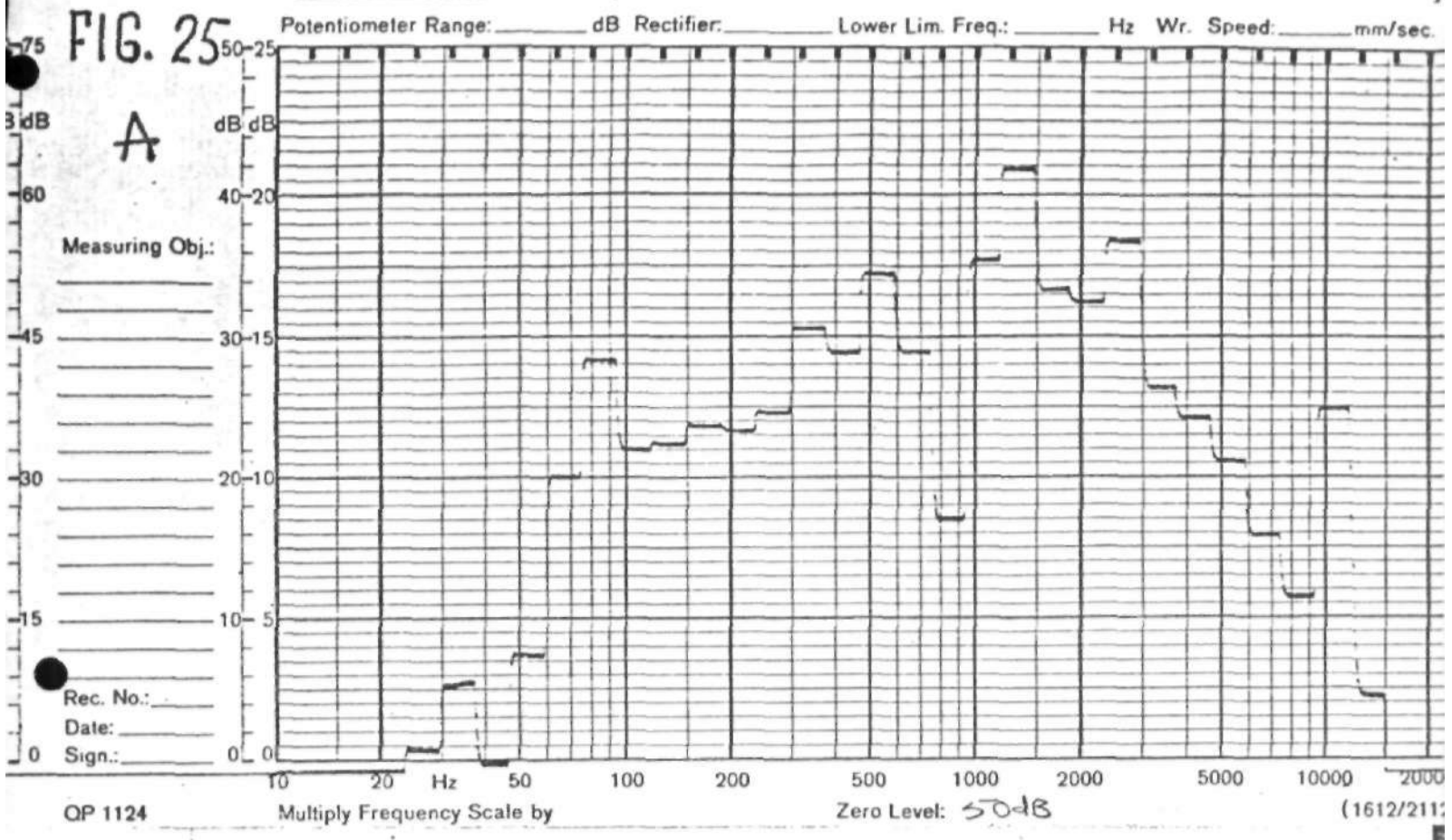


Typical hand-held sound-level meter

FIG. 25a

FIG. 25

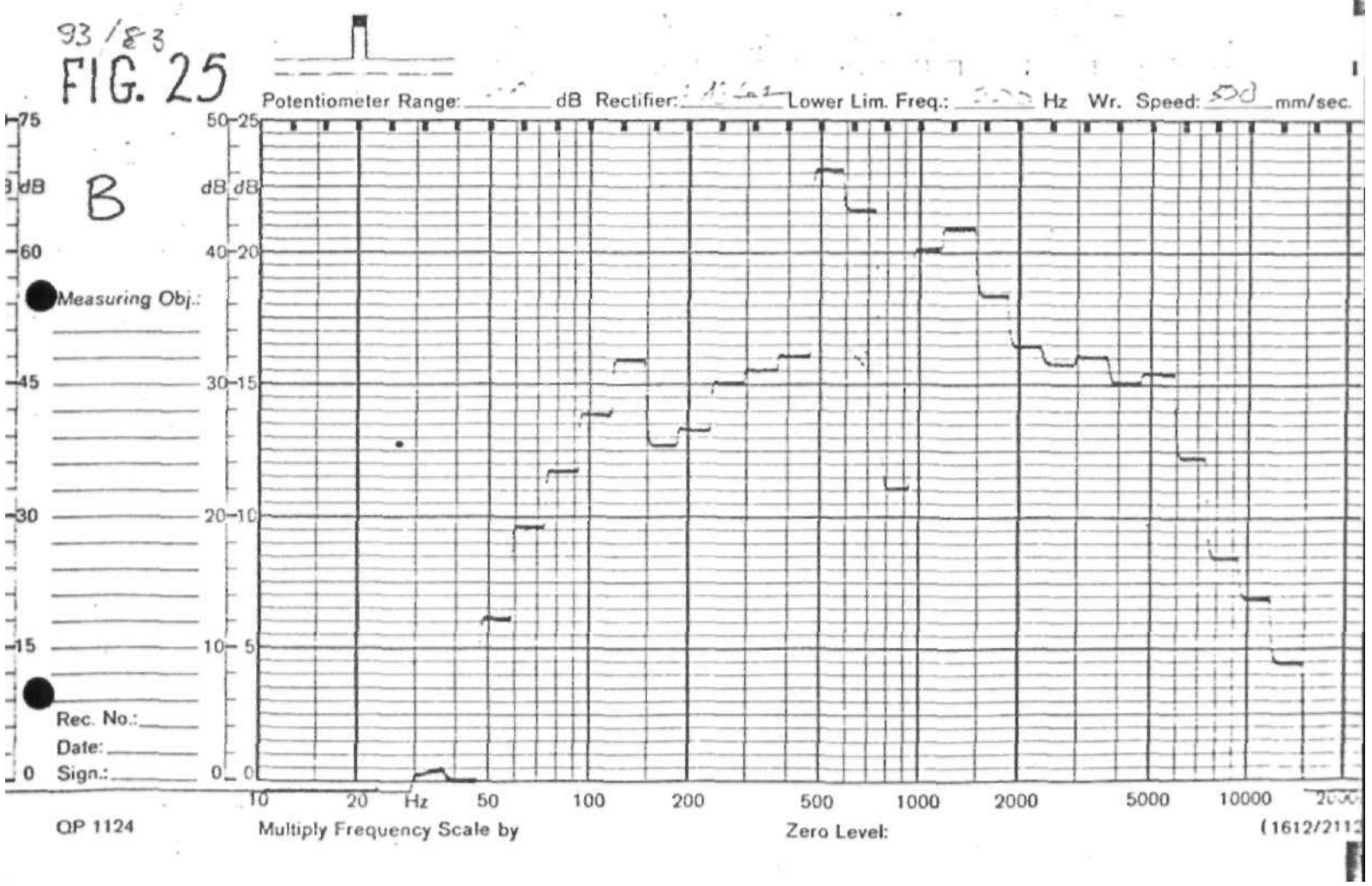
A



93/83

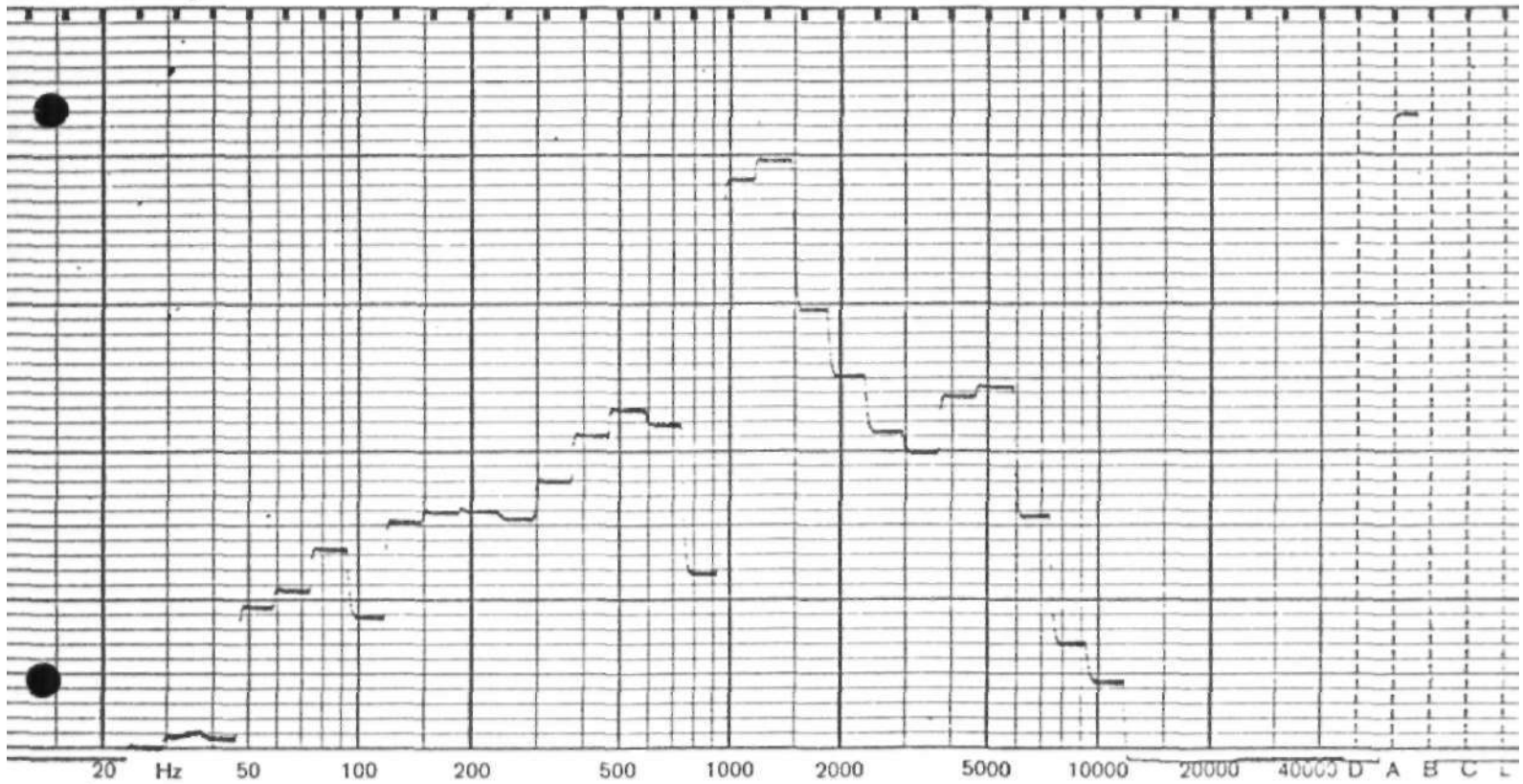
FIG. 25

B





otentiometer Range:_____ dB Rectifier:_____ Lower Lim. Freq.: _____ Hz Wr. Speed:_____mm/sec. Paper Speed:_____mm/sec



lultiply Frequency Scale by Zero Level: (1612/2112) A B C Lin.

