REFLECTIONS ON ENVIRONMENTAL CONTROL: LUMINOUS AND SONIC ENVIRONMENTS INSIDE THE DESIGN STUDIO

A THESIS
SUBMITTED TO THE DEPARTMENT OF
INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN
AND THE INSTITUTE OF FINE ARTS
OF BİLKENT UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF FINE ARTS

By
ÖMER ÖNEN
SEPTEMBER, 1995

REFLECTIONS ON ENVIRONMENTAL CONTROL: LUMINOUS AND SONIC ENVIRONMENTS INSIDE THE DESIGN STUDIO

A THESIS

SUBMITTED TO THE DEPARTMENT OF

INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN

AND THE INSTITUTE OF FINE ARTS

OF BİLKENT UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF FINE ARTS

By

Ömer Önen

September, 1995

Ömer ÖNEN
tarafından bağışlanmıştır.

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

Assoc. Prof. Dr. Cengiz Yener (Supervisor)

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

Prof. Dr. Mustafa Pultar

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

Asst. Prof. Dr. Nur Demirbilek

Approved by the Institute of Fine Arts

Prof. Dr. Bülent Özgüç, Director of the Institute of Fine Arts

ABSTRACT

REFLECTIONS ON ENVIRONMENTAL CONTROL: LUMINOUS AND SONIC ENVIRONMENTS INSIDE THE STUDIO

Ömer Önen

M.F.A in Interior Architecture and Environmental Design

Supervisor: Assoc. Prof. Dr. Cengiz Yener

September, 1995

In this thesis, two environmental control parameters -lighting and acoustics- are studied. Since one of architecture's primary concerns is to provide human being's with comfort, emphasis is put on the approach that design decisions pertaining to lighting and acoustics should be considered in the earlier phases of the designing process. The design studio has been chosen since it houses many different functions simultaneously, with its significance as the place where design education actually begins. Accordingly, norms, numeric standards and common designing principles are compiled for design studios. Then, the lighting (luminance, illuminance) and acoustics (sound pressure level) performances of the design studios of the Dept. of Interior Architecture and Environmental Design, Faculty of Art, Design and Architecture of Bilkent University are measured. The results are, finally, evaluated and concluded with general technical advises for the amelioration of the measured studios.

Keywords: Environmental Control, Lighting, Luminance, Illuminance, Acoustics, Sound Pressure Level, Design Studio.

ÖZET

ÇEVRE DENETİMİ ÜZERİNE DÜŞÜNCELER: TASARIM STÜDYOLARINDA AYDINLATMA VE SES ORTAMLARI

Ömer Önen
İç Mimari ve Çevre Tasarımı Bölümü
Yüksek Lisans
Tez Danışmanı: Doç. Dr. Cengiz Yener
Eylül, 1995

Bu tezde, çevre denetimi değişkenlerinden ikisi -aydınlatma ve akustik- çalışılmıştır. Mimarinin öncelikli ilgi alanlarından birinin insanlara konfor sağlamak olduğu düşünülerek, aydınlatma ve akustiği ilgilendiren tasarım kararlarının, tasarım sürecinin erken aşamalarında ele alımasının gerekliliği vurgulanmıştır. Tasarım stüdyosu, bir çok farklı işlevi eşzamanlı olarak barındırdığı ve tasarım eğitiminin başladığı yer olduğu için seçilmiştir. Bunlara bağlı olarak, tasarım stüdyosunu ilgilendiren standartlar ve genel tasarım ilkeleri derlenmiştir. Bir sonraki aşamada, Bilkent Ü., G.S.T.M.F., İç Mimari ve Çevre Tasarımı Bölümü stüdyolarının aydınlatma (parlaklık, aydınlık) ve akustik (ses düzeyi) performansları ölçülmüştür. Sonuçta, ölçümlerden elde edilen bulgular değerlendirilmiş, performansları ölçülen stüdyoların iyileştirilmesi için önerilerde bulunulmuştur.

Anahtar Sözcükler: Çevre Denetimi, Aydınlatma, Parlaklık, Aydınlık, Akustik, Ses Düzeyi, Tasarım Stüdyosu.

ACKNOWLEDGMENTS

My deepest gratitude goes to Mr. Cengiz Yener. Without his endless support and care, this thesis could have never been realized. His wisdom and knowledge in his field of studies is exceptional, as is his patience and assistance. I owe much of thesis to his unending patronage in all areas of education and his dedication to science.

In addition, I would like to thank Ayşıl Yavuz and Yıldırım Yavuz for their consistent interest and help throughout the development of the thesis. Their close attention played an important role in the finalization of the thesis.

Finally, I would like to thank Mr. Mustafa Pultar, Mr. Türel Saranlı, Mr. Önder Seren for their aid in the progress of the thesis; Miss Ebru Şahin and my family for their unforgettable collaboration during the two years of the Master's program at Bilkent.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

> ' On the error of those who practice without science.
> Those who fall in love with practice without science are like pilots who board a ship without rudder or compass, who are never certain where they are going.
> Practice ought always to be built on sound theory.'
>
> Leonardo da Vinci

The natural environment of the earth rarely provides its occupants with satisfactory conditions for optimum development and well-being. To overcome this obstacle, humans have built shelter; simply to protect themselves, to alter the conditions of nature and satisfy their psychological and physiological requirements at optimal levels. Throughout history, building makers have developed various solutions to the limitations introduced by local environmental conditions on human comfort. In a slow pace of trial and error, indigenous building types, with traditional solutions embodying the most suitable material and form combinations, have emerged. The major concern of architecture, accordingly, is to remove the gross environmental load of nature from the shoulders of humans by forming man-made environments where their sensory and behavioral conditions are optimally comfortable. This is only possible if man-made shelters function with environmental control mechanisms for protection from the hostile or disruptive external environmental conditions, such as air motion, noise, humidity, rain, electromagnetic radiation. Only then can humans maximize their capacities and focus their limited energy upon performing those tasks and activities which are the essence of the human experience.

Today, through rapid progress in building sciences, wide ranges of materials, products, forms, and solutions have become available. During the twentieth century, great achievements have been accomplished in the evolution of energy-consuming devices and comfort-oriented environmental control mechanisms. However, as a natural consequence of industrial and technological developments, more complex environmental problems have arisen. These new environmental problems -together with new environmental possibilities- are to be dealt in accordance with new demands from building functions and occupants.

As a result of this rapid growth, the role of the designer has evolved. It is crucial for designers to understand the primary nature of the relationship between the building and the natural environment, since a building is the most important instrument used to modify it. The topics a designer has to undertake have increased both in number and magnitude. For example, considerations of human sensory response and behavior to the surrounding environmental conditions have entered the domain of the designer. The breadth of knowledge applicable to architecture has grown tremendously, redefining architecture strictly as the group work of specialized professionals. Progress has accelerated research. Fundamental principles underlying new environmental phenomena are defined. Guiding standards are set for the designers by governmental and multinational research and development institutions. Methodology patterns are established for solving common environmental design problems inside the building.

At the outset of the thesis, it will be of good practice to clarify the intended meaning of the word 'environment', as this will ease understanding of the scope of the work. In the broadest sense, environment refers to nature and the borders of nature are set by the earth, on which all life forms exist. This definition, however, is far too general for the projected extent of the study. Rather, the environment and its relationship to humans is of particular interest. In order to enhance understanding, the definition of the environment should be limited to a ' momentary environment of one person in a defined position or state, where he responds in some way to the surrounding stimulus field ' (Szokolay 1). As the senses are concerned, the physical limits of man's environment can hardly be defined in exact terms, since stimuli arrive from a great range of distances. However, in order to set the basis on which this study will prosper, it is vital that certain limitations to the definition of environment are stated. The following sections will seek to explain the path on which the thesis will proceed.

1.1 Two Parameters of Environmental Control

It is necessary to consider two parameters of environmental control in the design process of buildings: Light and sound.

' Lighting design is considered to be the creative process to produce lighting methods and solutions for safe, productive and enjoyable use of the built environment, utilizing available illumination engineering technology' (Illumination Engineering Society, Application 1-1). It is much more than just a building system; it is both an art and a science. Lighting directly appeals to the senses, making it available for humans to perceive the surroundings through the interaction of light and shade. Bad lighting, alone, would be enough to mask the aesthetic beauty of any architectural building or artwork. Appearances of forms, colors, details, surfaces, textures and materials would be unrecognized in the absence of designed lighting. As again, the design decisions pertaining to natural and artificial lighting should be considered in the earliest phases of the course of design. Even though alterations can be made to the artificial lighting system of a building after it has been completed, the decisions concerning natural lighting should be dealt with in the beginning; for judgments of window sizes, permanent shading devices, and building orientation can hardly be modified after the construction of the building. Moreover, ' without good lighting, we would waste billions of dollars a year on salaries and benefits and ultimately on energy, spinning our wheels' (Steffy x). This leaves the designer with the theoretical and professional challenge of achieving high-quality environmental goals and specifications within the context of limited energy demand

and reasonable building and equipment costs. Again, it is the concern of the responsible designer to conceptualize or visualize lighted space and program his/her design accordingly. The sections on lighting of this thesis will seek to address the programming issues in lighting design applicable to design studios. Primary rule of thumbs will be pointed out within an outline as to help the designer to achieve successful lighting solutions. Numeric standards will be indicated enabling the designer to realize basic calculations.

The foremost principle of architectural acoustics is to ' design for good hearing and freedom from noise in and around buildings ' (Egan xv). This basic rule of acoustics have become an important new tool for shaping the built environment. It is important for the designer to realize the fact that diffusing the knowledge of acoustics and to promote its creative applications in design is of utmost significance for the success of his/her creation. ' Hopefully, not only better acoustical environments, but also better buildings should result ' (Egan xv). Acoustic requirements of a building should be taken into consideration during the earliest stages of the designing process. Although modifications can be made on the design later on, these will not be easy; for acoustical amelioration of spaces usually demand radical changes in the shapes of spaces. Once the building is constructed, it is very difficult to change shapes of spaces, room heights, and other related design decisions such as adjacencies to other spaces and buildings. Corrections in completed spaces are very laborious and expensive. To avoid this, the designer should understand the basic principles of acoustics. Thus, it is the responsibility of the designer to arrange for flawless relationships between spaces, shapes, volumes, adjacencies such that their buildings behave acoustically efficient while effectively serving the intended purpose for which they were constructed. It should be remembered that the ' correct application of the principles of architectural acoustics can considerably improve the quality of life at work, during leisure time and in the home' (Ginn 8). The objective of this argument is, therefore, to provide the designer with an extensive background on classroom - design studio- acoustics through compiling a set of fundamental concepts and definitions necessary for understanding architectural acoustics.

1.2 Methodology

This section of the thesis aims to identify the criteria on which the study stands. Decisions which determine the path of research will be explained in detail.

The bodies of knowledge of acoustics and illumination are very principal to environmental control. Through years of research and application, they have rightfully entered the realm of architectural practice and constitute an inseparable portion of the framework of intelligence which define architecture.

Architectural design, from a theoretical point of view, is a scenario. The designing of any structure depends upon a conceptualization of the events which are expected to take place within the structure. The architect, as the scenarist, conceives of the spaces where these events will occur, and through complex interactions of technical, aesthetically, and cultural reflections, forms a setting for the intended play. Many of the outcomes of architectural design are straightforward or unconscious representations of these scenarios.

Among the many variables of architecture, there is one constant; man. The whole architectural profession has one overruling motive; to satisfy the physical, psychological, and social needs of man.

From the point of interest of this research, the physical satisfaction of man steps forward as the most determinant factor of environmental control. In abstract terms, humans act as a meter of satisfaction through their responses and judgments. What conditions are suitable for or preferred by man can be established through well-planned and executed studies. However, man as the experimental subject, cannot provide the experimenter with precise measurements, for he/she can only make comparative judgments. Moreover, ' if a group of people is subject to the same environment, it will not be possible, due to biological variance, to satisfy everyone at the same time' (Fanger 13). Then, the aim of the designer should be to create an optimally comfortable environment for the group; a condition in which the highest possible percentage of the group is in comfort.

Despite the subjectivity of man, it should be realized that one of the purposes of this study is to understand the basic physical needs of man, in terms of sound and light, in a functionally predefined setting. The drive for limiting the research environment has several justifications. As a result of the surplus of information on the general headings of lighting and acoustics, the researcher was driven to seek ways to apply the mass compilations of information on a specific area, where there was a need for focusing. Due to its rich functional definition, which will be outlined in the next chapter, and its significance as the place where future designers are to be educated, the design studio appeared to be the perfect choice to consider.

One might argue the isolation of a classroom from its surroundings, as every system is a part of a larger system and that all systems are, to some degree, connected to each other. The classroom is surrounded by corridors and other classrooms; the faculty building is adjacent to roads and other school buildings; the university is an integral part of the texture of the city, with roads and building complexes neighboring it. Thus, the activities taking place within a classroom are, to a certain degree, a part of the universe, the ultimate system. However, such a strict abstraction is arbitrary. For research purposes, the isolation of a classroom from the rest of the system can be justified as it can be said that the classroom has measurable and controllable physical boundaries. This study, therefore, carefully assesses the activities taking place within a classroom - in this case a design studio- in terms of luminous and acoustical conditions.

The Faculty of Art, Design, and Architecture of Bilkent University is formed of three adjoining buildings (see Appendix A) which forms a monoblock structure, housing the departments of Interior Architecture and Environmental Design, Graphic Design, Fine Arts, and Urban Planning and Landscape Architecture. The faculty accommodates over 800 students in more than 30 design studios. Within this context, the selection of the Faculty of Art, Design and Architecture as the place for the measurements of design studios appeared as a correct decision, since the buildings concerned are supposedly constructed with the most up-to-date construction techniques and material choices reflecting present-day design developments and contemporary environmental concerns. Within the Faculty, the design studios of the Department of Interior Architecture and Environmental Design are selected. Ideally, one might think, that it would be more appropriate to measure all the studios of the Faculty. However, from a systematic standpoint, one will realize that limiting the number of studios is a requirement of the scope of the intended study. Moreover, one will discover in the following chapters of the thesis that a further elimination among the design studios of the Department of Interior Architecture and Environmental Design Building is carried out, due to the fact that the floor plans of the building are identical, with studios on top of each other, having similar physical and social characteristics. Studios with unique characteristics are also included in the study. Meanwhile, attention was shown to include one studio from all four classes of the department program.

1.3 Form

The form of the thesis is analytical. The thesis starts out with an introduction which, basically, aims to explain the principles on which the study develops. The second chapter aims to decorate the reader with in-depth explanations on the subjects pertaining to light and sound inside the design studio, setting a general outline for the technical scope of the parameters involved. The third chapter is constituted of the light and sound measurements, descriptions of the spaces from where and under which conditions they were taken, and further comments on the outcomes of the measurements. The conclusion chapter investigates the parameters of environmental control both separately and as a total, while suggesting improvements where necessary. Further analysis of the measurements are carried out in the form of numeric data and charts, in order to enhance cognition of the conditions of the studios measured. The appendices include the 1/200 plans of the three adjoining buildings of the Faculty of Art, Design and Architecture, specifications of the apparatus used in the measurements, and a glossary of definitions necessary for the understanding of the technical terminology used in the thesis.

2. ON LIGHT, SOUND AND STUDIO

This chapter focuses on the functional analysis of a design studio, the outlines of design studio lighting and design studio acoustics. The primary concern of this chapter is to prepare the grounds on which the measurements will follow and to set the basis for the systematic evaluation of the conclusion chapter.

2.1 The Design Studio

The design studio in the school of architecture has an importance far beyond that of simply learning course material. It is perhaps the most intense and multidimensional 'classroom' experience in all of higher education. In a very short time, 'the studio becomes the matrix within which a student develops the habit of thinking and talking both as a design professional and as a member of a team' (Pressman 2). However, the philosophical significance of the design studio is far too broad for the interests of this study. What is more important is the definition of a design studio in terms of the activities taking place in it. The recommended numerical quantities for the environmental parameters involved in the vision of the thesis can then be made.

The activities taking place in the studio can be classified in two main categories: individual work and group work. The individual tasks a design student accomplishes basically takes place on the work surface assigned for each student. Namely, these tasks are sketching, drafting, model making, reading and writing. Private design critiques between a student and a teacher can also be considered as an individual activity. Group work is very much alike individual work. Although the work surface required demands more space, this can be obtained through the effective arrangement of individual work surfaces. (However, it should be mentioned that interior and basic design considerations concerning the design studio are not within the scope of this thesis.) Group works, in addition, include activities such as inter-group meetings, class presentations, design juries, lectures and exhibitions. As one might notice right away, the activities inside the studio are diverse, which suggest a challenge for the designer such that all the activities listed above should find a place for themselves within the studio in harmony so that both group and individual work can take place simultaneously, without interrupting each other. Another point to consider in the design studio is the duration of the working hours. Many architectural education programs are similar in the sense that studios occupy the longest weekly class hours. Accordingly, due to the nature of architectural education and working habits, students are expected to and do spend long hours in the design studio. Wherever administrations permit, the design studios are open twenty-four hours a day - as is the case with many schools of architecture. In this perspective, the use of the design studio day and night requires a thorough investigation of the requirements of lighting and acoustics.

Therefore, it is the purpose of this study to highlight the need for different light and sound levels for the different activities, at different times of the day taking place inside the studio. The following sections aim at forming a general outline for the luminous and sonic environments inside the studio.

2.2 Design Studio Lighting

Providing adequate lighting systems for design studio facilities will require systematic planning from the outsets of the design process. Actually, in all educational facilities lighting, the best results may be expected when there is cooperation among designers, engineers and administrators in the initial planning stage.