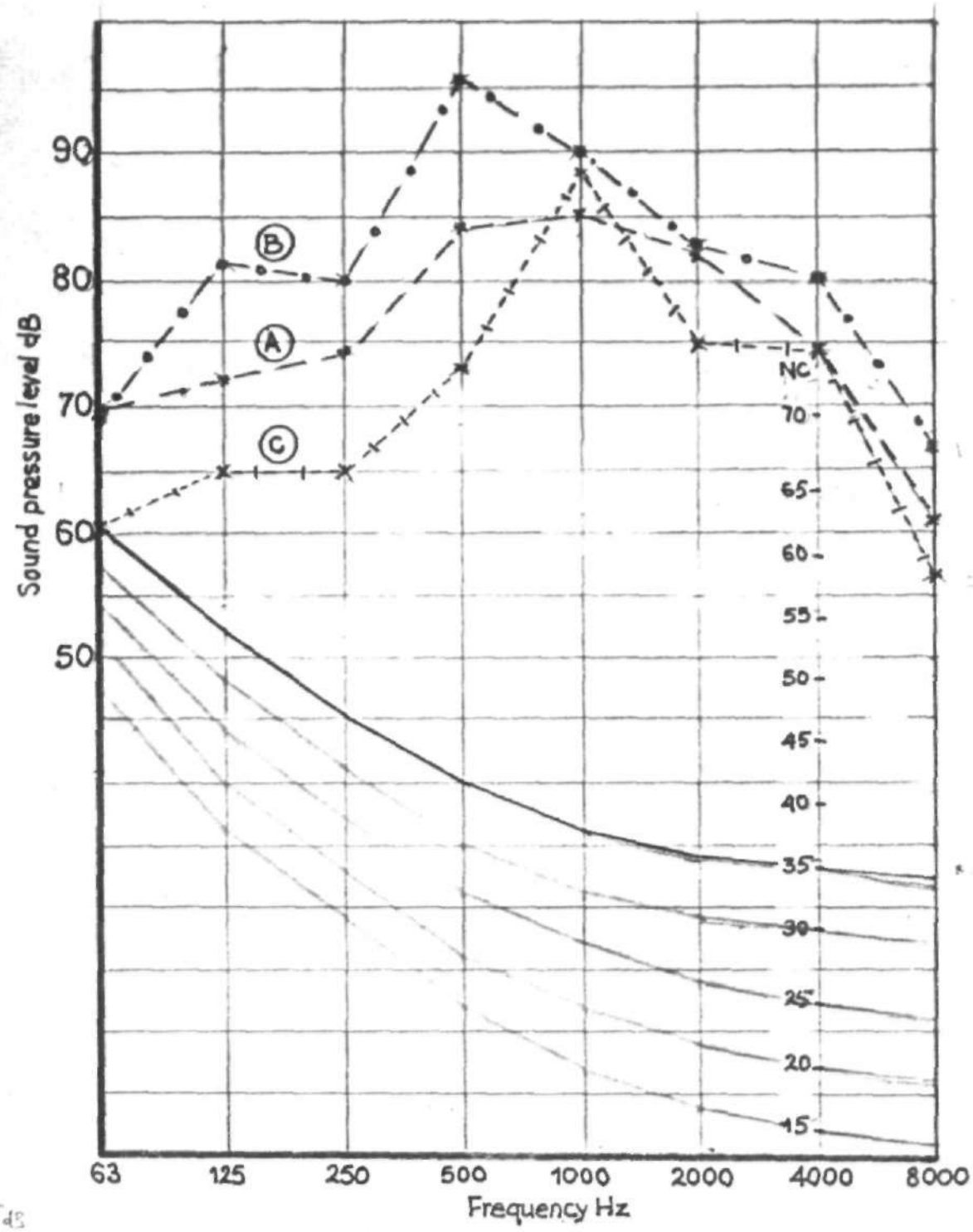


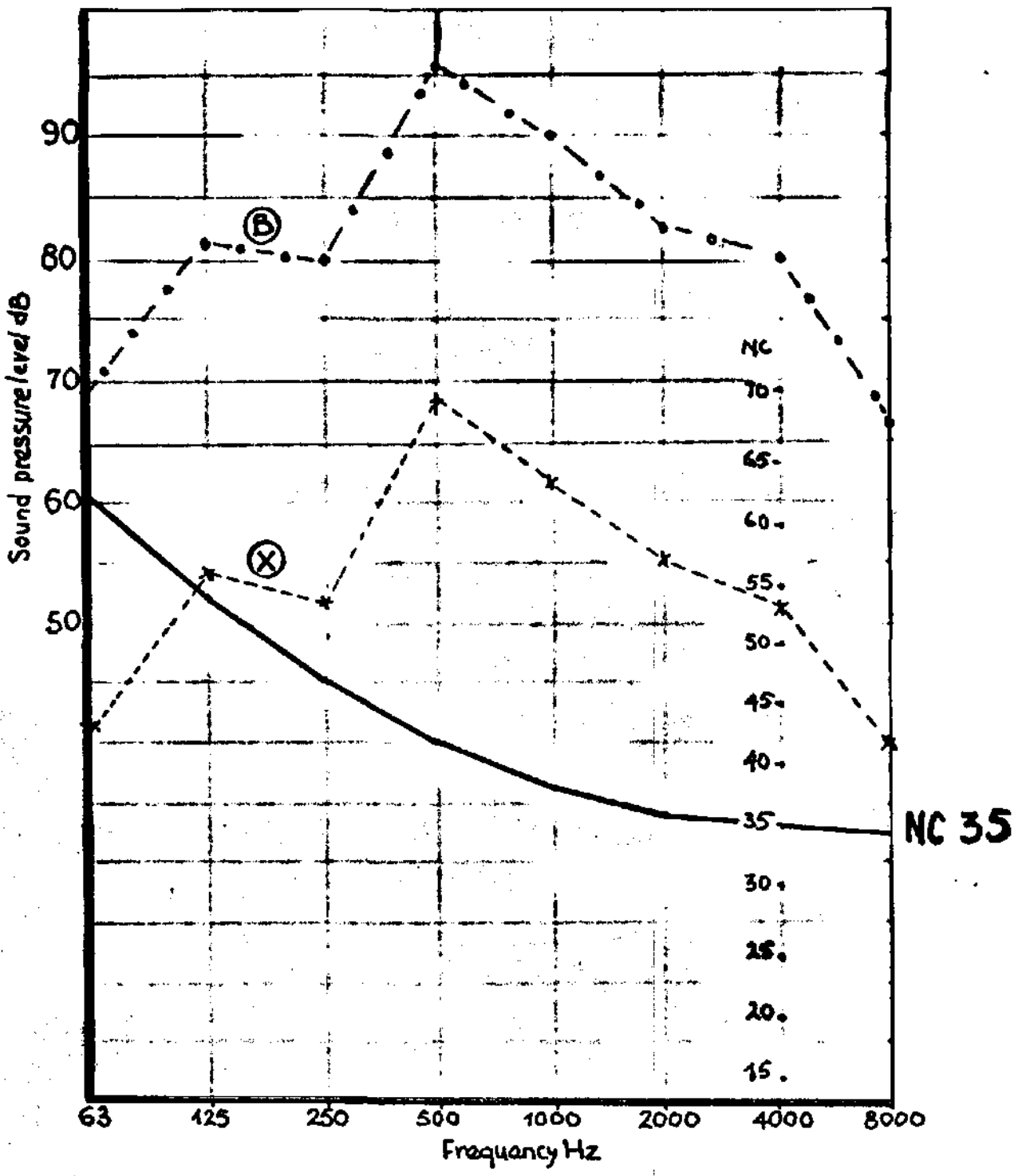
fig 26a

100 Hz → 71.5 dB

315 Hz → 87 dB.

FIG. 26 a

FIG. 26b



Ⓑ — Noise as measured at source

Ⓧ — Noise attenuated by 100m. distance

$$Wx = 10^{-2.4}$$

At 10 metres away at 500Hz

$$I_{10} = \frac{Wx}{2\pi \times 10^2}$$

$$= \frac{10^{-2.4}}{2\pi \times 10^2}$$

$$= \frac{10^{-4.4}}{2\pi}$$

Sound pressure level at 10 metres at 500Hz

$$SPL_{10} = 10 \log_{10} \frac{1}{2} \times \frac{10^{-4.4}}{10^{-12}}$$

$$= 10 \log_{10} \frac{1}{2} \times 10^{7.6}$$

$$= 68.00dB$$

Similarly the values of SPL for other frequencies are obtained and tabulated as follows in Table 4.

	Frequency in Hz	Sound Pressure Level in dB
1	63	60
2	125	54
3	250	52
4	500	68
5	1000	62
6	2000	55
7	4000	52
8	8000	39

Table 4
Background Noise SPL

Background Noise Levels: The recommended background noise level in the laboratory which in this case is treated as a classroom is NC 35. The sound pressure levels for NC 35 at different frequencies are shown in Table 5.

	Frequency in Hz	Sound Pressure Level in dB
1	63	60
2	125	52
3	250	45
4	500	40
5	1000	36
6	2000	34
7	4000	33
8	8000	32

Table 5

NC 35 SPL

If the sound pressure levels in the same frequencies in the two tables above are compared, it will be observed that the sound pressure levels from the background noise are higher than the standard required by NC 35. The interpretation of this is that the noise from the car depot is capable of interfering with speech and in fact it can totally mask it.

Sound Control : The knowledge of the noise characteristics just outside the external wall and the level of the internally permissible noise makes the solution of the local noise problem simple. The Sound Reduction Index of the external wall necessary to filter the noise from the car depot can be calculated if the difference of the sound pressure levels on either side of the wall is known at 500Hz. This frequency is chosen because empirical results have shown that the Sound Reduction Index (SRI) at 500Hz is invariably similar to the average of SRI over the frequency range of 100 to 3510Hz. The SRI at 500Hz is applicable in ABU's case because speech intelligibility spans over the frequency range of 300 to 3000Hz. Now Table 6 gives the sound pressure level difference between the background noise and NC 35 at 500Hz as 28dB. The external wall must therefore be designed to reduce the background noise level by 28dB.

Frequency (Hz)	63	125	250	500	1000	2kHz	4000	8000
External Sound Press. Level (SPL_1)	41	54	52	68	62	55	52	39
NC 35 (SPL_2)	60	52	45	40	36	34	33	32
$SPL_1 - SPL_2$	-19	2	7	28	26	21	19	7

Table 6

Now SPL_2 = SPL_1 - SRI + 10 log S - 10 log A

where SRI= Sound Reduction Index (500Hz)

S = External Wall Area - 18 x 3 = 54 m^2

A = Internal absorption in the laboratory

= Plaster absorption + Absorption of 25 students

= 261.72 x 0.07 + 25 x 1.0

= 43.3 m^2

SPL_1-SPL_2= 28 dB (at 500Hz)

SRI_{500} = 28 + log 54 - 10 log 43.3

= 28 + 17.32 - 16.36

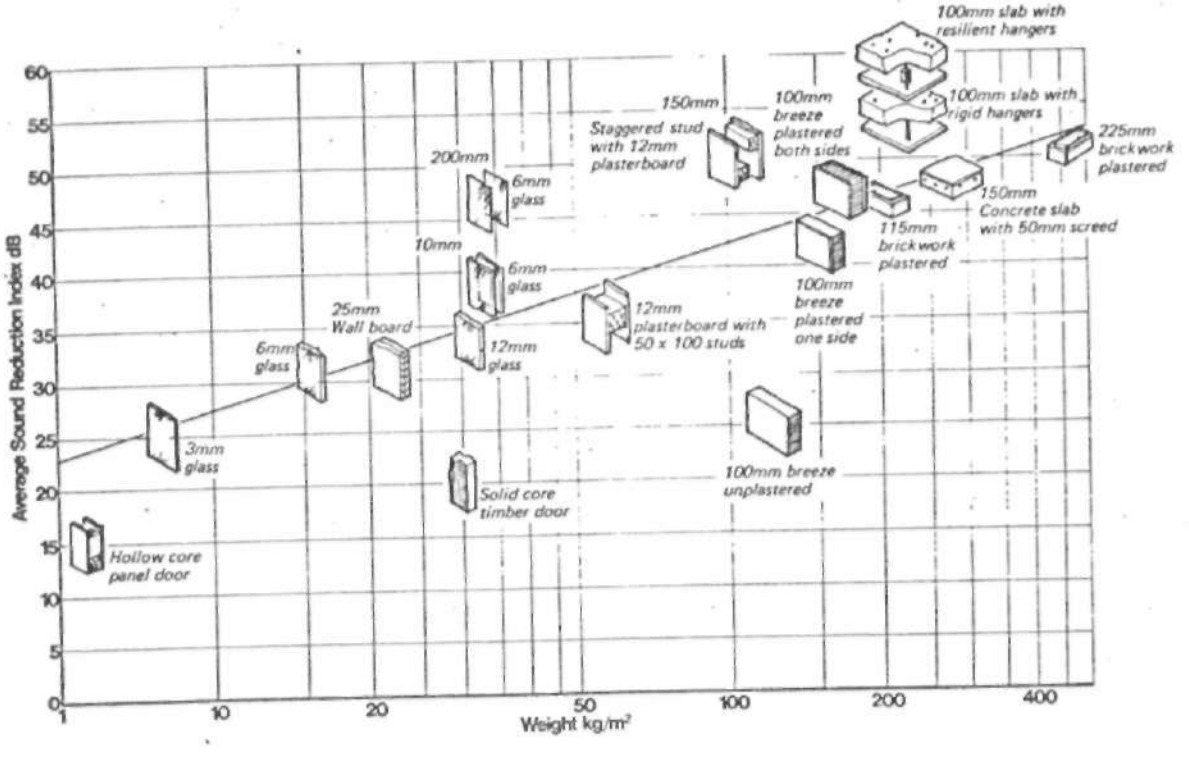
= 28.96

≅ 29 dB

CHECKING : The material used for the ABU laboratory walls is breeze concrete known locally as 'cement block'. It is actually a hollow block with an air-gap of 7 and 15 cm for block width of 15 and 22.5 cm respectively. Figure 27 shows that '100mm breeze concrete plastered on both sides' has a Sound Reduction Index of 45 dB - SRI_w. Now SRI_w = 45 dB > SRI_{500} = 29 dB. This means that the wall is good enough to reduce the noise from the car depot to an acceptable level. There is, of course, an assumption that the cement blocks used for the ABU laboratory walls are physically confirmed to have the same SRI as the breeze concrete in the figure above.