According to the Illumination Engineering Society of North America (IESNA, Guide, 4), the project considerations for designing lighting are summarized as economic considerations, energy, color, reflectances, architecture, operation hours, use of the space, acoustics, physical factors, dust and dirt, safety and emergency lighting , maintenance and codes. To begin with, the initial and life cycle cost of the system constitute the economic considerations of lighting design while the amount of energy consumed by and released from the system -as heat- form the energy factor. Color temperature of the light should coordinate with the color of the space. Color rendering properties of lamps are important since colors should be distinguished accurately in the design studio. High reflectances of surfaces in the studio increase the efficiency of the lighting installation and vice versa. Size, shape, style, texture, and orientation of the space -which altogether belong to architecture- effect the selection and placement of the luminaries together with the hours of operation. Use of the space is the functional definition of the studio, of the activities which will occur inside, their locations, frequency and importance. In acoustical terms, it is expected that the lighting system of the design studio should perform quiet operation. This factor is determinant in the selection of the luminaries. Physical factors such as vibrations, temperature, shock and voltage variations affect the choice of the luminaries. Dust and dirt, together with maintenance, are important in conserving the efficiency of the luminaries installed. Safety of the occupants will also be determined by the lighting levels mentioned in the codes. Finally, the codes pertaining to lighting, which are to be specified in this and the fourth chapters, should be followed.

From the above listed project considerations for lighting design derive general lighting criteria. These are illuminance levels, visibility, visual comfort, luminances, color rendering and color temperature of the lamps. The headings on illuminance and luminance levels are the main focuses of this study.

In determining the quantity of illumination necessary for any interior, there are certain questions which need to be surveyed. IESNA (Guide, 9) puts forward a set of questions to be considered, which focus on the future occupants and activities of that particular space. These questions are: ' What are the tasks; how much time and what percentage of this time is spent on each task; how important is each task, speed, accuracy; which tasks are visually most difficult, most fatiguing; what are the occupants' ages ?'. The logic behind surveying the teaching and administrative staffs as well as the students is to obtain complete information for developing lighting criteria.

After a careful consideration of the tasks involved, the need for speed and accuracy, the ages of the observers, as well as other factors, required illuminances can be determined. Since it is uncommon for the design studio to contain only one visual task, a thorough evaluation of the visual needs of each task should be realized. Accordingly, a level of illumination should be defined for each task and through a flexible lighting system with multilevel controls, the user should be enabled to adjust the luminance level from task to task.

It should be mentioned that providing the required quantity of illuminance is of little value if the proper illumination quality is not achieved. What is meant by the quality of illuminance is the ease at which a visual task is performed - quickly and accurately-, while the visual environment is perceived as pleasing and comfortable. The quality aspects of lighting embraces the considerations of luminance, luminance ratios, light distribution, task specularity and diffusion, surface reflectances, location of lighting equipment, color and shadows. According to the IES Lighting Handbook 1987 Application Volume (6-3), ' quality of illumination implies that all luminances contribute favorably to visual performance, visual comfort, ease of seeing, safety and aesthetics in relation of the visual tasks involved'. Figure 2.2.1 below demonstrates the relationship between the luminances of significant surfaces and the visual task.

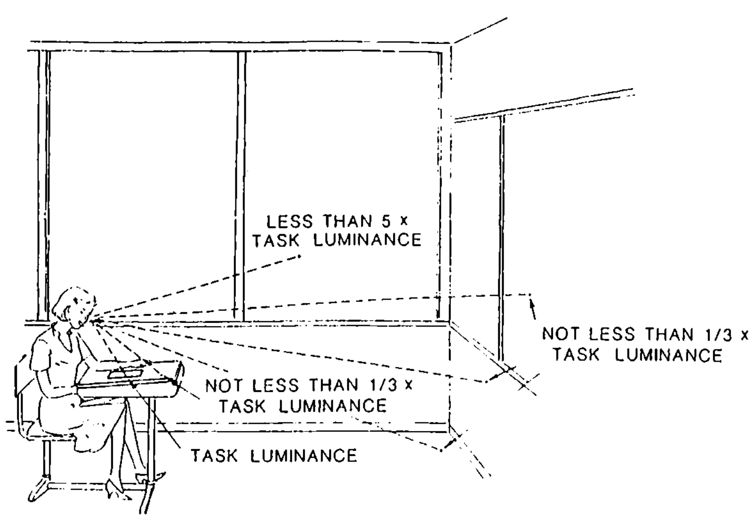


Figure 2.2.1 Luminance Relations between the Visual Task and Surrounding Surfaces

Therefore, the luminance relationships of the various surfaces in the studio should be designed within acceptable limits. As the eye wanders from surface to surface, i.e. from the colored collage work to the glossy whiteboard, it adapts from one luminance to another. The luminances should be arranged so that the differences in between surfaces do not create discomfort in the eye, due to the elongation of adaptation time. Illumination Engineering Society (IES) summarizes the rule of thumbs to be taken into consideration while calculating luminance ratios within a space:

> - In general, for good visual performance the luminance of any significant surface normally viewed directly should not be greater than five times the luminance of the task.
> - No large area, regardless of its position in the room, should be less than one-third the luminance of the task.
> - Surfaces immediately adjacent to the visual task should not exceed the luminance of the task, but should be at least one-third the luminance of the task.
> - The difference in luminance between adjacent surfaces in the visual surround should be kept as low as possible (IES, Application, 6-3).

Reflectances of the surfaces and finishings inside the design studio play a significant role in the effectiveness of the designed lighting system. As can be seen, below, in Figure 2.2.2, the recommended reflectances for surfaces and furnishings should be arranged together with control media at the windows in order to balance interior and exterior luminances.

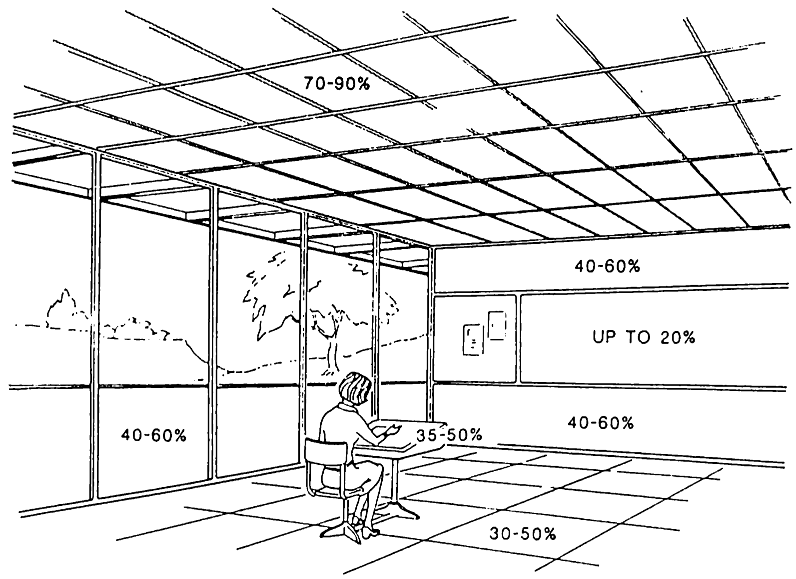


Figure 2.2.2 Recommended Reflectances for Surfaces and Furnishings in the Design Studio

Illuminances and luminances inside the design studio are very difficult to obtain and require complex calculations and extensive study. The balances reached as a result are very vulnerable to glare, as it will produce excessively high luminances within the space. Glare can be an end product of uncontrolled daylight and sunlight from windows, high-luminance luminaries and specular surfaces and other sources.

The dimensions of all the parameters effecting the lighting design of a studio are numerous. The following paragraphs aim at concluding the rules of thumb pertaining thereto.

Numerous areas in schools need different lighting design solutions due to their unique nature. The design studio, being the most unique and complicated of all, demand high quality illumination since discrimination of fine detail is frequently required for extended periods of time. In addition, the instruments used for drafting, such as hands, T-squares and triangles, obstruct the task and reduce efficiency and visibility. Shadows can be eliminated through the selection of large luminous areas and overall ceiling lighting systems. When these systems are not applicable, side illumination of the work surface should be considered. ' In such a system, the absence of any luminaire in the offending zone also minimizes veiling reflections and reflected glare' (IESNA, Guide, 21). Figure 2.2.3 below shows the relationship of the offending zone to the angle of motion of the work surface and the eye movements relative to the task surface.

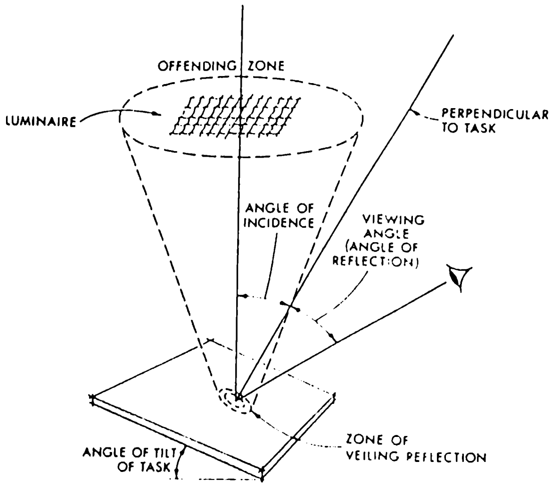


Figure 2.2.3 The Angular Relationship of the Work Surface and the Offending Zone

A movable supplementary lighting equipment attached to the side of the work surface will enable the student to position for critical task requirements and to overcome shadows and reflections. Since the appearance of colors in the studio become significant at times, the selection of the color rendering properties of the light source becomes important. ' Lamps with high color rendering capability provide a more natural appearance of colors over a wide range - even though they may be lower in efficacy. Light from the north sky is often considered for such facilities' (IESNA , Guide, 20). Displays and models will require directional concentrating sources for improved visibility at a distance. Supplementary lighting from adjustable luminaries can provide the model or display with a definite directional light, at times emphasizing texture and glaze. 'An independent portable lighting system, separate from the general lighting system and with some degree of flexibility with respect to aiming and interchangeability of light sources, is often useful for exhibitions' (IESNA, Guide, 21).

There are many possibilities concerning the decisions of design studio lighting. Generally, the considerations are the determination of the studio illuminance level(s), selection of the correct luminaire(s), precise placement of luminaire(s), special area lighting decisions, lighting controls, lighting for special activities and task/ambient lighting. Within this general outline, the goal of educational facility lighting is to provide an optimum visual environment for both the student and the instructor to enhance the learning process.

2.3 Design Studio Acoustics

Within the design studio, the basic expectations are short reverberation time, low background noise, minimum flutter echo, ease of conversation between individuals, groups and the whole class, high intelligibility of words, low input noise from the surroundings and flexibility in acoustical arrangements due to the functional adaptability of the design studios.

Due to the nature of the designing process, a quiet ambiance free from annoying sounds is usually expected. It should be mentioned that ' noise heard in the form of unexpected loud sounds can cause pronounced physiological effects- increase in heart rate, change in breathing, even an increase in digestive activities' (Templeton and Saunders 6). In this sense, according to Templeton and Saunders, 'the important factors which would appear to influence the subjective disturbance due to sound are sound pressure level, duration of exposure, evolution of sound event, frequency spectrum, sound character, individual susceptibility, personal attitude to noise or sound generator, mood of listener, state of health, and activity engaged during sound event' (8).

Egan lists the important criteria for room acoustics design as ' low level of background noise, evenly distribution of sound energy throughout the listening space, avoiding echoes and focusing effects, sufficiently loud desired sounds and proper reverberation time characteristics' (170).

There are two main categories to be considered: The effective absorption of sound within the studio and the effective isolation of sound generated at the outside of the studio.

The intelligibility of speech plays a crucial role inside the design studio. During individual, group, or class discussions, it is of utmost importance that the intelligibility of words are at least satisfactory. A disadvantage of the design studio from regular classrooms is that it does not have a particular order of sitting, as in an auditorium. Rather, the layout of the individual work surfaces are arranged as a result of the social interactions between the students of the design studio. Therefore, the source, path, receiver relationship can not be constructed, making it difficult for the designer to conceptualize an order for the walls of the design studio. When considering the design studio as purely a place for organized group seating and discussion, the reverberation time should be controlled around 0.75 seconds (Templeton and Saunders 134). The reverberation time appears as 0.8 seconds in Egan (88), with the indication that longer reverberation times reduce the intelligibility of speech the same way noise masks speech signals. The ceiling should be kept low with sound-absorbing materials for controlling the buildup of noise within the studio and made to act as a surface reflecting sound toward the other side, unless supplementary carpeted floors and sound absorptive wall finishes are not provided. ' It is preferable to place absorption on the side walls rather than on the ceilings' (Egan 88), as this will prevent flutter echo. However, sound-absorbing materials should not be used on surfaces which should provide useful sound reflections. When the design studio is used in the classroom order and function, it is generally advised that ' the distance between speaker and the rear of the classroom (design studio) should be short so that loudness will be sufficient throughout the room and the audience should have the ability to see the person talking' (Egan 88) and in places where the distance from the speaker to the farthest listener exceeds 10m. a speech reinforcement sound system may be used. In addition to the reverberation time, Templeton indicates that '40 dB average separation between adjacent working areas should be aimed for, and that the background noise level should not exceed the 38 dB limit' (68), for a higher background noise level would mask speech intelligibility. Egan indicates this number to be 34 dB (88). In open plans such as the design studio, local screening and absorption play a particularly important role in reduction of noise.

Another factor to be dealt with is the large window panes and door openings particular to design studios. These huge openings mean the intrusion of external noises, which should be controlled through well-insulated window and door systems and building orientation. Moreover, ' site features such as hills or slopes, earth berms, thin-wall barriers, and nearby buildings to reduce intruding environmental noise by interrupting the direct sound path (Egan 273)' can be considered as an effective method of the isolation of sound.

Egan has prepared a checklist for the designer to consider for the effective isolation of sound in any enclosed space. The headings of the checklist are as follows:

- Select noise criteria for all activity spaces in buildings. Lay out rooms so sources of noise will be located away from spaces requiring quiet or provide insensitive buffer zones between to reduce transmitted airborne noise.

- Use sound-absorbing materials to reduce the buildup of noise levels in rooms and to muffle sound transmission through wall, plenum, or other cavities where sound absorption can contribute somewhat to sound isolation.

- Use heavy or double-layer constructions to achieve effective isolation, especially at low frequencies.

- Balance wall and ceiling constructions so that they will have nearly the same transmission losses.

- Seal all openings or cracks in building constructions because sound will travel through any opening regardless of its size. Sound leaks can greatly diminish the effectiveness of any sound-isolating construction (Egan, 273).

In the following chapters, among these outlines, the measurements on acoustics will seek ways to come up with conclusions for the current conditions of the design studios at the Department of Interior Architecture and Environmental Design, at the Faculty of Art, Design; and Architecture of Bilkent University.

3. THE MEASUREMENTS

3.1 Description of the Studios

Before proceeding with the measurements on luminance, illuminance, and sound pressure level, it appears to be necessary to give explanatory physical information on the spatial characteristics of the studios, since these will be of importance for the understanding of the results.

The FA 214-215 studio, as shown in the 1/100 building plans (Appendix B), is built facing south, overlooking the academic parking lot of the Faculty, the new Architecture building site on the right , towards the continuation of the steep campus road, the dormitory buildings of the University and in far distance, the construction of the Bilkent-3 towers of Emlak Bank. On the north is a secondary corridor and partly the main corridor of the second floor of the FA building. The west wall is adjacent to a computer laboratory, and the east wall forms the corner of the east wall of the building, with no openings on it. The FA 214-215 studio is also one of the larger studios of the Faculty, crowded by the large number of freshman students in the interior and a vast number of passerbys on the outside.

The FA 217-218 studio, as shown in the 1/100 building plans (Appendix B), is oriented to the east, facing a frequently used high-steep campus road, the Emlak Bank III and Bilkent, Faculty of Architecture construction sites nearby and a west sectional view of Ankara. On the west of the studio is a main corridor of the FA building, very frequently used by noisy passerbys, especially on June 5, 1995. On the north and south are two less frequently-used corridors of secondary importance.

The FA 317-318 studio, as shown in the 1/100 building plans (Appendix B), is looking to the east, right above the FA 217-218 studio. Therefore, since two studios are of exactly the same size, shape and orientation, their physical characteristics are almost the same. However, it should be emphasized that the FA 317-318 studio is, compared with the FA 217-218 studio, more distant to the steep campus road, due to its elevation. Moreover, since this studio is on the top floor of the building, the traffic of the main corridor on the west, and the two secondary corridors on the north and south is much less crowded than the FA 217-218 studio.

The FCZ 23 studio, as shown in the 1/100 building plans (Appendix B), is constructed looking north, to the Social Sciences Building and a downhill garden through three self-standing, U-shaped screen walls, ornamented by window openings. On the south, the studio faces the entrance hall of the FC Building, a non-crowded, moderately quiet area, occasionally occupied by groups on particular events, such as exhibitions. On the west, behind the thick walls of the building lies a garden, facing the campus' main pedestrian walkway axis. Finally, on the east, the building is elevated above a garden adjacent to the steep campus road mentioned above. It should be mentioned that the FCZ 23 studio is the largest studio of the three faculty buildings.

The FC 111 studio, as shown in the Appendix B, 1/100 building plans, is oriented to the south, looking on the quiet inner courtyard of the Faculty buildings, below the construction site of the new Architecture building, to the Food Center, Bookstore, and Gymnasium on the far right, across the main pedestrian walkway axis of the University. On the north is a secondary corridor connecting to the main corridor of the first floor of the FC building. However, since this secondary corridor is also linking the FC and FB buildings, it is occasionally exposed to more frequent traffic. The west wall of the studio is adjacent to another design studio, while the east wall is shared with a very seldom used laboratory. The FC 111 is probably one of the smallest design studios of the Faculty.