The mass of the concrete bolck is used here to control the noise and therefore the control is in the mass region where for every doubling of

FIG. 27


Average Sound Reduction Index dB
Weight kg/m²
0
5
10
15
20
25
30
35
40
45
50
55
60
1
10
20
50
100
200
400
Hollow core panel door
3mm glass
6mm glass
25mm Wall board
10mm
6mm glass
200mm
6mm glass
12mm glass
Solid core timber door
12mm plasterboard with 50 x 100 studs
150mm
Staggered stud with 12mm plasterboard
100mm breeze plastered both sides
100mm breeze plastered one side
100mm breeze unplastered
100mm slab with resilient hangers
100mm slab with rigid hangers
225mm brickwork plastered
150mm Concrete slab with 50mm screed
115mm brickwork plastered

weight there is a Sound Reduction Index improvement of 5 dB. If this principle is applied to the SRI of the concrete block, its performance can be observed in other frequencies, as in Table 7.

Frequency (Hz)	63	125	250	500	1kHz	2	4	8kHz
Concrete block SRI (dB)	30	35	40	45	50	55	60	65

Table 7 - Concrete block SRI

A comparison of concrete block SRI and the required insulation gives Table 8. This shows that the concrete block wall is capable of reducing noise beyond satisfactory levels in all frequencies.

Frequencies (Hz)	63	125	250	500	1000	2kHz	4kHz	8kHz
Concrete block SRI (dB)	30	35	40	45	50	55	60	65
$SPL_1 - SPL_2$ (dB)	-19	2	7	28	26	21	19	7

Table 8

6.4. VENTILATION AND AIR-CONDITIONING : The approach here to thermal comfort is similar to that adopted for lighting design where the laboratory space is dealt with under two sub-headings : the windowless area and the section with windows.

Windowless Area : It is difficult to have this area well ventilated by natural means. It is still more difficult to obtain here satisfactory comfortable thermal conditions for the occupants. The blind box must therefore be air-conditioned. The decision to air-condition this space can be justified if the following facts are considered :

a) The need to dissipate heat generated by the equipment - all of them generate heat.

b) The need to filter dust and dirt that are present in the North-East

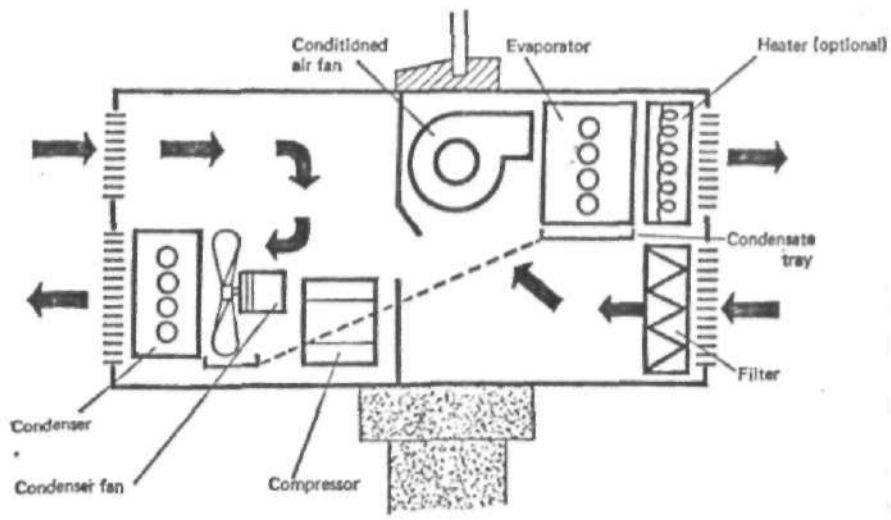
Trade Wind - the harmattan.

c) And above all, the room must be adequately ventilated for comfort and efficient performance of tasks.

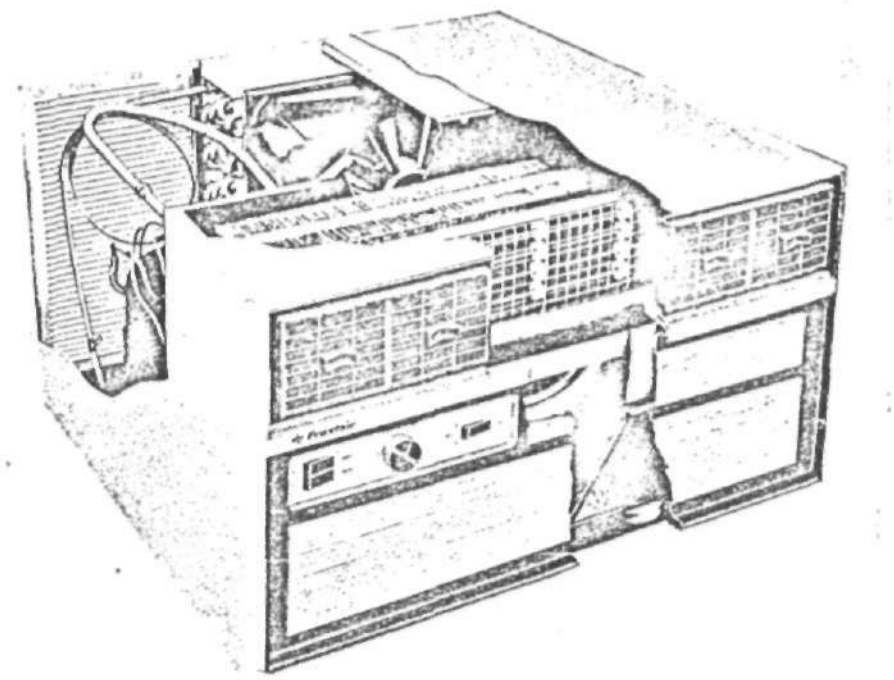
This room can be air-conditioned in two ways. The first method may be by applying the conventional air-conditioning system while the second is by the use of 'packaged air-conditioners'. Now the conventional air-conditioning system otherwise known as central air-conditioning system will need the purchase and installation of the refrigeration plant, ducts, diffusers, the grills and cooling tower. It can be concluded, without carrying out the cost analysis of this system, that a laboratory of the size proposed for ABU cannot justify an investment on the central air-conditioning system. It may be argued that the expansion of the laboratory may dictate this system and therefore it is better done now than later. Well, the rooms of the laboratory will be occupied at different times and consequently the maximum load on this air-conditioning system will be too small to justify an investment on a central air-conditioning system.

The alternative is to patronize the package air-conditioning manufacturer. The term 'package air-conditioning' is apt to mean many things to different people. To some it suggests only small room units, to others it may mean anything up to a large, pre-engineered chilled water plant. In this case it is the small room unit that is being considered. This air-conditioning unit is a system or arrangement of equipment used to achieve and maintain desired conditions of temperature, relative humidity and cleanliness of air in a given space. And its control is right on the unit which operates independently. There are many types of 'package air-conditioners' But the one that suits ABU conditions is the unit that combines air handling components and the refrigeration equipment in a single cabinet as in fig.28. Among the air handling components is the air-filter which is usually made

FIG. 28

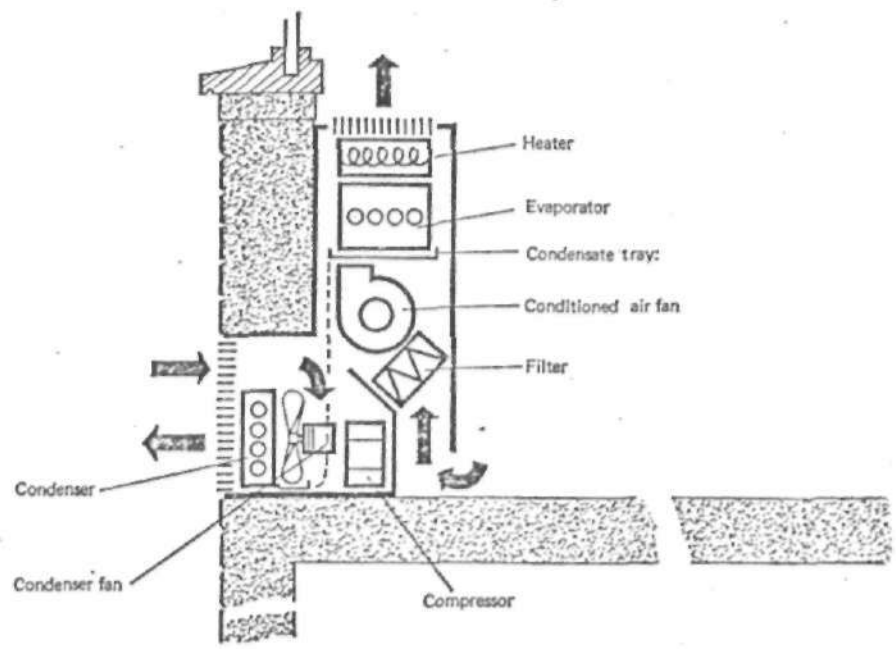


Room mounted unit in window.



Cut away view of window or wall mounting room unit. Prestair Ltd.

28



Console unit mounted through-the-wall.

from common material such as glass or synthetic fibres. In cases when filtration demands more attention, a special filter is often added. These special filters may include :

a) Automatic roll filters to reduce filter maintenance.

b) Charcoal activated filter to remove odours and gases.

c) Electrical filters to remove smoke, pollen or other very fine dust.

It is the electrostatic filter that is appropriate for the ABU laboratory because the common filter normally supplied with the package unit will be inadequate in coping with the dust from the North-East Trade Wind.

Area With Windows : This space cannot be air-conditioned because of the very large volume of air needed in the Wind Tunnel. It would have been possible to air-condition the space if the central air-conditioning system was to have been employed. The rate of air supply by the system could have been designed to equal air rate of flow in the Wind Tunnel. But it has been explained above that it is economically not viable to invest money in the central system. The other option open to any designer is the use of the package unit. Again, the basic problem is the rate of air flow and supply from the Wind Tunnel and air-conditioning system respectively. Here the rate of air supply is constant and will be less than the rate of air flow in the Wind Tunnel and consequently points of negative wind pressure will be created within this space. In turns, leakages will be created by force through the building fabric for inflow of air from outside to occupy the negative pressure points. With this phenomenon, the design of any air-conditioning system for this space will be a total failure. Finally, the method of ventilation of this space will have to be by natural means, where windows are large and window panes are of glass louvres. In fact this is the existing situation at ABU laboratory. If this situation is adopted and the laboratory is naturally ventilated, a dilemma is unlikely to be faced in the space under

consideration. Filtration of the air will be difficult because the space is not air-conditioned and the large amount of air to be drawn into the Wind Tunnel will infest the equipment with cumbersome dust. This dust can make breathing difficult, visual activities can be made impossible, and above all, the smoke path in the model room can be interferred with. Yet a rational decision needs to be taken over the ventilation of this space. A decision based on economic and technical reasons is that natural means must be employed to ventilate the Wind Tunnel room. But the dust problem must be solved and the only way of dealing with it is to occasionally collect the dust deposits in the room with a vacuum cleaner. The collection of dust may be carried out just before any experiment with the Wind Tunnel commences. Therefore it should be noted that a vacuum cleaner is indispensable with the Wind Tunnel and it must be purchased.

7. COST ANALYSIS

The examination of the viability of this project in terms of government expenditure and eventual local man-power productivity is the purpose of this cost analysis. Many methods can be applied in this exercise and each economic method will lead to a rational conclusion. But it is more rational to understand that once a laboratory has been established, the resources used have been irrevocably commited. Past design analysis and decisions are of no relevance to the future except when employed as horses of experience. Future action, therefore, can only be based on making the best use of what is available at present. Decisions depend on future costs and benefits, on comparisons between immediate and future costs and the values these will create. At any rate, it should be mentioned that this approach is only for exploratory purposes.

The two groups of costs that are involved in this comparison are the University (government) total investment and the graduate total output

during the period of productivity terminating at the end of his life expectation. The University includes building costs, equipment costs and staff costs. These costs must now be analysed.