3.2 The Measurements

3.2.1 Luminance Measurements

The luminance measurements were recorded between May 23- May 29. The measuring process took place at the Department of Interior Architecture and Environmental Design; Faculty of Art, Design, and Architecture of Bilkent University, Ankara, in the 1st, 2nd, 3rd, and 4th class design studios' final juries of the academic year 1994-1995. Detailed information on the process are given on the recorded data tables (3.2.1 to 3.2.4), figures (3.2.1 to 3.2.8) and related paragraphs.

The measurements were taken in the FCZ 23, FA 214-215, FC 111, and FA 317-318 studios. Plans of these studios and the exact locations of where the measurements were taken are given in detail in the figures 3.2.2, 3.2.4, 3.2.6, 3.2.8.

Equipment Used

The equipment used for obtaining luminance data was the Minolta Luminance Meter LS-100 and necessary accessories. Further information regarding the specifications of the apparatus is given in Appendix A.

Settings

Unit:	cd/m^2
C.C.F./LUMI.:	none
PEAK/CONT.:	Continuous
Calibration:	Preset
Measuring Mode:	ABS.
Response:	Fast

Methodology

The luminance measurements aimed at recording the amount of light that reflected from the surfaces of the presentation boards , on which design projects were presented during design juries.

The objective behind this experiment was to observe how the jury members, the student presenting his/her work, and the students watching the jury were affected by the amount of light reflected from the presentation boards. As shown on the corresponding figures 3.2.2, 3.2.4, 3.2.6, 3.2.8, the luminance meter was placed in two adjacent points, equally distant from the wall, facing the presentation board. The first point was chosen on the far left part of the board while the other being placed on the far right section, in order to have a broader information on the distribution of the reflecting light. Thus, the instrument was capable of recording, in 30-minute intervals, the luminance value (in cd/m^2) at the exact location where the jury was being held. Accordingly, it was possible to infer, from the recorded luminance values, whether the occupants mentioned were able to see the visual task with ease and accuracy or not.

Notes on the Recorded Data

May 29, 1995 (FCZ 23): On this partially cloudy day, eleven measurements were taken between 11:00 and 16:30 hours, at 30 min. intervals, at two locations, indicated as A and B in table

3.2.1. The lowest A and B luminance measurements were taken at 12:30, respectively as 31.9 cd/m^2 and 28.7 cd/m^2.

Sample Number	Time	Luminance Value A (cd/m2)	Luminance Value B (cd/m2)	Mean
1	11:20	66.79	137.4	102.1
2	11:50	80.80	47.74	64.27
3	12:20	73.30	60.87	67.09
4	12:50	78.97	74.70	76.84
5	13:20	73.53	74.51	74.02
6	13:50	71.62	77.84	74.73
7	14:20	100.9	74.71	87.81
8	14:50	118.2	94.33	106.3
9	15:20	83.60	82.29	82.95
10	15:50	76.47	77.60	77.04
11	16:20	80.8	79.83	80.32

Table 3.2.1 The Luminance Data of FCZ 23 (4th class) on May 29th, 1995

However, these values do not appear in table 3.2.1, due to the fact that at that exact moment, as a result of a steady decline in the luminance, the jury members felt the need to turn on the florescent lights. From this time on, the values are recorded under daylight as well as supplementary artificial lighting. Actually, the highest A value of the day was reached under this combination, as 118.2 cd/m^2 at 14:50 and the peak B value as 137.4 cd/m^2 at 11:10, recorded at the far north-west end of the studio, under partial morning sunlight exposure. Finally, the daily averages appeared as 82.3 cd/m^2 for A and 80.2 cd/m^2 for B. Here, it should be reminded that the FCZ 23 studio has, only, a long façade looking north, with three projections towards the garden, with no openings on the west, east or south.

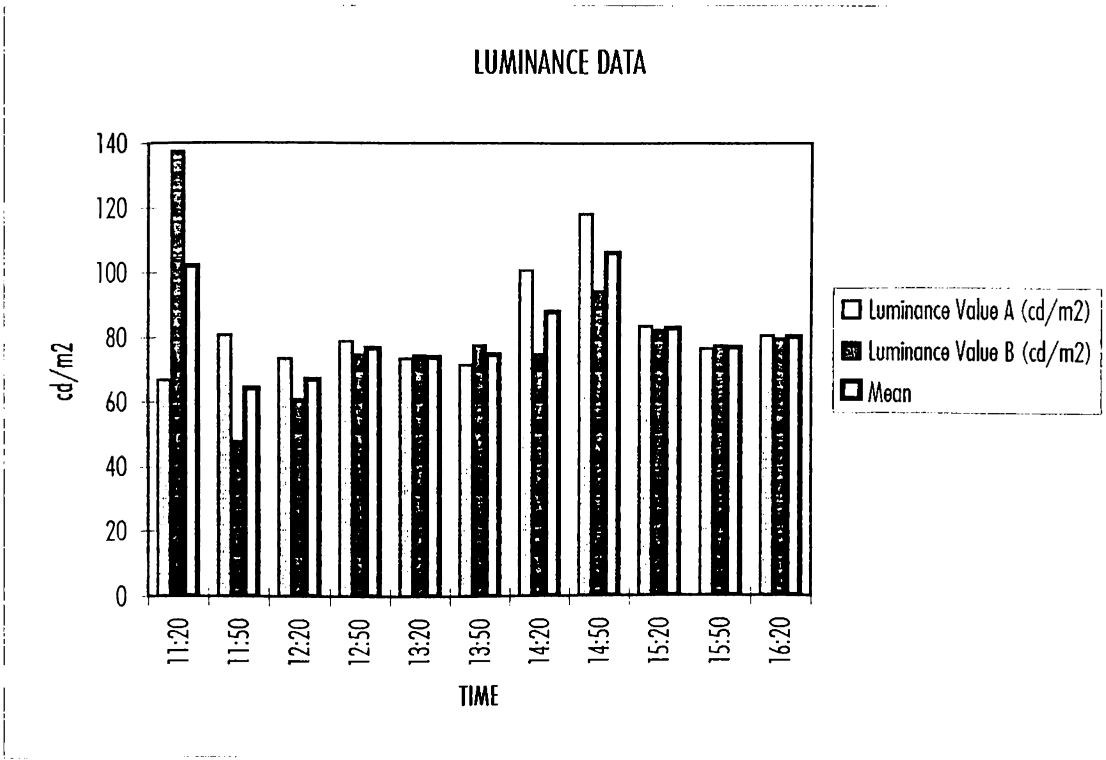


Figure 3.2.1 The Luminance Data of FCZ 23 (4th class) on May 29th, 1995

May 26, 1995 (FA 214-215): On this dominantly shiny -but sometimes partially cloudy- day, thirteen measurements were recorded between 10:30 and 16:30 hours, at 30 min. intervals. During the whole time, no lights were turned on by the jury members in this studio facing south. The jury was held on the far south-east corner of the studio; making clear the relatively high morning values of B. The lowest values were 83.6 cd/m^2 for A at 16:30 and 100.8 cd/m^2 for B at 13:00 hours. The averages came out as 130.9 cd/m^2 for A and 163.7 for B.

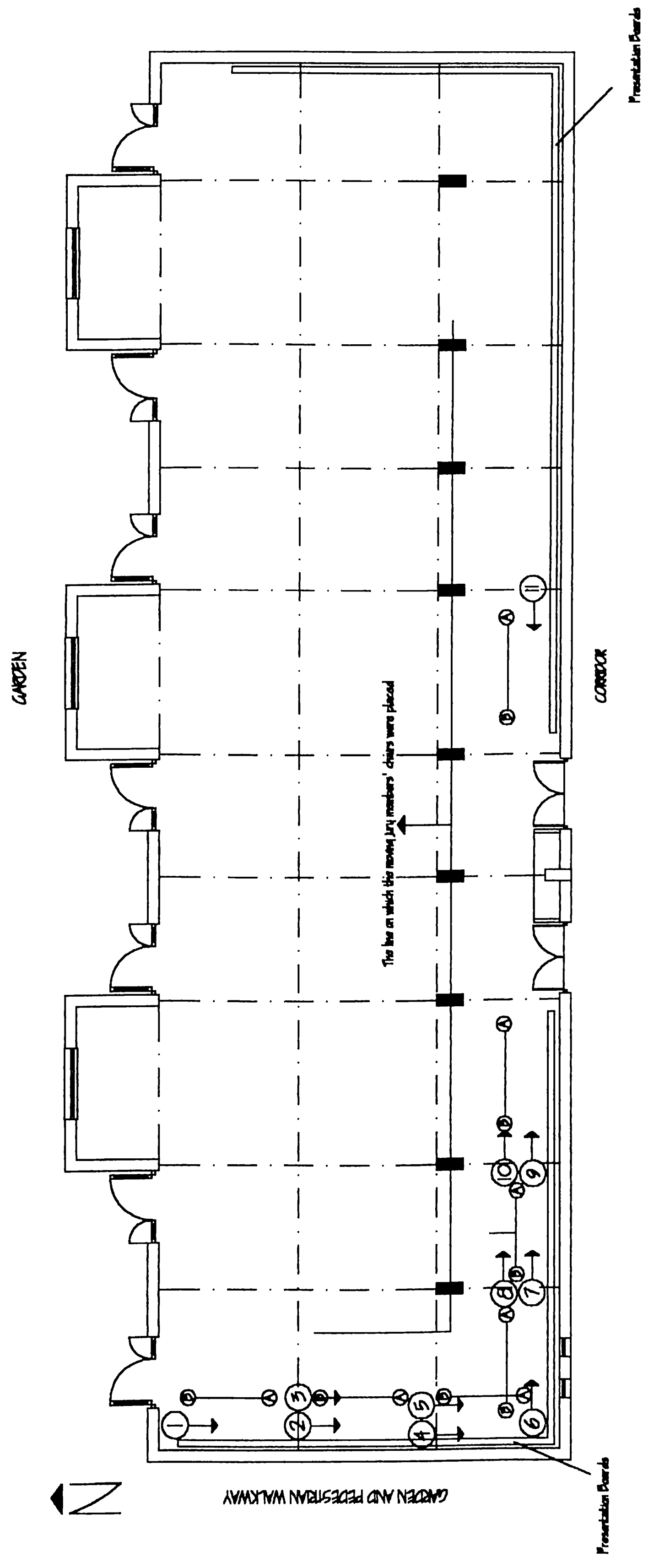


Figure 3.2.2 The Luminance Measurements in FCZ 23 (4th class) on May 29th, 1995

The highest values, on the other hand, were recorded at 11:00 a.m. for B as 286.8 cd/m^2, and 167.6 cd/m^2 at 12:00 noon for B; both in the morning when the sun entered the studio through the large window panes on the far south-east wall.

Sample Number	Time	Luminance Value A (cd/m2)	Luminance Value B (cd/m2)	Mean
1	10:30	125.5	270.3	197.90
2	11:00	133.7	286.8	210.25
3	11:30	146.7	182.4	164.55
4	12:00	167.8	167.6	167.70
5	12:30	141.7	171.0	156.35
6	13:00	93.77	100.8	97.29
7	13:30	123.5	165.3	144.40
8	14:00	130.9	118.3	124.60
9	14:30	132.7	126.0	129.35
10	15:00	119.9	143.4	131.65
11	15:30	139.3	145.3	142.30
12	16:00	162.6	145.7	154.15
13	16:30	83.62	105.1	94.36

Table 3.2.2 The Luminance Data of FA 214-215 (1st class) on May 26th, 1995

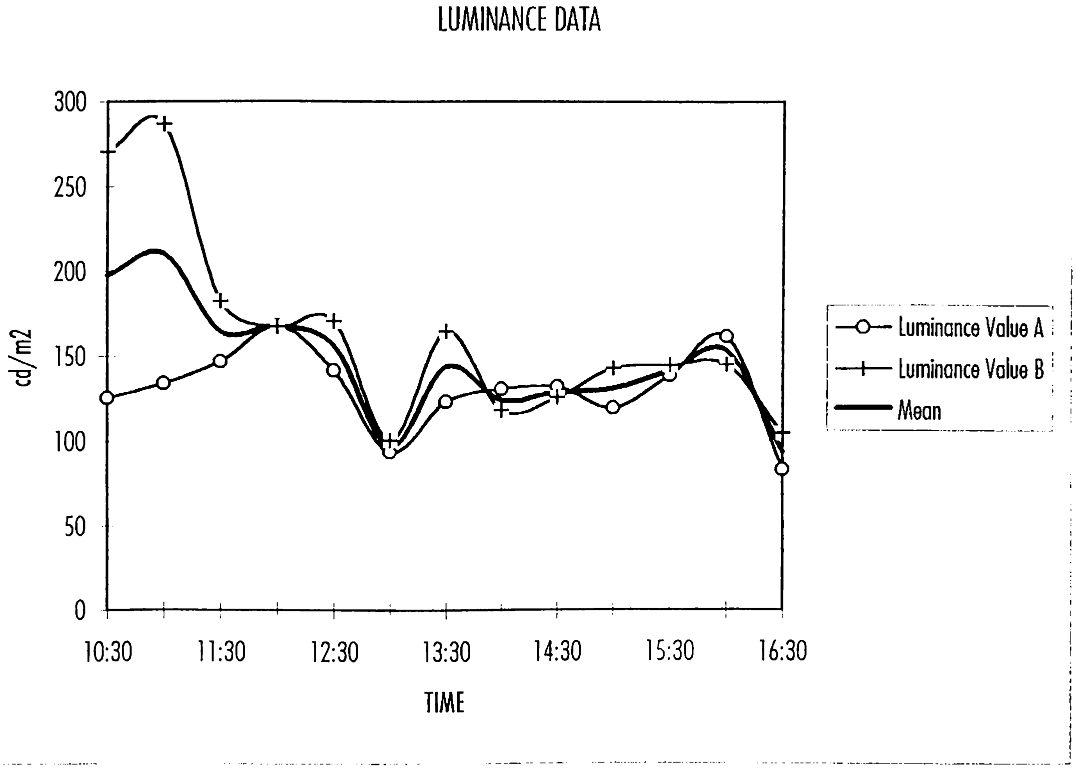


Figure 3.2.3 The Luminance Data of FA 214-215 (1st class) on May 26th, 1995

May 25, 1995 (FC 111): On a completely open and sunny sky, seventeen measurements were recorded between 10:30 and 18:30 at 30 min. intervals. This studio is also looking only to the south, with the jury located on the north wall, explaining why the B values were higher in the morning while the A values took control in the afternoon, starting at 15:00 hours. The highest values of the day were 170.6 cd/m^2 for A and 189.4 cd/m^2 for B, both at 14:00 noon. The lowest value for A, which was on the western side of the studio, was 82.1 cd/m^2 at 10:30 early in the morning.

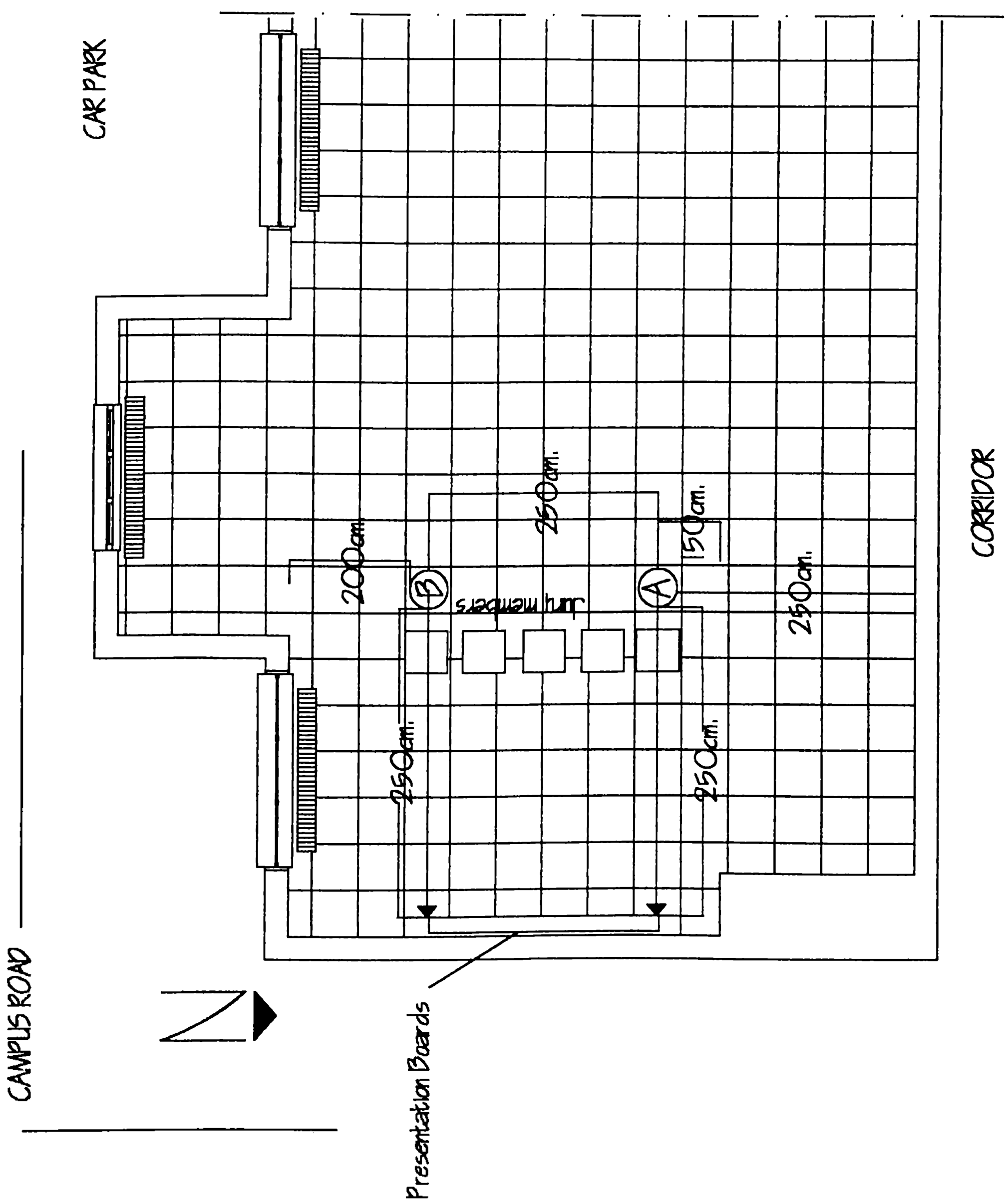


Figure 3.2.4 The Luminance Measurements in FA 214-215 (1st class) on May 26th, 1995

In this studio, 66.3 cd/m^2 had been the lowest B value at 18:30, for B which was located on the eastern part of the studio. However, since the FB building's western wall was blocking the eastern morning sun of the studio, the morning luminance was lower than expected for B. When the sun rose enough to send its rays into the studio at 14:00, the values reached their climax for the day. Finally, the daily averages for A and B were 125.2 and 120.8 cd/m^2 respectively. No lights were turned on in this studio throughout the day.