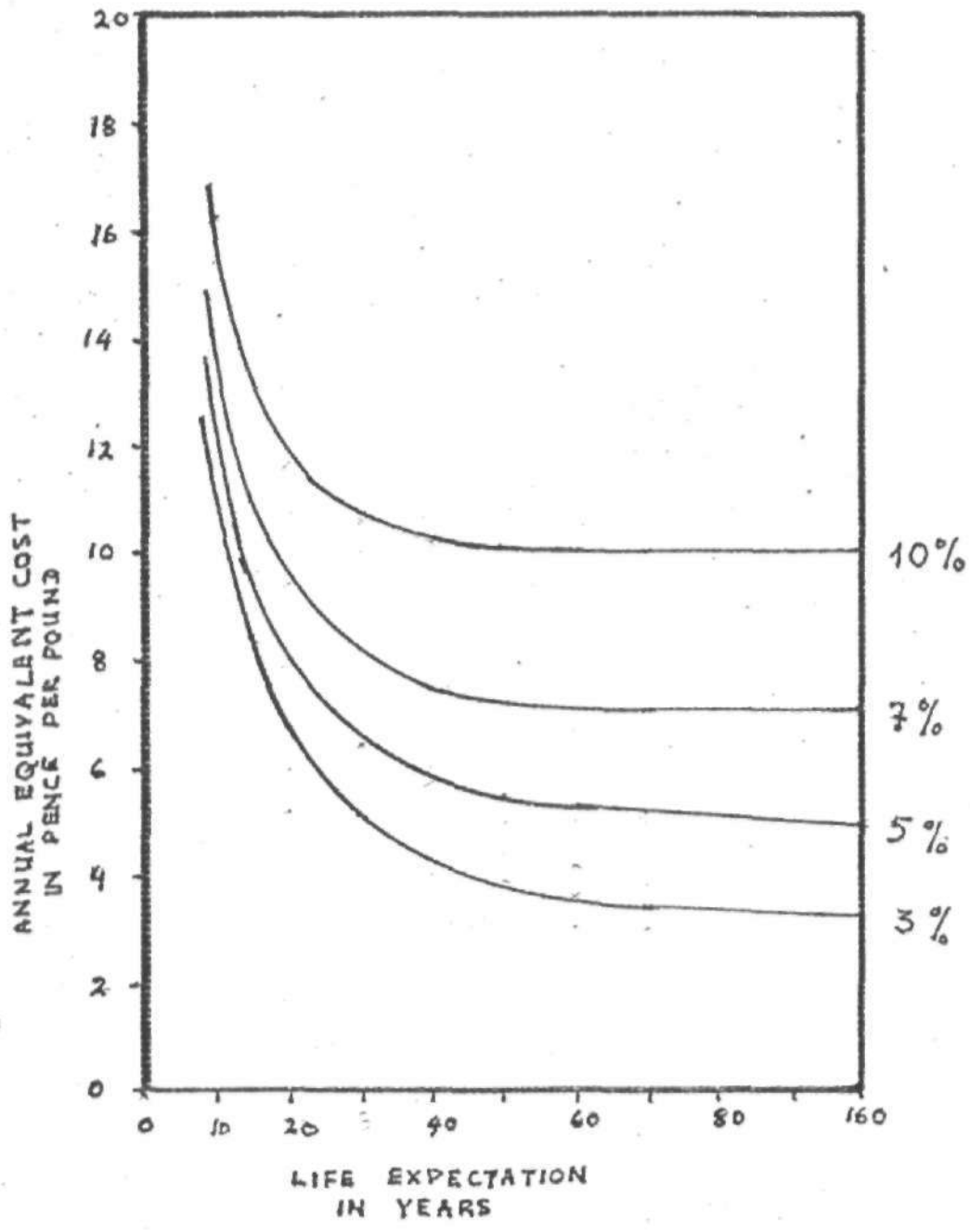
7.1. Building Costs : The costs of a laboratory building do not cease with the costs of construction but continue throughout the life of the building in the form of maintenance and other running costs, the costs of adaptation to meet changing requirements and costs of inconveniences imposed by the building on the activities carried on within it. In the application of a 'comparative technique' effective cost is an annual one. Thus usually the annual equivalent of the initial cost of the building is of more importance than the initial cost itself. The annual cost depends on the rate of interest and the economic life of the building as well as on the cost of development. Now as life which can be taken for the building increases, the annual equivalent cost falls. The rate of fall declines as the life further increases until a point is reached where annual equivalent cost becomes relatively stable. This theory can be confirmed if Table 9, copied from 'Building Design Evaluation' by P.A. Stone is studied.

Life in Years	Rate of Interest			
	3%	5%	7%	10%
10	11.7	13.0	14.2	16.3
15	8.4	9.6	11.0	13.2
20	6.7	8.0	9.4	11.7
30	5.1	6.5	8.1	10.6
40	4.3	5.8	7.5	10.2
50	3.9	5.5	7.2	10.1
60	3.6	5.3	7.1	10.0
70	3.4	5.2	7.1	10.0
100	3.2	5.0	7.0	10.0
	R. I. in pence			

Table 9
Annual Equivalent of £1/- of Initial Cost

With a rate of interest of 3 percent, relative stability is reached with a life of about 70 years; the corresponding period is about 50 years when

FIG. 29


20
18
16
14
12
10
8
6
4
2
0
ANNUAL EQUIVALENT COST IN PENCE PER POUND
0
10
20
40
60
80
160
LIFE EXPECTATION IN YEARS
10%
7%
5%
3%

$$\therefore A_n(1 + I\%) - A_n = 1 - \frac{1}{(1 + I\%)^n}$$

$$A_n = \left\{ \frac{1 - \frac{1}{(1 + I\%)^n}}{I\%} \right\} \text{ ..... (3)}$$

Now Annual Equivalent Cost (AEC) for 'n' years is $1/A_n$ (See Building Design evaluation by P.A. Stone pages 185 – 197)

$$AEC = 1/A_n \text{ ..... (4)}$$

Building AEC : The initial building cost in 1976 in Kaduna State is ₦16.00 or £12.52 per cubic foot i.e.

$£12.52/ft^3 = £10.764 \times 12.52/m^3$

$= £134.77$ per cubic metre

ABU lab space $= 3 \times 18.3 \times 9.1\ m^3 = 499.59$

Building cost $= £134.77 \times 499.59$

$= £67326.83$

The annual equivalent cost of ABU laboratory building can be calculated since the following data are now available:

a) Building life expectancy – 50 years

b) Interest rate – 7%

c) Initial building cost – £67326.83

Substituting for these values in equation (4)

$$\text{Building AEC} = \frac{\frac{7}{100}}{\left[1 - \frac{1}{(1 + \frac{7}{100})^{50}}\right]} \times £67326.83$$

$= 0.07246 \times £67326.83$

$= £4878.49$

Running Costs (Building)

These costs are estimated as annual equivalent costs with conventional methods. And

Maintenance = £340.00

Electricity = £360.00

Lamps replacement = £285.00

£985.00

Total annual equivalent cost for building is AEC_1 which is

Building AEC = £4878.49

Running cost = £ 985.00

AEC_1 = £5863.49 ..... (I)

7.2. Equipment AEC: The life expectation of any equipment is between 15 and 20 years. After this period, the equipment is expected to be replaced or another type of equipment set up in its place. Now the life expectation of the equipment in the ABU laboratory is taken as 20 years which is half of the period required to calculate the annual equivalent cost. In order to employ 40 years of life expectation and 10% interest for the calculation of AEC, it is assumed that all the equipment is replaced after 20 years and that no expansion takes place between this period.

The initial costs of the equipment are as follows: (Costs are in pounds)

Artificial Sky	£ 4950.00
Artificial Sun	4950.00
Heliodon	380.00
Wind Tunnel	6050.00
Stabiliser (Power)	2200.00
Daylight photometer	300.00
Architectural Illuminance Meter	500.00
Hagner Luminance Meter	1000.00
Illuminance Meter	130.00
Daylight Factor Meter	150.00
Sound level Meter, Calibrator and Recorder	1000.00
Whirling Hygrometer	500.00
Smoke generator and Air Velocity meter	495.00
Velocity Measurement Equipment	770.00
Demonstration Equipment (Colour)	1210.00
Model room (Art. light study)	1100.00
	£25685.00

Since the life expectation is taken to be 40 years - 2 x 20 real life expectation - the initial cost of equipment is doubled and the cost is now

= £2 x 25685.00

= £51370.00

Air-Conditioner - The operative life of a package air-conditioner is five years which is 1/8 of 40 years. So the unit will be replaced 8 times before the laboratory life expectation expires. If two units are installed in the laboratory and each unit costs £500.00, then the total initial investment can be assumed to be £8000.00 for 16 units.

Now	Total equipment cost	=	£51370.00
	Contingency sum	=	5000.00
	Consultancy (UCL) charges	=	4000.00
	Installation cost	=	2000.00
	Air-conditioning cost	=	8000.00
			£ 70370.00

Again, the annual equivalent cost is calculated with the following data:

Equipment initial cost	=	£70370.00
Interest rate	=	10%
Equipment life expectation	=	40 years

$$\therefore AEC = \frac{\frac{10}{100}}{\left[1 - \frac{1}{(1 + 0.1)^{40}}\right]} \times £70370.00$$

= 0.10226 x £70370.00

= £7196.00

The total annual equivalent cost is the sum of the following:

Equipment AEC	=	£7196.00
Maintenance cost	=	800.00
Electricity	=	320.00
Lamps replacement	=	200.00
		£8516.00 ..... (II)

7.3. Investment On Staff - The staff maintenance cost include the following :

a) Salary per annum

b) Fringe benefits per annum

c) Training estimate per annum

The total maintenance cost is estimated thus :

1 Lecturer in charge	=	£8898.4
1 Technician	=	£6319.2
2 Assistant Technicians	=	£3949.5
		£19167.10

i.e. £19167.10 *per annum* = AEC .....(III)

The total of all annual equivalent costs is AEC_T

(I) : Building	.....	£5863.49
(II) Equipment	.....	£8516.04
(III) Staff	.....	£19167.10
		£33546.63

The annual equivalent cost to be invested by the University is AEC_T where

$$AEC_T = £33546.63 \quad \ldots\ldots\ldots (IV)$$

The Federal Government of Nigeria expend ₦4500 or £3554.55 on every student annually. Therefore on 60 graduate architects, the Government will invest G.I. where

$$G.I._t = £60 \times 3554.55$$

$$= £213273.00$$

$$AEC_T = \frac{33546.63}{213273.00} \times 100\% \text{ of G.I.}$$

$$= 15.73\% \text{ of G.I.}$$

7.4. Architects Productivity

Life expectation	30 years
Salary	₦ 6000 initial/ per annum
Number of graduates ...	60

Annual productivity is treated as the repayment of annual equivalent cost.

If annual basic salary is the value attached to the architects annual

productivity then the productivity of all graduate architects per annum is

= £60 x 6000 x 0.7825

= £281700.00

But investment on laboratory is 15.73% of the total government investment. If it is assumed that productivity is proportional to investment, then a proportion of productivity is equal to a proportion of investment. Hence only 15.73% of productivity will be compared with AEC_T

∴ 15.73% of £281700.00

= £44311.41

Comparison :

£44311.41 > £33546.63

Since output is greater than input and since it can be said that the government annual profit is £44311.41 - £33546.63 = £10764.78, the project is viable.

Errors :

There are many sources of error in this analysis. All except two of the sources of error have negligible effects on the final result. Rate of global inflation is a factor which is deliberately ignored. And the productivity of the architect should have been computed with the application of arithmetical progression summation formula. In the final comparison, the two will cancel out and the error introduced in this analysis is minimal.

8. CONCLUSION

One of the criteria by which a project can be judged is whether it is implemented; the one thrown onto the shelf is nothing but analysis of the then existing factors which will need review to apply to the present or the future. The implementation of any project depends largely on the availability of funds and the viability of such projects. But a developing technology must play down the viability aspect of any analysis if dangerous

constraints are not to be imposed on the development of a developing nation. The comfort and efficiency of man are what really matter and that is what technology sets out to achieve.

BIBLIOGRAPHY

1. The Design of Research Laboratory – The Nuffield Foundation – London 1961.
2. Laboratory Planning – J.F. Munce –London 1962.
3. Practical Laboratory Planning – W.R. Ferguson – London 1973.
4. Hospital Lighting – Edited R.G. Hopkinson – London 1964
5. Building Design Evaluation – P.A. Stone – London 1975, pp.185–198.
6. Acoustic Tests and Measurements – Don Davis – Slough Bucks 1975.
7. A Study of Interior Illumination Due to Skylight Under Tropical Conditions – J. Longmore, R.G. Hopkinson – Netherlands 1967.
8. Packaged Air Conditioning – The Electricity Council – London 1974, pp. 7–15
9. Teaching Laboratories – RIBA Conference – London 1958.
10. Design and Performance of Wind Tunnel for Building Research – D.E. Sexton – Garston
11. Growth and Changes in Laboratory Activity – Laboratory Investigation Unit – London 1971.
12. An approach to Laboratory Building – Laboratory Investigation Unit – London 1969.
13. IES Code, Interior Lighting – The IES – London 1977.
14. Ahmadu Bello University Calendar 1978/79 – ABU Press Ltd. – Zaria 1978.
15. Efficient Electricity Use – Edited C.B. Smith – New York 1976.
16. Manual of Tropical Housing and Building – Koenigsberger, Ingersoll, Mayhew and Szokolay – Hong Kong 1978.
17. Acoustic Noise and Building – P.H. Parking, H. Humphreys and Cowell – London 1979.
18. Electricity 'Questions and Answers' – K.G. Jackson – Aylesbury Bucks. 1976.
19. Interior Lighting Design – Edited D.W. Wurrant – London 1977.
20. Practical Building Acoustics – Sound Research Laboratory – Sudbury Suffolk 1976
21. Environmental Physics 'Lighting' – D.C. Pritchard – London 1978, pp. 76–78.
22. Daylighting – R.G. Hopkinson, J.Longmore and Petherbridge – London 1966 pp. 383–384.
23. Concept in Architectural Acoustics – M.D. Egan – New York 1972.