Sample Number	Time	Luminance Value A (cd/m2)	Luminance Value B (cd/m2)	Mean
1	10:30	82.13	72.16	77.15
2	11:00	89.16	93.11	91.14
3	11:30	94.45	97.04	95.75
4	12:00	121.6	124.9	123.3
5	12:30	129.6	149.5	139.6
6	13:00	166.5	154.7	160.6
7	13:30	167.6	165.4	166.5
8	14:00	170.6	189.4	180.0
9	14:30	164.5	170.5	167.5
10	15:00	140.8	128.9	134.9
11	15:30	160.0	128.7	144.4
12	16:00	134.3	129.1	131.7
13	16:30	121.8	116.5	119.2
14	17:00	91.68	95.31	93.50
15	17:30	108.2	91.32	99.76
16	18:00	98.87	81.36	90.12
17	18:30	86.20	66.34	76.27

Table 3.2.3 The Luminance Data of FC 111 (3rd class) on May 25th, 1995

LUMINANCE DATA

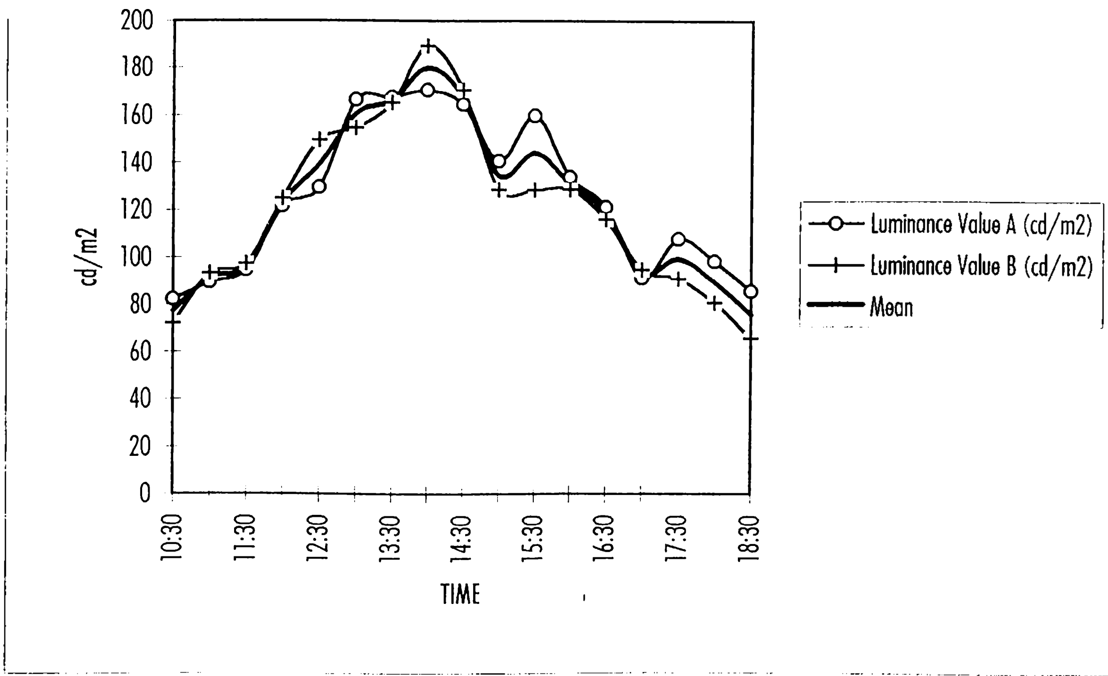


Figure 3.2.5 The Luminance Data of FC 111 (3rd class) on May 25th, 1995

May 24, 1995 (FA 317-318): On a partly cloudy, otherwise sunny day, eighteen measurements were recorded between 11:00 and 19:30, at 30 min. intervals. It should be remembered that this studio was facing east, the jury being held on the far north-western section of the studio, with the A measurement point located on the western side of the studio and the B placed nearer to the eastern part. As the sun rose to the top of the building, a constant decline in the luminance values could be observed. As a result, at 14:30, the jury members decided to turn on the florescent lights for some extra light.

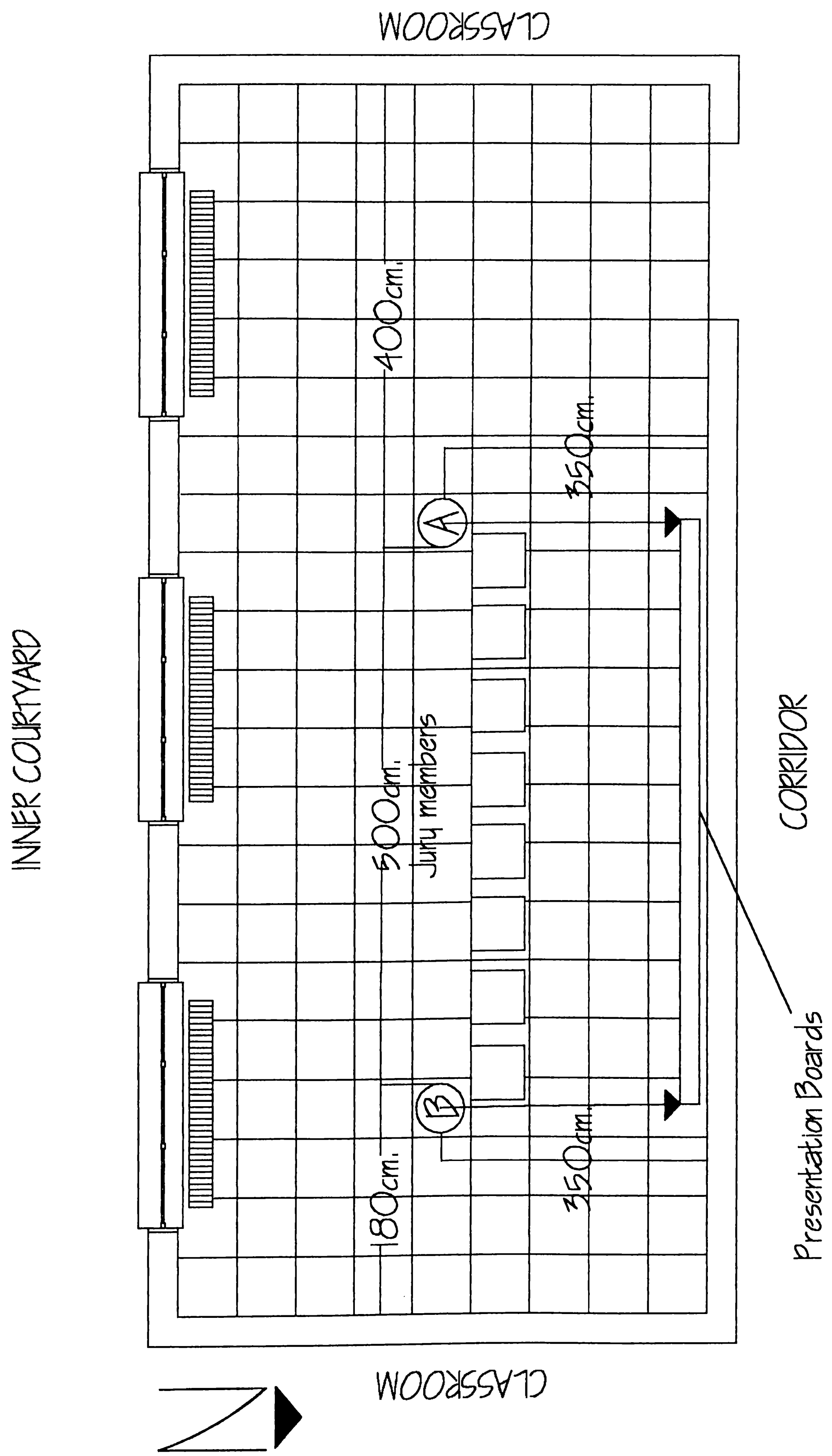


Figure 3.2.6 The Luminance Measurement in FC 111 (3rd class) on May 25th, 1995

This action caused a recognizable shift in the luminance level, which almost immediately entered another declining phase as the sun moved from east to west. The minimum values for A and B were 78.7 cd/m^2 and 80.8 cd/m^2 respectively. The averages were calculated as 108.06 cd/m^2 for A and 121.4 cd/m^2 for B. Finally, the maximums reached 139.8 cd/m^2 for A and 150.3 cd/m^2 for the B measurement point.

Sample Number	Time	Luminance Value A (cd/m2)	Luminance Value B (cd/m2)	Mean
1	11:00	112.9	150.3	131.6
2	11:30	97.13	133.7	115.4
3	12:00	111.0	145.9	128.5
4	12:30	91.88	136.3	114.1
5	13:00	78.74	106.4	92.57
6	13:30	82.64	105.7	94.17
7	14:00	86.46	127.8	107.1
8	14:30	141.9	146.5	144.2
9	15:00	136.1	159.3	147.7
10	15:30	139.8	148.5	144.2
11	16:00	109.1	127.5	118.3
12	16:30	121.1	116.4	118.8
13	17:00	124.6	106.2	115.4
14	17:30	107.2	97.43	102.3
15	18:00	110.8	103.9	107.4
16	18:30	107.4	95.51	101.5
17	19:00	101.0	97.30	99.15
18	19:30	85.29	80.84	83.07

Table 3.2.4 The Luminance Data of FA 317-318 (2nd class) on May 24th, 1995

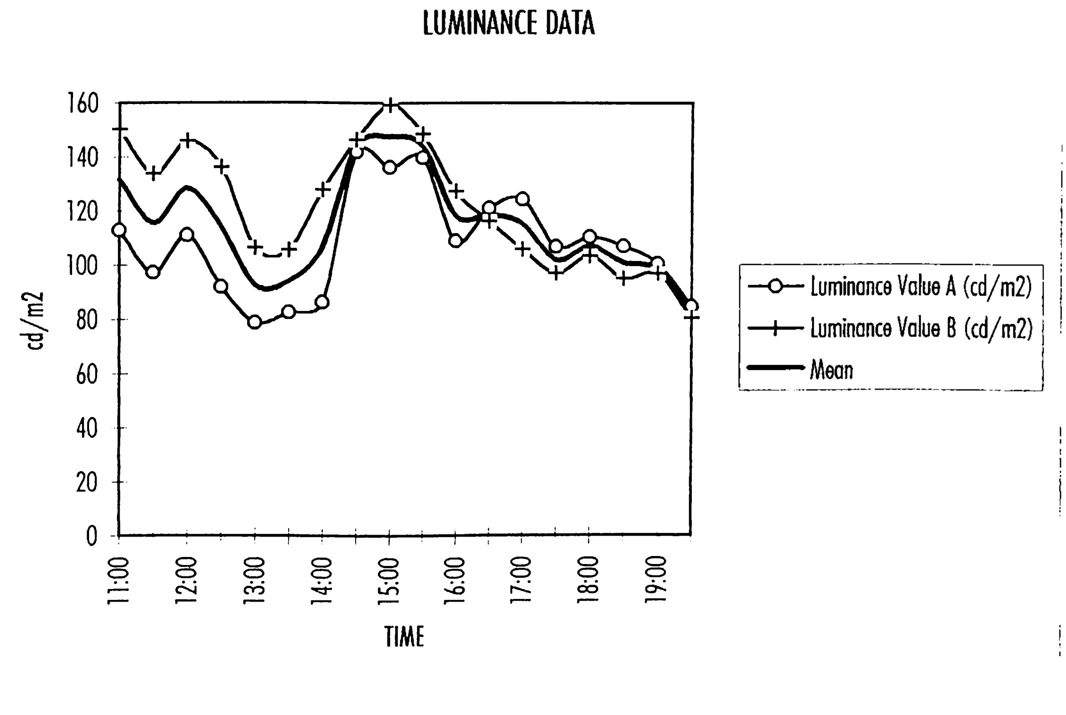


Figure 3.2.7 The Luminance Data of FA 317-318 (2nd class) on May 24th, 1995

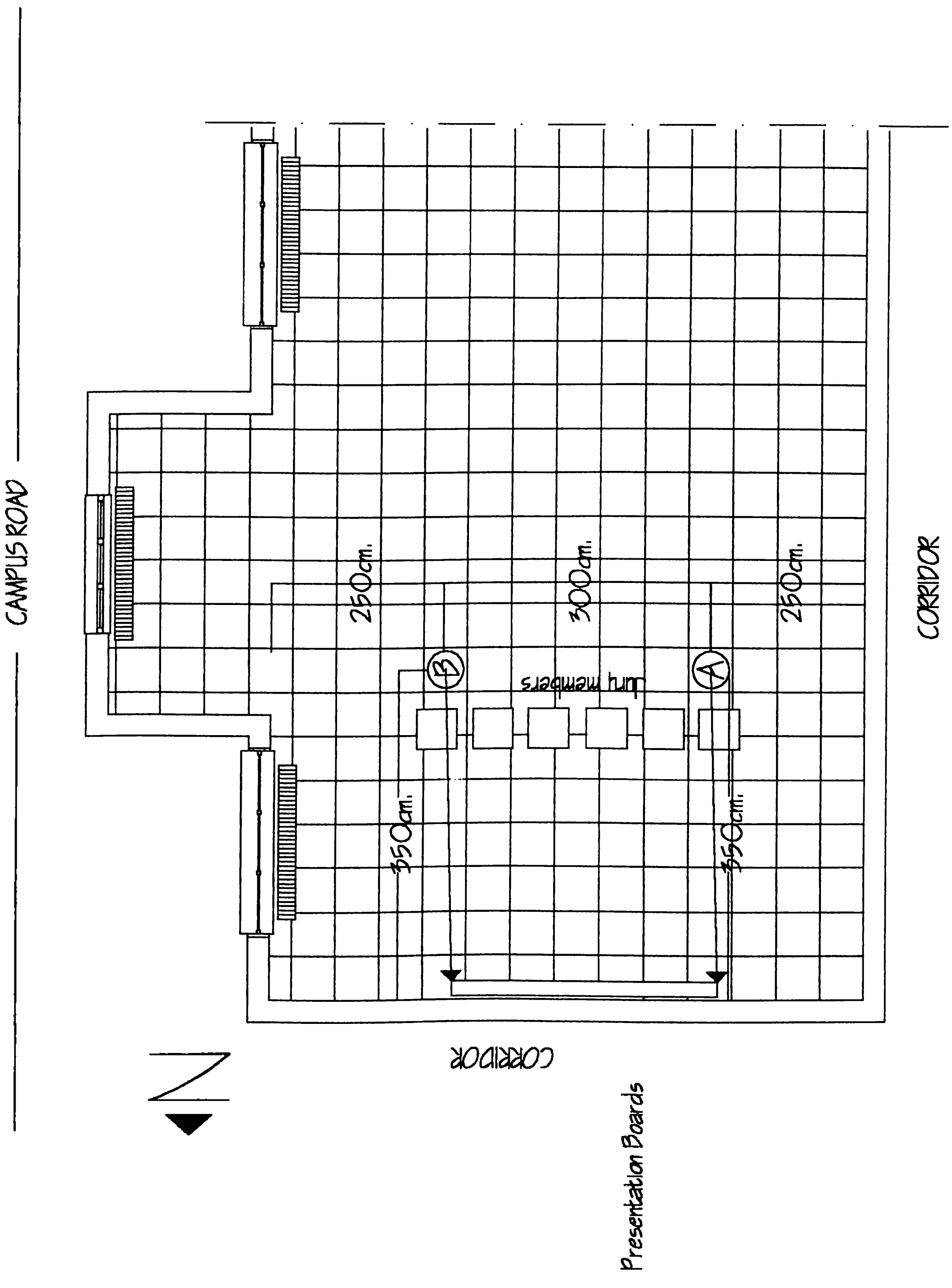


Figure 3.2.8 The Luminance Measurements in FA 317-318 (2nd class) on May 24th, 1995

3.2.2. Illuminance Measurements

The measurements were recorded between May 23- May 29. The measuring process took place at the Department of Interior Architecture and Environmental Design; Faculty of Art, Design, and Architecture of Bilkent University, Ankara, in the 1st, 2nd, 3rd, and 4th class design studios' final juries of the academic year 1994-1995. Detailed information on the process are included on the recorded data tables (3.2.5 to 3.2.8), figures (3.2.9 to 3.2.16) and related paragraphs.

The illuminance measurements were taken in the FCZ 23-24, FA 214-215, FC 111, and FA 317-318 studios. Plans of these studios and the exact locations of where the measurements were taken are given in detail in the figures 3.2.10, 3.2.12, 3.2.14, 3.2.16.

Equipment Used

The equipment used for obtaining illuminance data was the Minolta Illuminance Meter and necessary accessories. Further information regarding the specifications of the apparatus are supplied in Appendix A.

Settings

Unit:	lx
Response:	Fast
Norm./St.Dev.:	Norm.
AUTO/MANU.:	AUTO

Methodology

The illuminance measurements aimed at recording the amount of ambient light which was present in the design studios, where design projects were presented during design juries. The aim behind this experiment was to observe how the jury members, the student presenting his/her work, and the students watching the jury were affected by the amount of ambient light in the studio. As shown on the corresponding figures 3.2.10, 3.2.12, 3.2.14, 3.2.16, the illuminance meter was placed in two points, equally distant from the wall, in front of and below the presentation board. The first point was chosen on the far left part of the board while the other being placed on the far right section, in order to have a broader information on the distribution of the ambient light. Thus, the instrument was capable of recording, in 30-minute intervals, the illuminance value (in lux) at the exact location where the jury was being held. Accordingly, it was possible to infer, from the recorded illuminance values, whether the occupants mentioned were able to see the visual task with ease and accuracy or not.

Notes on the Recorded Data

Due to the close relation of luminance data to illuminance data, the notes on the data recording conditions will be similar. To avoid repetition, only those spatial characteristics of the studios pertaining to illuminance measurements will be discussed.

May 29, 1995 (FCZ 23): Eleven measurements were realized between 11:00 and 16:30 hours, at 30 min. intervals. The day was generally sunny, with occasional clouds. The measurements were taken at two points, as A and B, whose locations are indicated in figure 3.2.10. The minimum A and B values were 190 lux at 11:50 and 327 lux at 16:20 while the maximums appeared as 448 lux at 15:20 and 600 lux at 11:00 respectively. Therefore , the averages came up to 349 lux for A and 416.6 lux for B. Again, in direct parallelity with the luminance measurements, the artificial lighting system was activated when the values went down to a minimum of 114 lux for A and 105 lux for B at both 12:50 noon. However, these values are not seen in table 3.2.5, but are replaced by the new values which also include supplementary artificial lighting. While this additional light shifted the illuminance values, a similar decreasing trend was noticed as the sun moved from east to west.

Sample Number	Time	Illuminance Value A (lx)	Illuminance Value B (lx)	Mean
1	11:20	286	600	443
2	11:50	190	440	315
3	12:20	216	474	345
4	12:50	375	379	377
5	13:20	397	391	394
6	13:50	374	398	386
7	14:20	400	402	401
8	14:50	438	442	440
9	15:20	448	366	407
10	15:50	361	363	362
11	16:20	354	327	340.5

Table 3.2.5 The Illuminance Data of FCZ 23 (4th class) on May 29th, 1995

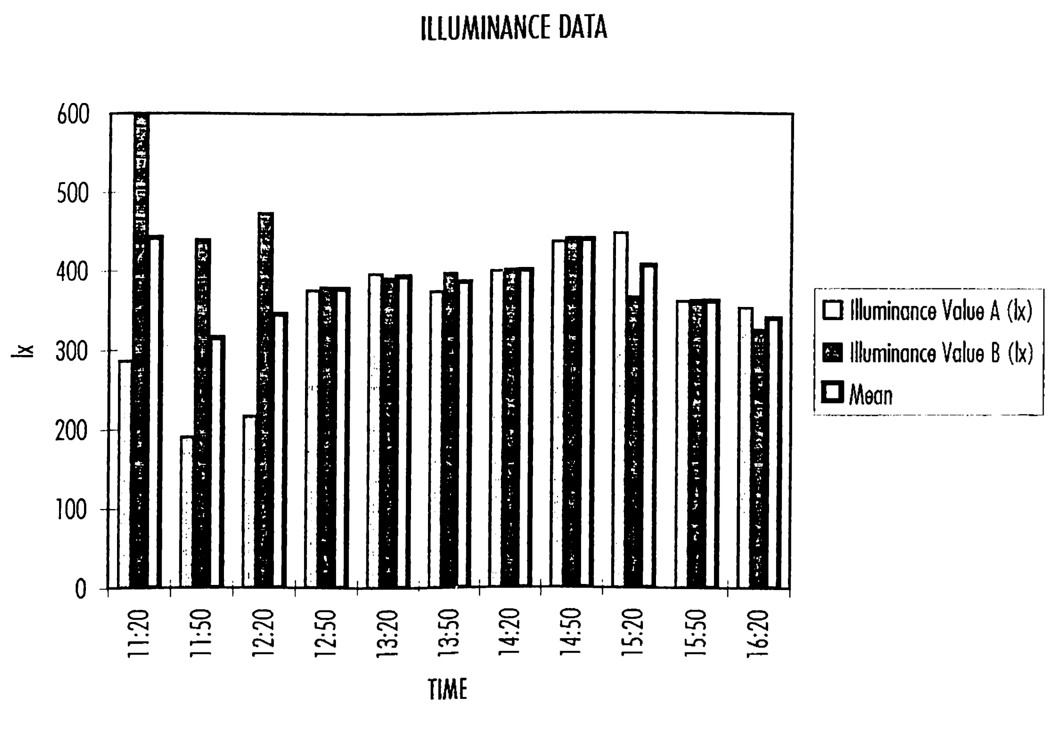


Figure 3.2.9 The Illuminance Data of FCZ 23 (4th class) on May 29th, 1995

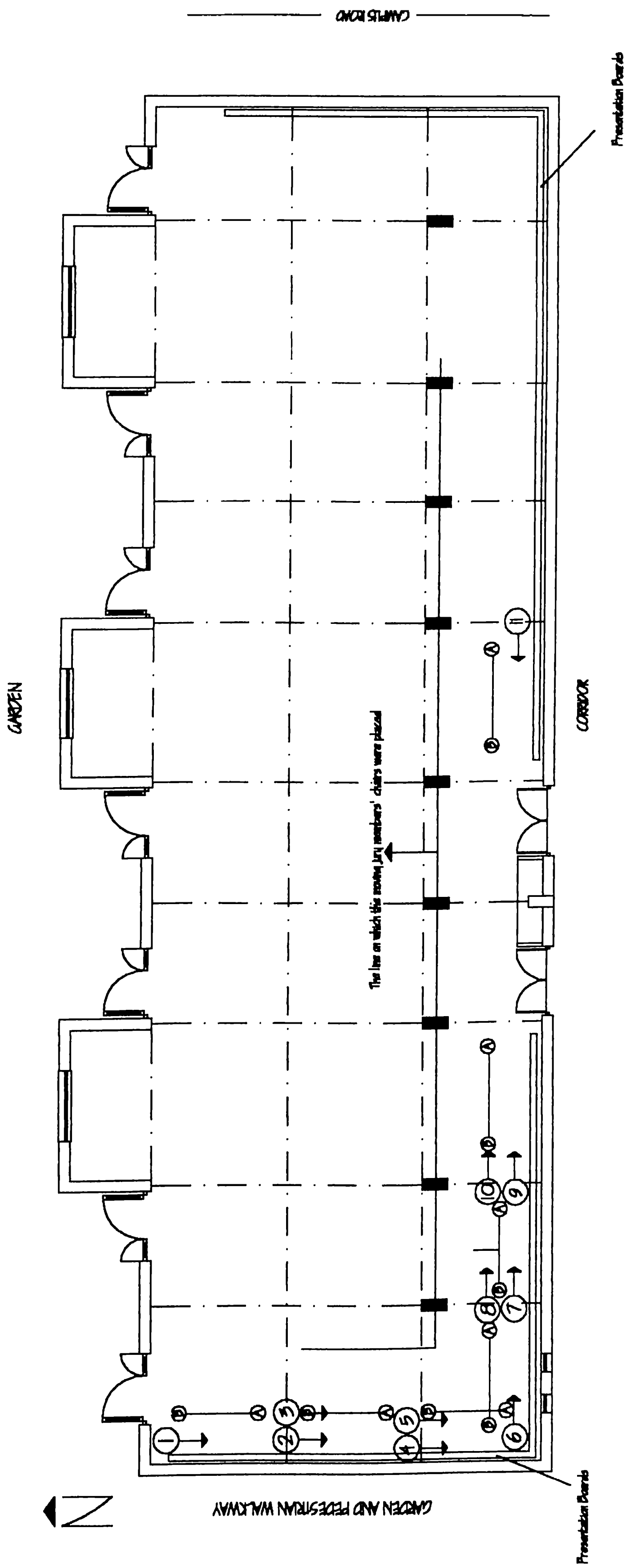


Figure 3.2.10 The Illuminance Measurements in FCZ 23 (4th class) on May 29th, 1995

May 26, 1995 (FA 214-215): As mentioned before, the day was mostly sunny and partly cloudy. Thirteen measurements were taken between 10:30 and 16:30 hours, at 30 min. intervals. No supplementary lighting was used whatsoever throughout the jury period.

Sample Number	Time	Illuminance Value A (lx)	Illuminance Value B (lx)	Mean
1	10:30	537	1310	923.5
2	11:00	644	1430	1037
3	11:30	595	1060	827.5
4	12:00	653	1050	851.5
5	12:30	700	1350	1025
6	13:00	348	978	663
7	13:30	574	1040	807
8	14:00	548	882	715
9	14:30	555	817	686
10	15:00	517	863	690
11	15:30	543	758	650.5
12	16:00	561	1270	915.5
13	16:30	519	1120	819.5

Table 3.2.6 The Illuminance Data of FA 214-215 (1st class) on May 26th, 1995

Here, the daily lowest values were 348 lux for A at 13:00 and 758 lux for B at 15:30 noon. The averages, then, came up to be 561.1 lux for A and a high 1071.4 lux for B. The highest value for A was reached at 12:30 at a sunny noontime while B climbed up to a good 1430 lux at 11:00 with the help of south-eastern morning sun.

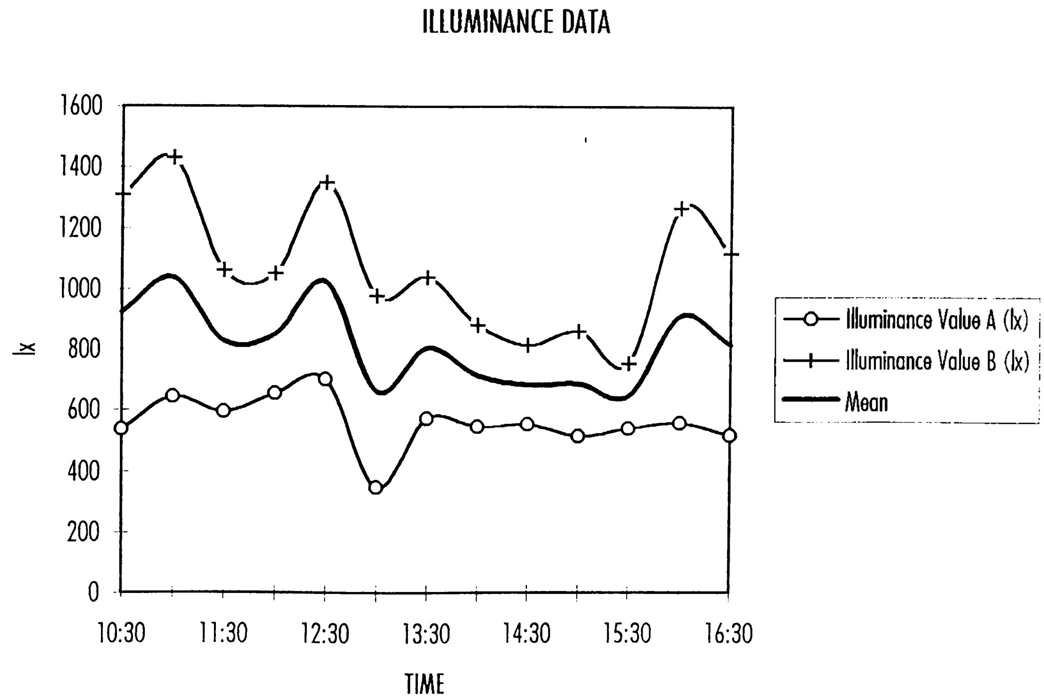


Figure 3.2.11 The Illuminance Data of FA 214-215 (1st class) on May 26th, 1995

May 25, 1995 (FC 111): Seventeen measurements were taken, in 30 min. intervals, between 10:30 and 18:30 on this sunny and open day. Even though the studio was facing south, the values came up lower than expected, due to the light gradient factor as explained in the corresponding luminance data paragraph. Thus, the daily lows were 252 lux for A at 18:00 and 225 lux for B at 18:30, both when the sun had started to decline. The highs, on the other hand, appeared as 624 lux for A at 14:30 and 672 lux for B at 13:00, both in the early afternoon. The averages were calculated as 463.6 and 624 lux for A and B respectively. Again, no supplementary artificial lighting was used during the jury session.

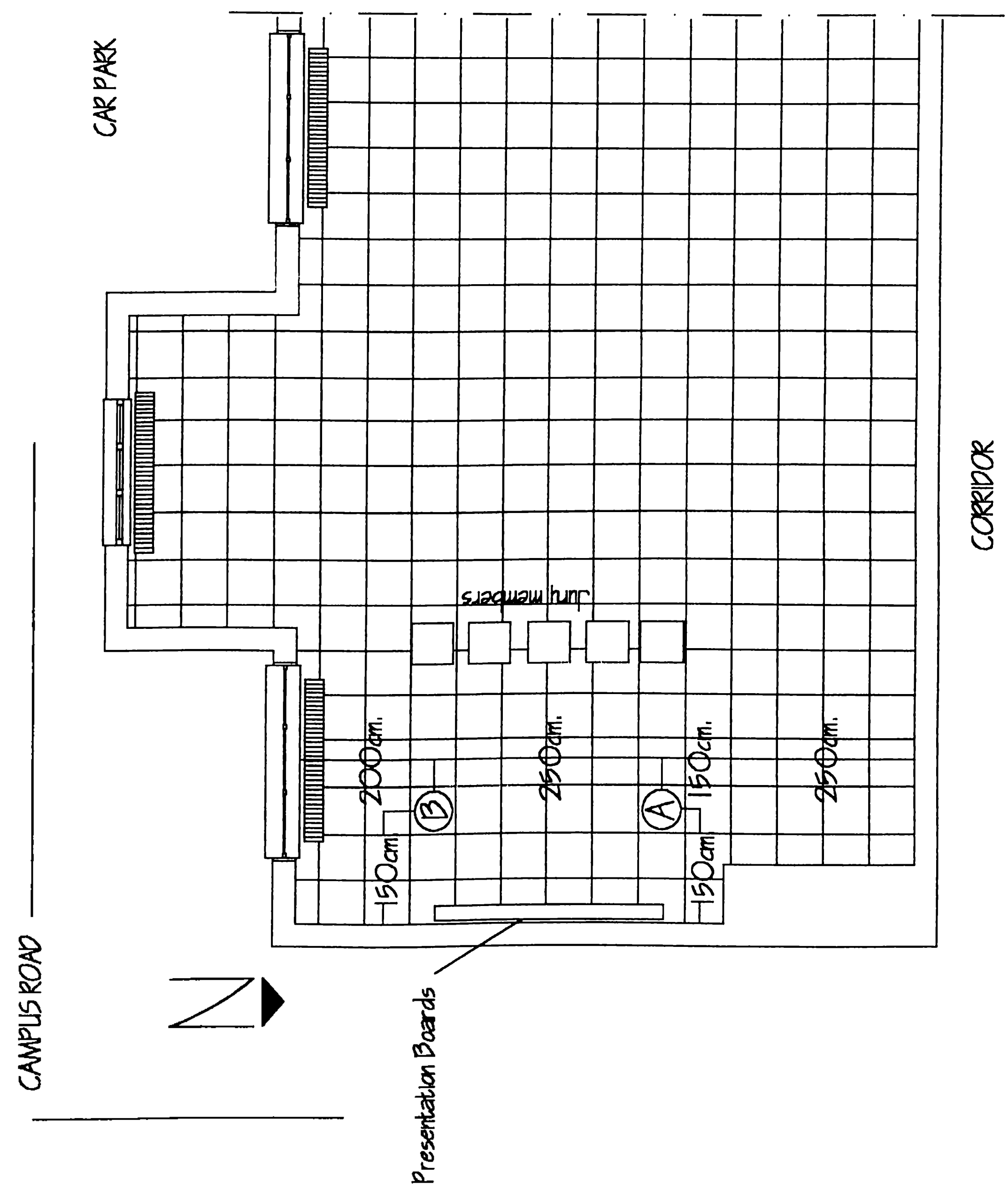


Figure 3.2.12 The Illuminance Measurements in FA 214-215 (1st class) on May 26th, 1995

Sample Number	Time	Illuminance Value A (lx)	Illuminance Value B (lx)	Mean
1	10:30	304	309	306.5
2	11:00	327	358	342.5
3	11:30	401	424	412.5
4	12:00	417	508	462.5
5	12:30	524	594	559
6	13:00	557	672	614.5
7	13:30	597	663	630
8	14:00	600	579	589.5
9	14:30	624	630	627
10	15:00	513	505	509
11	15:30	553	539	546
12	16:00	508	534	521
13	16:30	417	382	399.5
14	17:00	358	336	347
15	17:30	356	359	357.5
16	18:00	252	264	258
17	18:30	259	225	242

Table 3.2.7 The Illuminance Data of FC 111 (3rd class) on May 25th, 1995

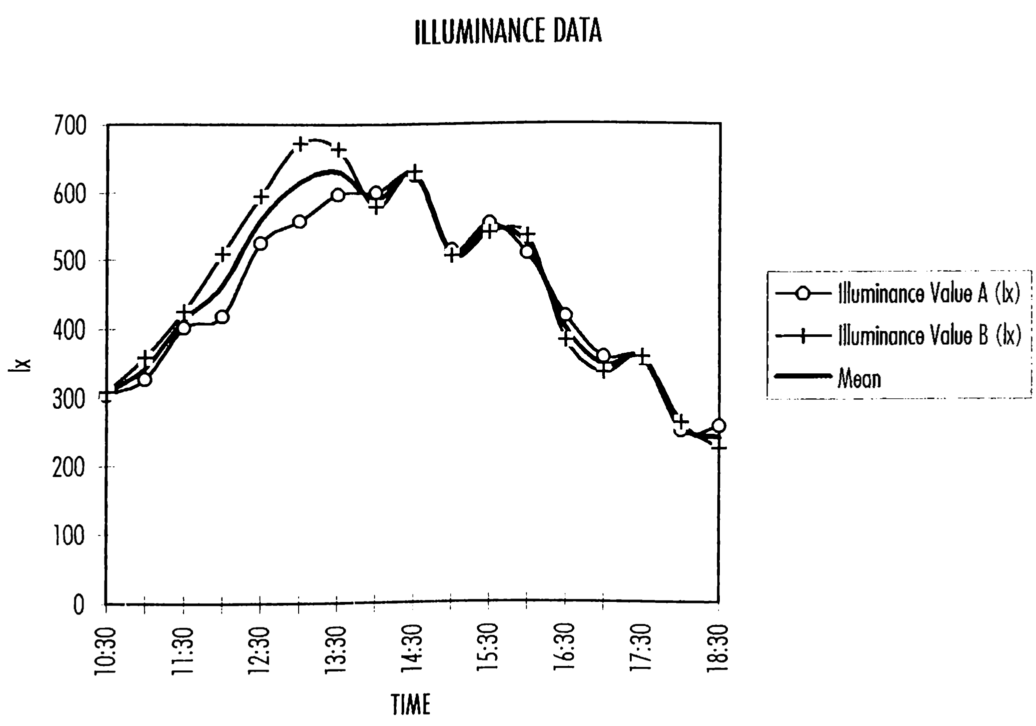


Figure 3.2.13 The Illuminance Data of FC 111 (3rd class) on May 25th, 1995

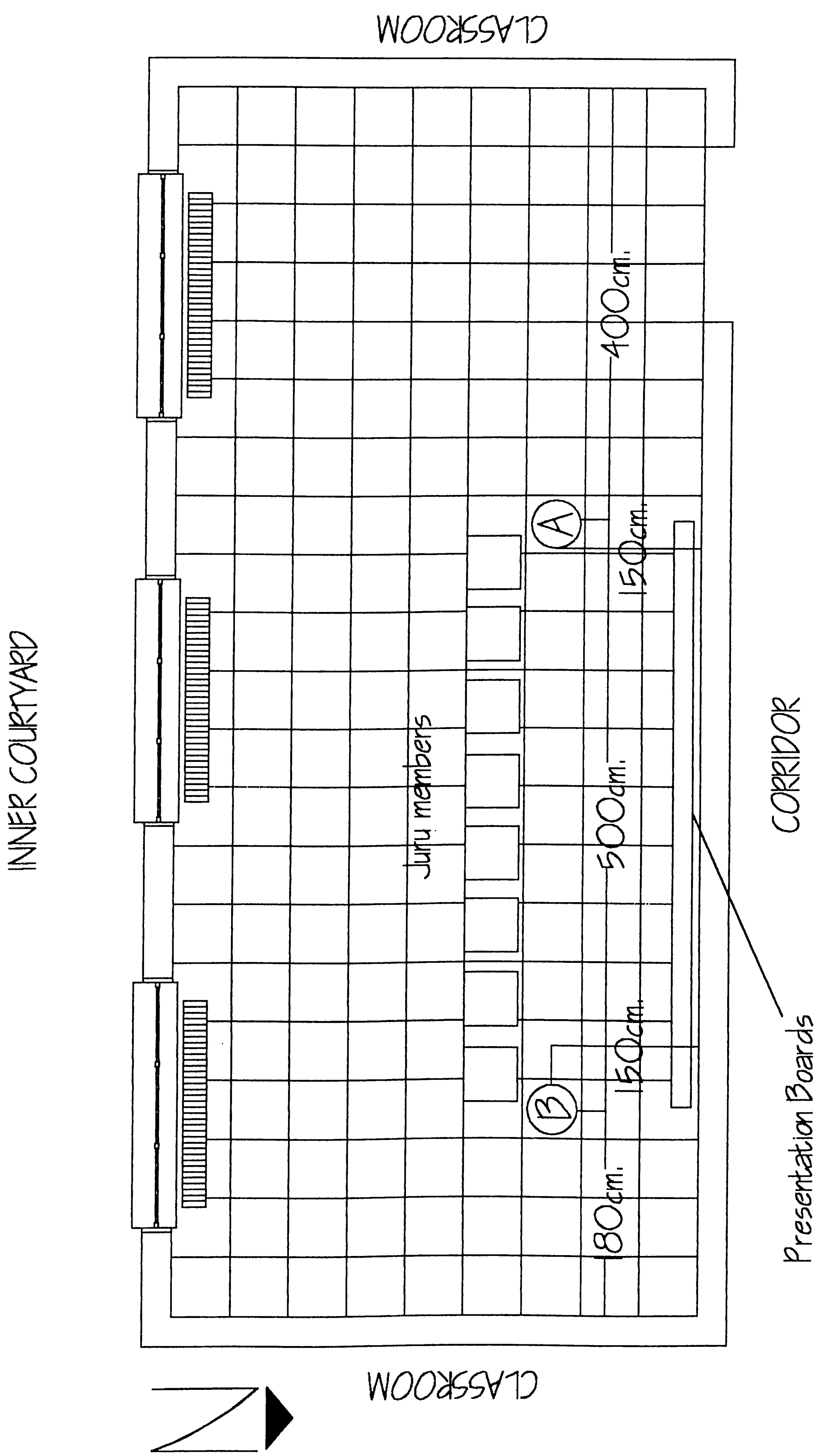


Figure 3.2.14 The Illuminance Measurements in FC 111 (3rd class) on May 26th, 1995

May 24, 1995 (FA 317-318): On this partly cloudy day, between 11:00 and 19:30, eighteen measurements were succeeded at 30 min. intervals. At 14:30, as the sun moved up towards the west, the illuminance values went down to 324 lux for A and 533 lux for B. The supplementary florescent lighting system was, then, turned on until the end of the jury. However, as the sun moved away, the illuminance values started to fall again. The minimum values were 358 lux at 14:00 for A, right before the lights were turned on. The lowest for B appeared at 19:30 as 457 lux, just as the sun faded away and the night fell. Daily averages were, then, 512.6 lux for A and 768.5 lux for B, who was the closer measurement point towards the windows.

Sample Number	Time	Illuminance Value A (lx)	Illuminance Value B (lx)	Mean
1	11:00	610	1210	910
2	11:30	434	839	636.5
3	12:00	471	919	695
4	12:30	402	869	635.5
5	13:00	378	748	563
6	13:30	413	688	550.5
7	14:00	358	684	521
8	14:30	604	868	736
9	15:00	639	839	739
10	15:30	624	747	685.5
11	16:00	604	692	648
12	16:30	593	640	616.5
13	17:00	571	623	597
14	17:30	526	583	554.5
15	18:00	547	576	561.5
16	18:30	515	555	535
17	19:00	501	527	514
18	19:30	436	457	446.5

Table 3.2.8 The Illuminance Data of FA 317-318 (2nd class) on May 24th, 1995

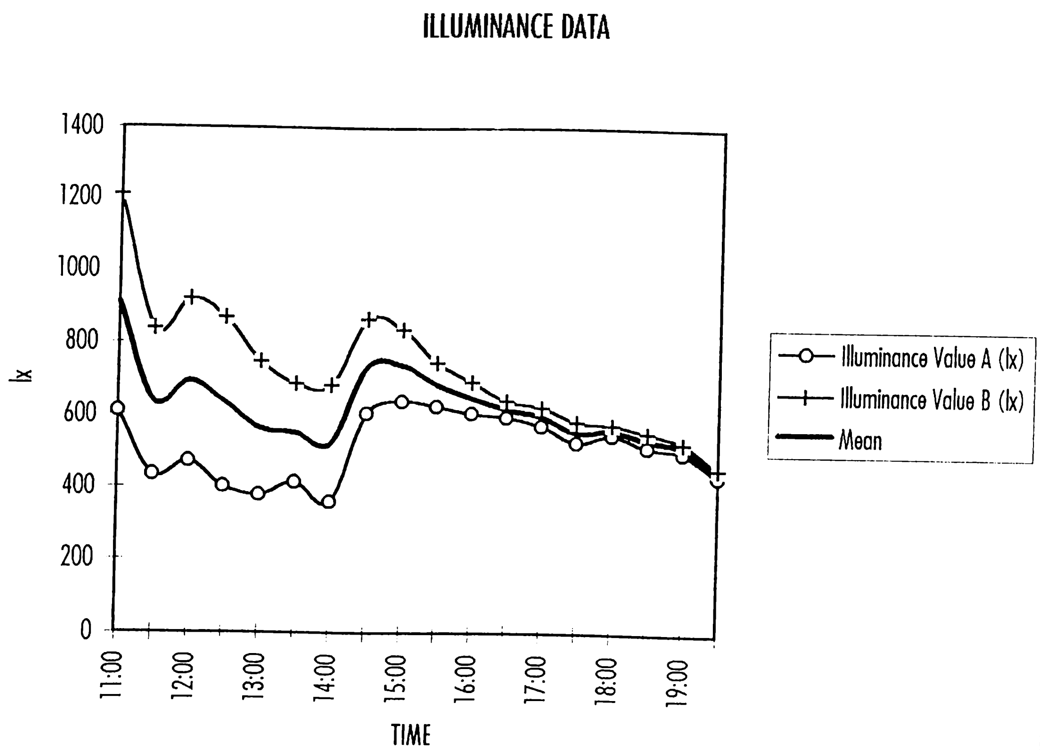


Figure 3.2.15 The Illuminance Data of FA 317-318 (2nd class) on May 24th, 1995

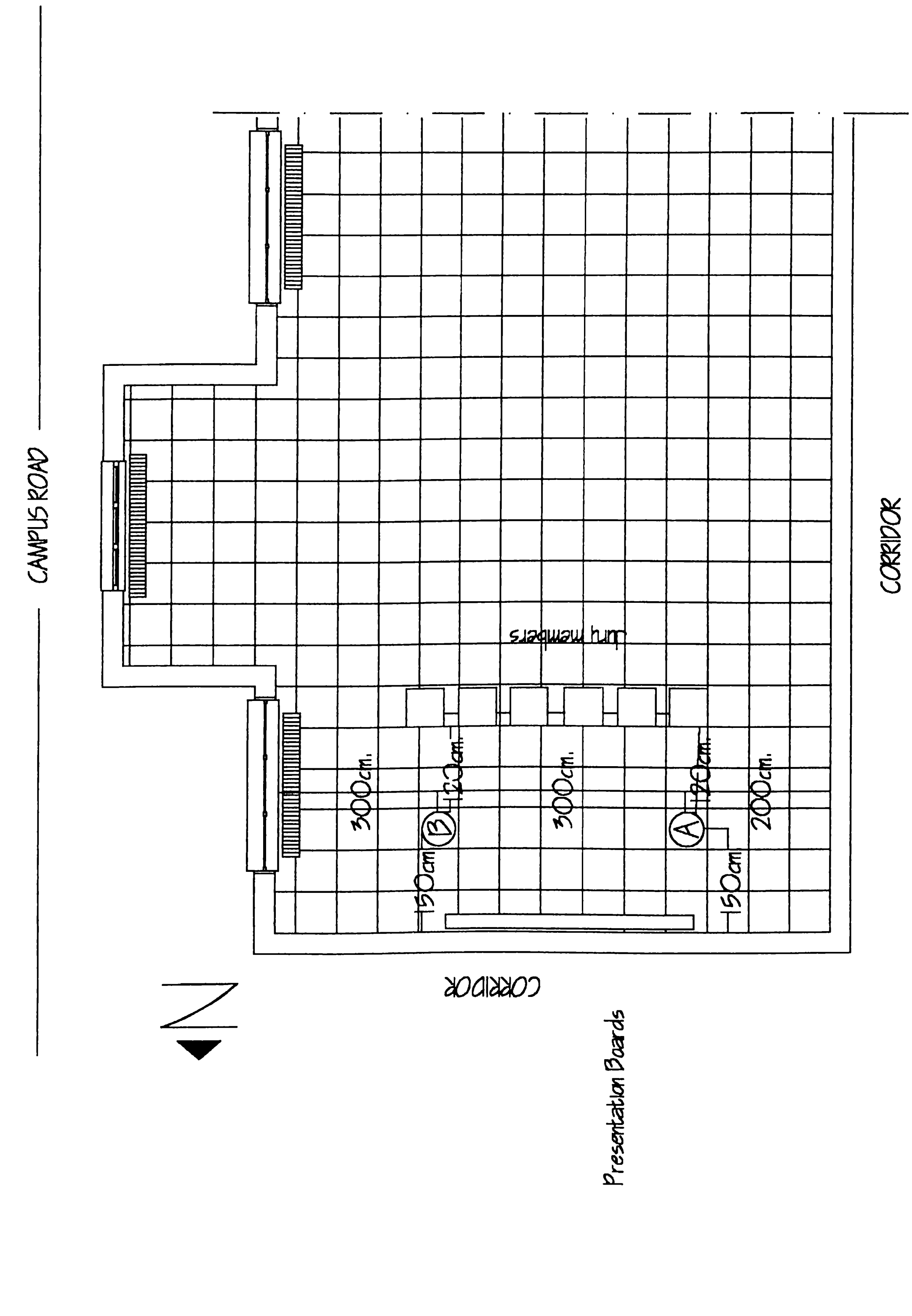


Figure 3.2.16 The Illuminance Measurements in FA 317-318 (2nd class) on May 24th, 1995

3.2.3 Sound Pressure Level Measurements

The measurements were recorded between May 23- June 5. The measuring process took place at the Department of Interior Architecture and Environmental Design; Faculty of Art, Design, and Architecture of Bilkent University, Ankara, in the 1st, 2nd, 3rd, and 4th class design studios' final juries of the academic year 1994-1995. Detailed information on the process are given on the recorded data tables (3.2.9 to 3.2.14), figures (3.2.17 to 3.2.28) and related paragraphs.

The sound pressure level measurements were taken in the FA 217-218, FCZ 23, FA 214-215, FC 111, and FA 317-318 studios. Plans of these studios and the exact locations of where the measurements were taken are given in detail in the figures 3.2.18, 3.2.20, 3.2.22, 3.2.24, 3.2.26, 3.2.28

Equipment Used

The equipment used for obtaining sound pressure level data was the Bruel&Kjaer Precision Integrating Sound Level Meter Type 2230 and necessary accessories. Further information regarding the specifications of the apparatus is given in the Appendix A.

Settings

Detector:	RMS
Time Weighting:	Slow
Display Variable:	SEL, Leq, Max., Min., SPL
Sound Incidence:	Random
Ext. Filter:	Out
Test:	Operate
FSD:	Variable: 70(90)dB to 120(140) dB
Reset:	All
Freq. Weighting:	A

Methodology

The sound pressure level measurements aimed at recording the maximum, average, and background sound pressure levels of the design studios during design juries. The reason behind this experiment was to infer how the jury members, the student presenting his/her work, and the students watching the jury were affected by the sound pressure level in the studio and its surroundings. As shown on the corresponding plans 3.2.18, 3.2.20, 3.2.22, 3.2.24, 3.2.26, 3.2.28, the sound level meter was placed next to the presentation board and the student being examined, facing the jury members, the spectators, and the rest of the studio in depth. Thus, the instrument was capable of recording, in 30-minute periods, the sound pressure level (in dBA) at the exact location where the jury was being held. Accordingly, it was possible to induce, from the recorded sound pressure levels, whether the persons mentioned were in comfort or not.

Notes on the Recorded Data

June 5, 1995 (FA 217-218): The measurement-taking process started at 10:30 and lasted until 21:00 hours, at 30-min. periods. This jury was the most crowded one among all the juries observed.

Sample Number	Time	SEL (dBA)	Leq (dBA)	Min. (dBA)	Max. (dBA)
1	10:30-11:00	101.3	71.1	53.0	80.6
2	11:00-11:30	100.1	67.2	48.1	79.3
3	11:30-12:00	99.1	67.1	53.7	80.0
4	12:00-12:30	100.1	67.7	56.2	81.1
5	12:30-13:00	101.3	68.8	55.9	85.9
6	13:00-13:30	102.9	69.8	55.3	82.6
7	13:30-14:00	100.5	68.6	54.0	84.8
8	14:00-14:30	100.1	68.6	50.5	83.9
9	14:30-15:00	100.7	67.9	54.4	81.0
10	15:00-15:30	98.6	66.0	46.4	83.6
11	15:30-16:00	100.1	66.8	49.9	76.7
12	16:00-16:30	97.4	66.3	54.2	82.6
13	16:30-17:00	100.9	68.8	54.3	90.4
14	17:00-17:30	99.9	66.0	52.6	77.6
15	17:30-18:00	96.8	65.8	49.6	81.6
16	18:00-18:30	98.4	65.7	51.1	77.0
17	18:30-19:00	98.9	66.4	45.8	86.2
18	19:00-19:30	98.5	67.0	52.7	87.0
19	19:30-20:00	99.7	66.9	53.7	85.3
20	20:00-20:30	96.3	64.1	44.4	80.1
21	20:30-21:00	94.7	62.0	42.0	72.1

Table 3.2.9 The Sound Pressure Level Data of FA 217-218 (3rd class) on June 5th, 1995

There was an average of 35-45 students watching the jury throughout the day except for the lunch break (measurement no. 10(Leq): 66.0 dBA) and the last 30-min. period (measurement no. 21: Leq: 62.0 dBA, SEL: 94.7 dBA -lowest). In fact, these two measurements stood out as the two lowest Leq values of the day. The average Leq of the jury was 67.08 dBA, while the highest Leq of the day was 71.1 dBA (SEL: 101.3 -highest), at 10:30-11:00, right before the beginning of the jury. The maximum (Max.) sound pressure level of the day was reached between 16:30-17:00 p.m. with an outstanding 90.4 dBA Finally, the background sound pressure level appeared to be 22.7 dBA at 21:15, after everybody had left

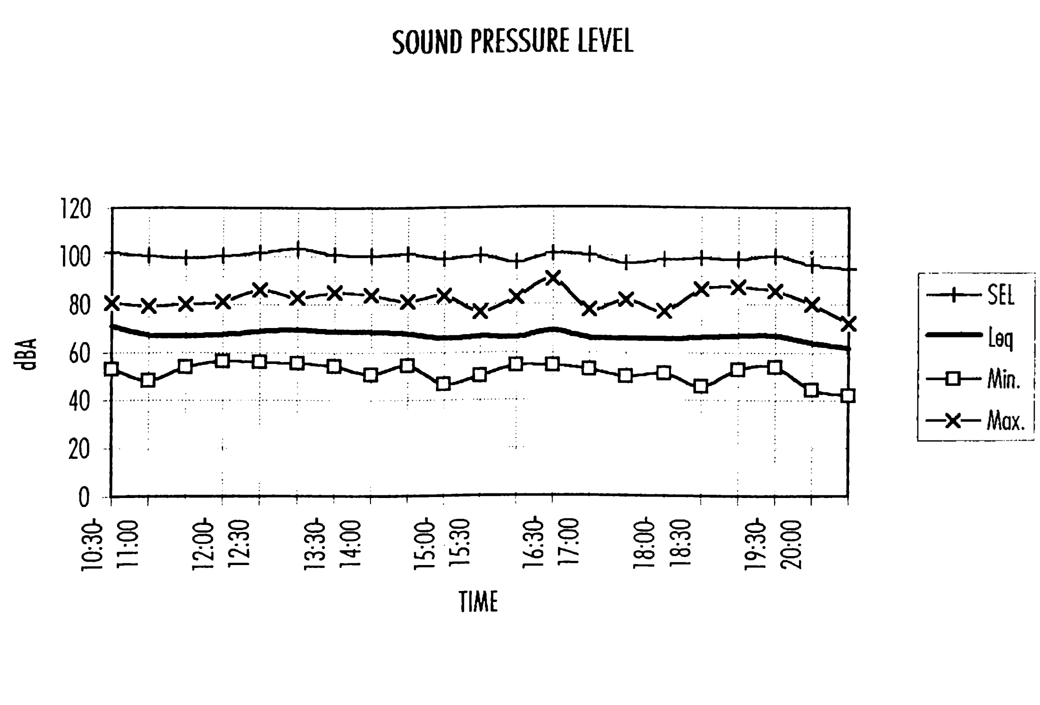


Figure 3.2.17 The Sound Pressure Level Data of FA 217-218 (3rd class) on June 5th, 1995

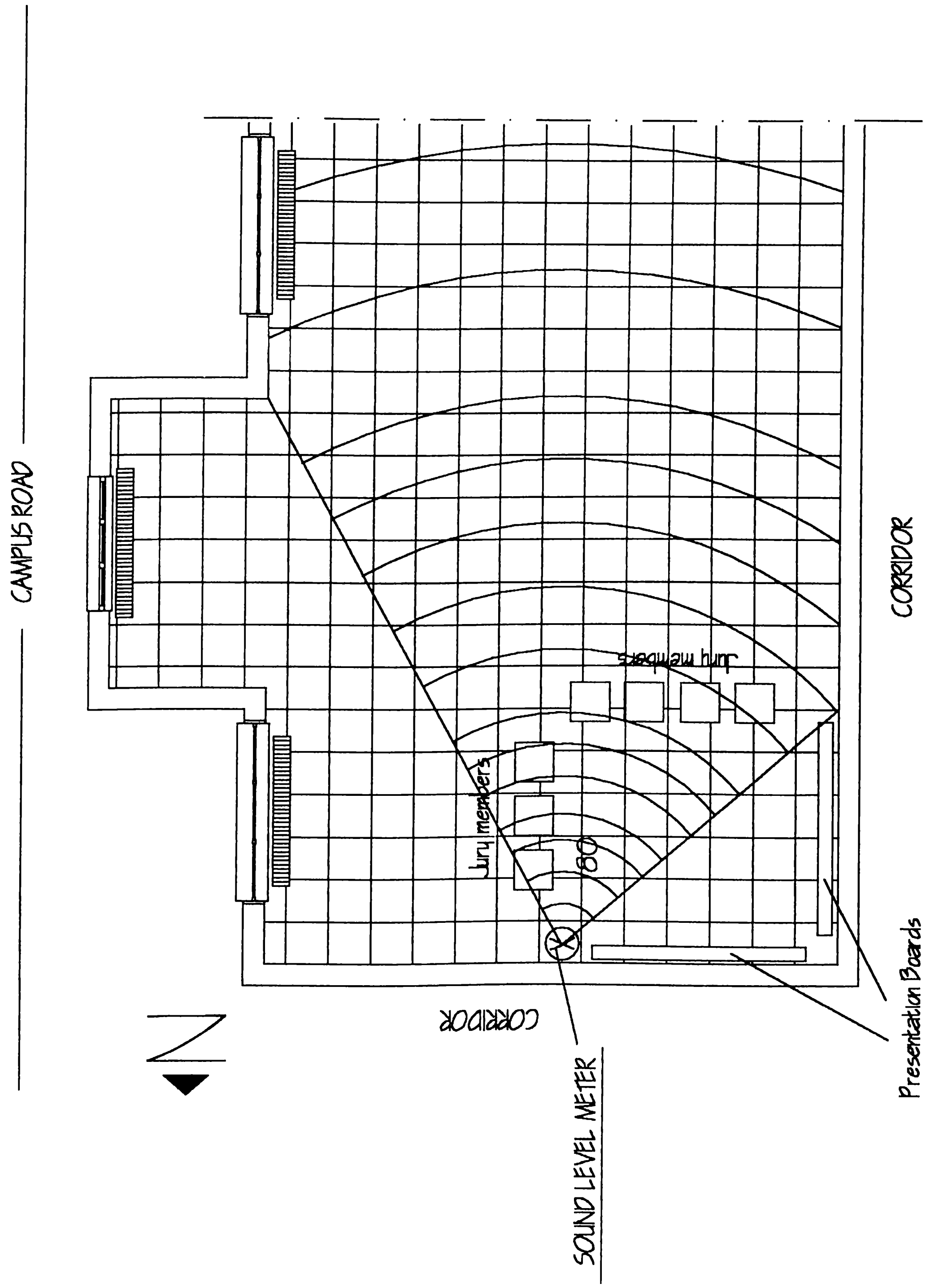


Figure 3.2.18 The Sound Pressure Level Measurements in FA 217-218 (3rd class) on June 5th, 1995

June 1, 1995 (FCZ 23): The measurement-taking process started at 14:30 and ended at 18:30 hours, at 30-min. intervals. The number of people who watched the juries never exceeded 15, including the jury members and the student being examined. There were only 8 data recorded. Among these, the lowest Leq value appeared to be 60.5 dBA (SEL: 91.4 -lowest) at 17:30-18:00 hours, while the average Leq came out to be 63.31 dBA. The highest Leq showed up to be 65.6 dBA, at 15:00-15:30. The maximum (Max.) sound pressure level was a high 87.3 dBA, reached between 16:30-17:00. The background sound pressure level was measured at 18:45 as 31.7 dBA.

Sample Number	Time	SEL (dBA)	Leq (dBA)	Min. (dBA)	Max. (dBA)
1	14:30-15:00	95.9	65.4	48.7	81.8
2	15:00-15:30	97.4	65.6	44.2	79.4
3	15:30-16:00	96.7	64.7	40.7	76.2
4	16:00-16:30	95.3	62.3	41.8	81.1
5	16:30-17:00	95.1	63.1	37.8	87.3
6	17:00-17:30	95.1	61.5	43.3	80.8
7	17:30-18:00	91.4	60.5	38.2	74.7
8	18:00-18:30	95.8	63.4	37.0	85.4

Table 3.2.10 The Sound Pressure Level Data of FCZ 23 (4th class) on June 1st, 1995

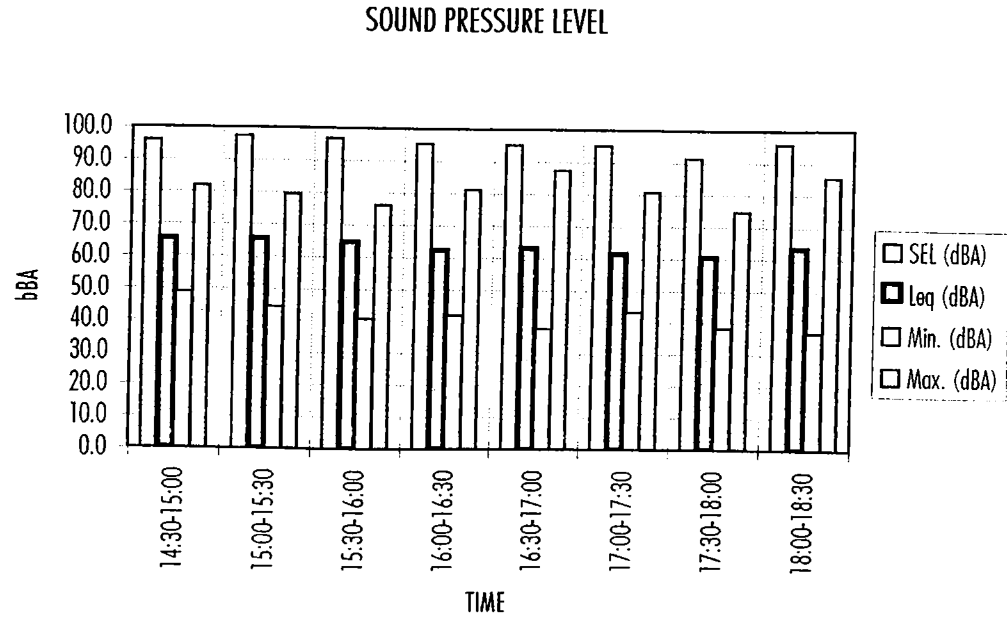


Figure 3.2.19 The Sound Pressure Level Data of FCZ 23 (4th class) on June 1st, 1995

Sample Number	Time	SEL (dBA)	Leq (dBA)	Min. (dBA)	Max. (dBA)
1	11:15-11:45	95.5	61.5	46.1	87.8
2	11:45-12:15	93.4	61.6	46.0	74.1
3	12:15-12:45	96.2	63.3	43.0	89.0
4	12:45-13:15	96.1	63.5	48.6	75.1
5	13:15-13:45	95.2	63.7	44.8	85.7
6	13:45-14:15	94.6	61.5	41.2	75.1
7	14:15-14:45	95.2	63.2	42.7	76.9
8	14:45-15:15	95.2	63.4	42.1	75.7
9	15:15-15:45	95.2	63.5	41.4	74.4
10	15:45-16:15	93.5	61.6	43.7	85.4
11	16:15-16:45	95.7	59	42.7	83.3
12	16:45-17:15	95.7	59	42.1	83.3
13	17:15-17:45	95.7	59	41.4	83.3

Table 3.2.11 The Sound Pressure Level Data of FCZ 23 (4th class) on May 29th, 1995

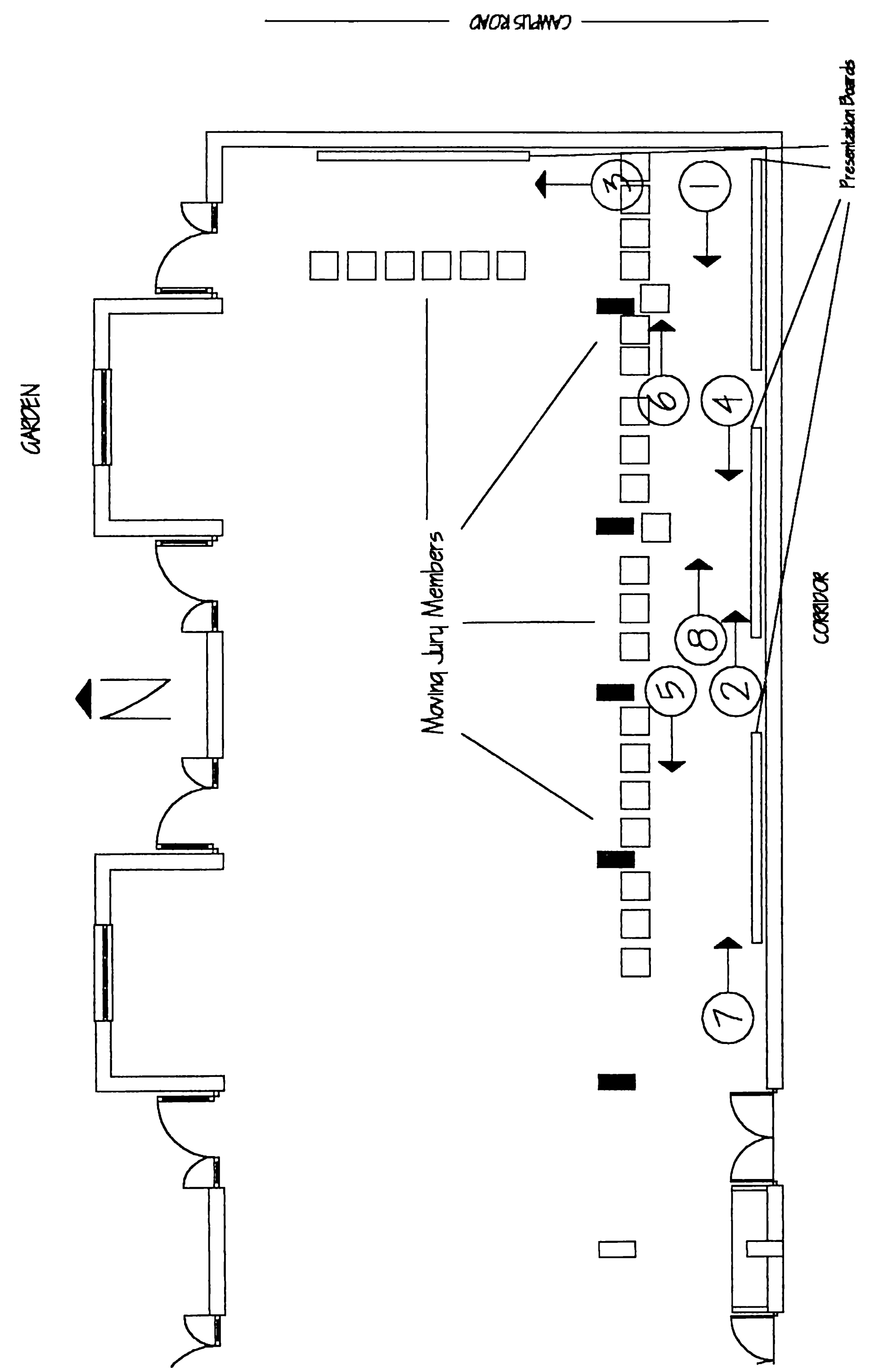


Figure 3.2.20 The Sound Pressure Level Measurements in FCZ 23 (4th class) on June 1st, 1995

May 29, 1995 (FCZ 23): The measurements were recorded between 11:15 and 17:45, at 30-min. periods. Thirteen measurements were attempted during this period, with an average attendance of 15-20 persons. However, between 14:15 to 15:15, no data could be recorded due to a battery failure of the sound level meter. Thus, the number of measurements taken went down to ten. The lowest Leq value was a steady 59.0 between 16:15 and 17:45. Meanwhile, the average Leq appeared to be 61.37 dBA. At 3:15-13:45, the Leq reached its highest value as 63.7 dBA. A disturbing 89.0 dBA of maximum (Max.) sound pressure was felt between 12:15-12:45. Finally, the background sound pressure level was recorded as 35.9 dBA at 18:00.

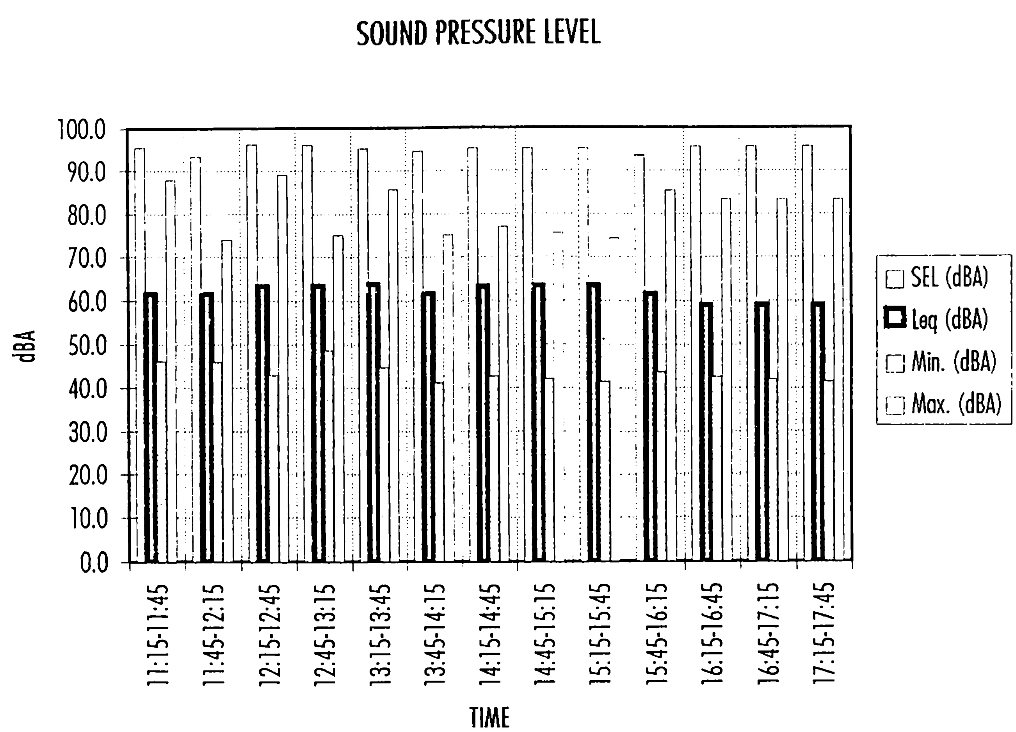


Figure 3.2.21 The Sound Pressure Level Data of FCZ 23 (4th class) on May 29th, 1995

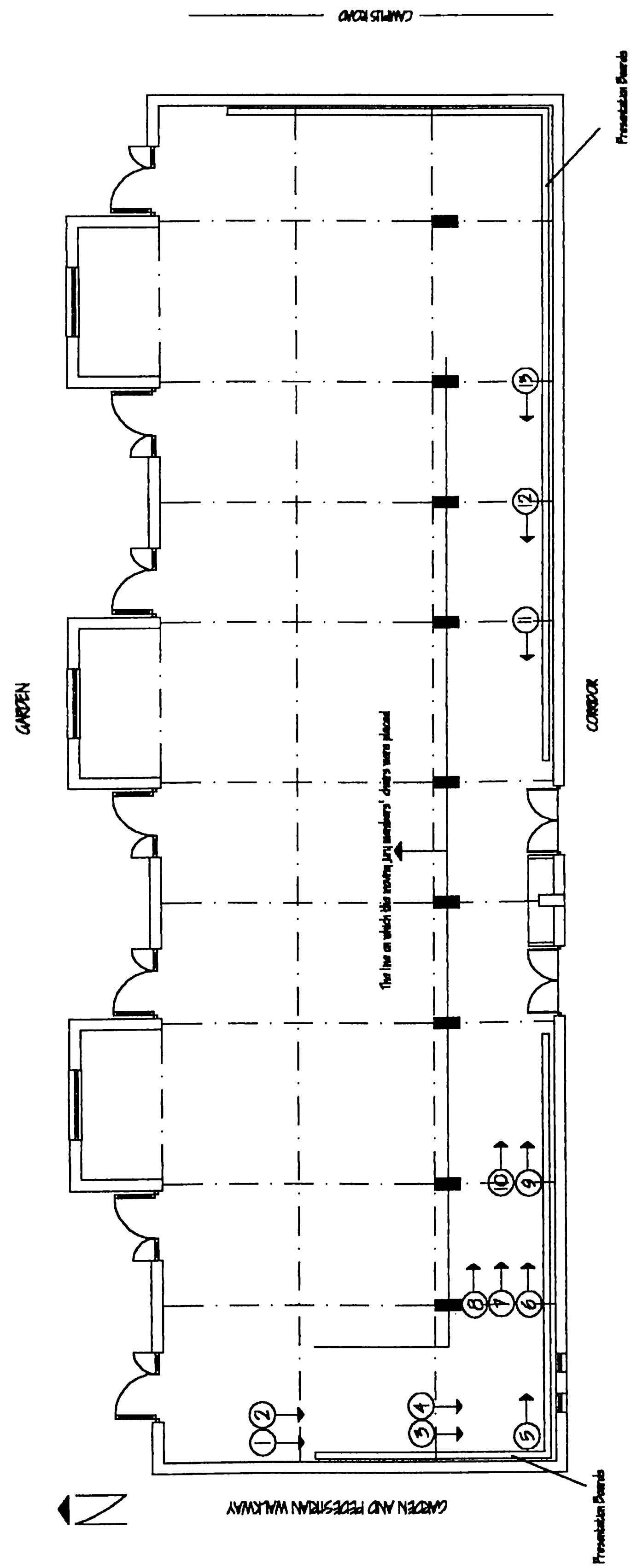


Figure 3.2.22 The Sound Pressure Level Measurements in FCZ 23 (4th class) on May 29th, 1995

May 26, 1995 (FA 214-215): The measuring period was realized between 10:30 to 16:30. A total of twelve measurements were taken, in 30 min. periods, while an average of 8 to 12 persons, in total, witnessed the juries. Within this period, the lowest Leq value was 57.4 dBA (SEL: 87.9 -lowest), at 15:00- 15:30; the average being 60.97 dBA; and the highest Leq value coming out as 64.1 dBA (SEL: 97.1 -highest) at 16:00-16:30 hours. Again, at 16:00-16:30, a mind-boggling 88.8 dBA of maximum (Max.) sound pressure was heard by the attendants of the jury. At 17:00, the background sound pressure was measured as 37.3 dBA.

Sample Number	Time	SEL (dBA)	Leq (dBA)	Min. (dBA)	Max. (dBA)
1	10:30-11:00	92.9	59.9	46.7	71.9
2	11:00-11:30	94.0	61.1	48.3	77.9
3	11:30-12:00	95.8	62.7	44.4	85.9
4	12:00-12:30	94.7	62.3	45.9	79.4
5	12:30-13:00	93.7	62.0	43.6	77.8
6	13:00-13:30	95.7	63.2	46.5	84.8
7	13:30-14:00	94.3	61.5	45.4	83.4
8	14:00-14:30	90.9	59.9	42.6	76.0
9	14:30-15:00	92.2	58.7	37.5	76.8
10	15:00-15:30	87.9	57.4	39.8	67.8
11	15:30-16:00	91.2	58.8	37.6	71.4
12	16:00-16:30	97.1	64.1	37.3	88.8

Table 3.2.12 The Sound Pressure Level Data of FA 214-215 (1st class) on May 26th, 1995

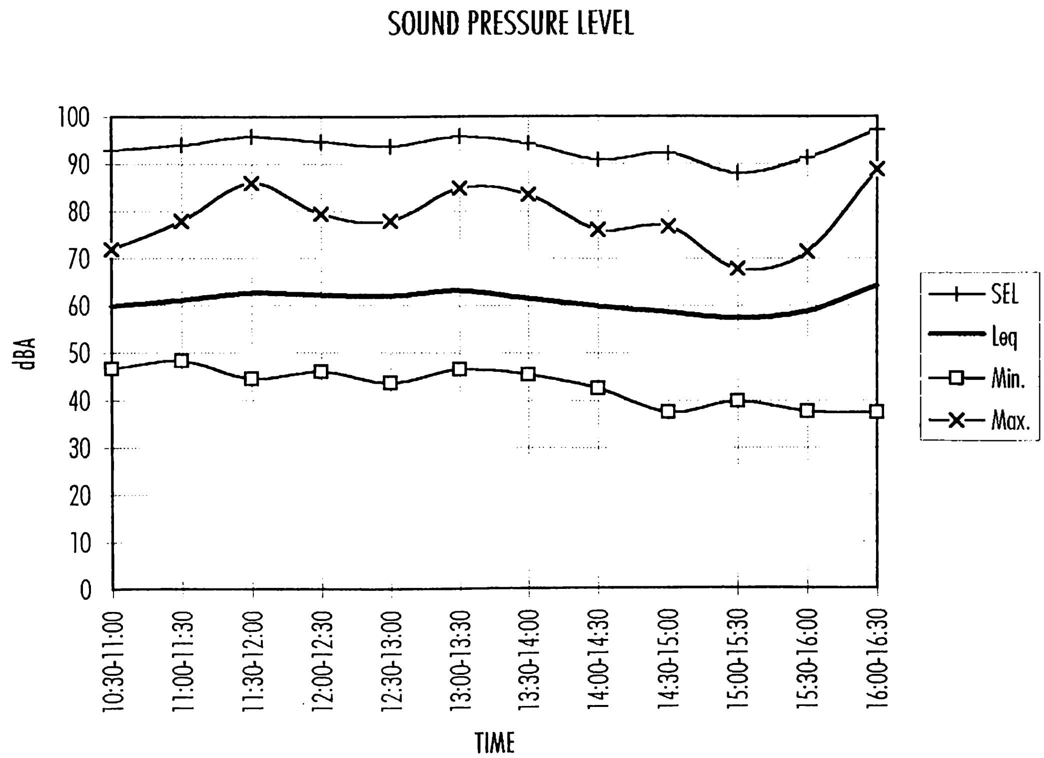


Figure 3.2.23 The Sound Pressure Level Data of FA 214-215 (1st class) on May 26th, 1995

May 25, 1995 (FC 111): There were 15 data recorded between 10:30 and 18:45 with an average participation of 15-20 persons per 30 min. period. Again, the measurement phase was disturbed, between 16:00-17:00, due to battery failure of the sound level meter. Of the 15 data sets, the lowest Leq value took place between 18:30-18:45, during the last session of the jury, as 57.9 dBA (SEL: 88.1 -lowest). The average, was calculated as 61.82 dBA. The highest Leq value was recorded between 14:30-15:00 as 64.7 dBA. At 10:30-11:00, a 85.1 dBA of sound pressure was generated, standing up as the maximum (Max.) of the recording session. Lastly, at 19:00, the background sound pressure Level came out to be 27.2 dBA.

Sample Number	Time	SEL (dBA)	Leq (dBA)	Min. (dBA)	Max. (dBA)
1	10:30-11:00	92.7	61.4	48.1	85.1
2	11:00-11:30	94.3	62.0	46.8	82.1
3	11:30-12:00	92.2	60.0	46.2	83.3
4	12:00-12:30	91.6	58.2	43.8	75.8
5	12:30-13:00	94.1	62.1	46.9	81.7
6	13:00-13:30	94.9	61.7	45.1	78.6
7	13:30-14:00	95.0	63.2	49.6	79.6
8	14:00-14:30	94.9	62.1	46.7	77.0
9	14:30-15:00	95.9	64.7	50.8	82.8
10	15:00-15:30	96.0	63.8	48.4	81.1
11	15:30-16:00	95.7	63.2	49.8	75.5
12	16:00-16:30	96.5	64.2	49.5	77.3
13	16:30-17:00	96.9	64.5	49.8	76.9
14	17:00-17:30	93.8	62.0	46.6	73.7
15	17:30-18:00	96.2	63.6	44.9	80.5
16	18:00-18:30	93.4	61.4	46.2	78.9
17	18:30-18:45	88.1	57.9	27.2	75.6

Table 3.2.13 The Sound Pressure Level Data of FC 111 (3rd class) on May 25th, 1995

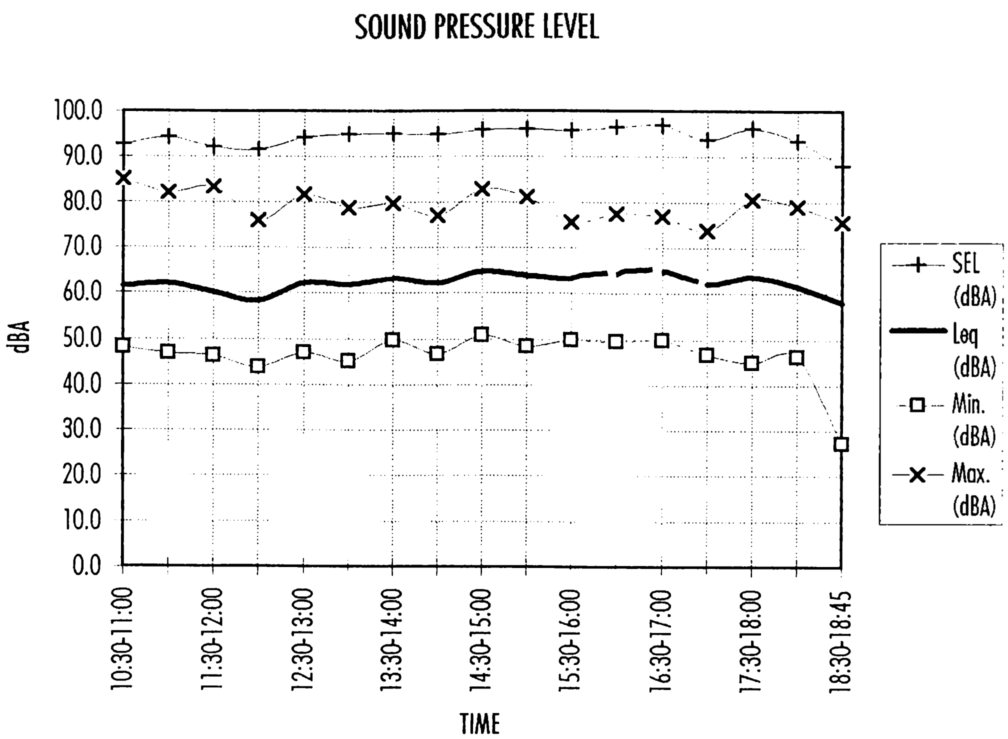


Figure 3.2.25 The Sound Pressure Level Data of FC 111 (3rd class) on May 25th, 1995

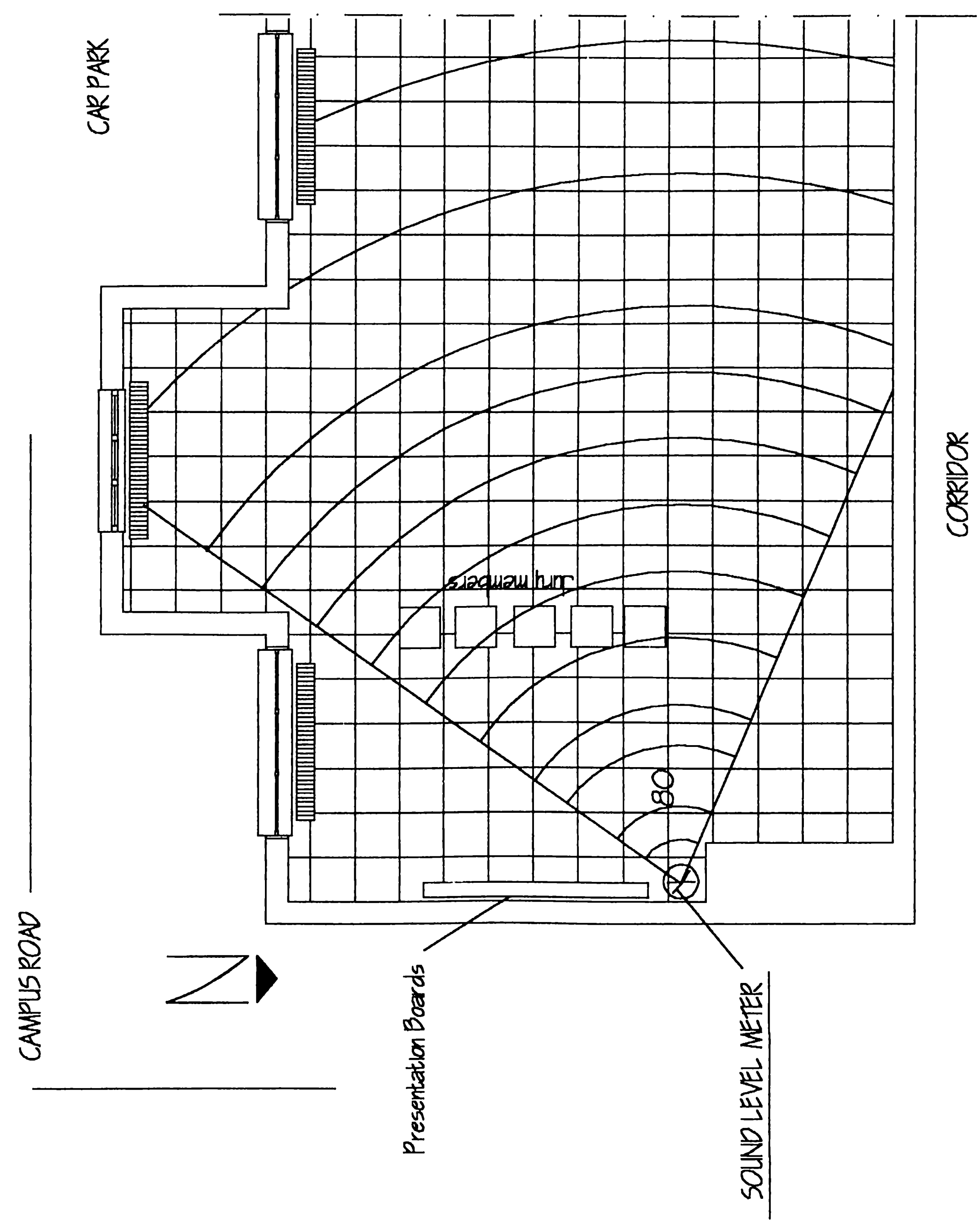


Figure 3.2.24 The Sound Pressure Level Measurements in FA 214-215 (1st class) on May 26th, 1995

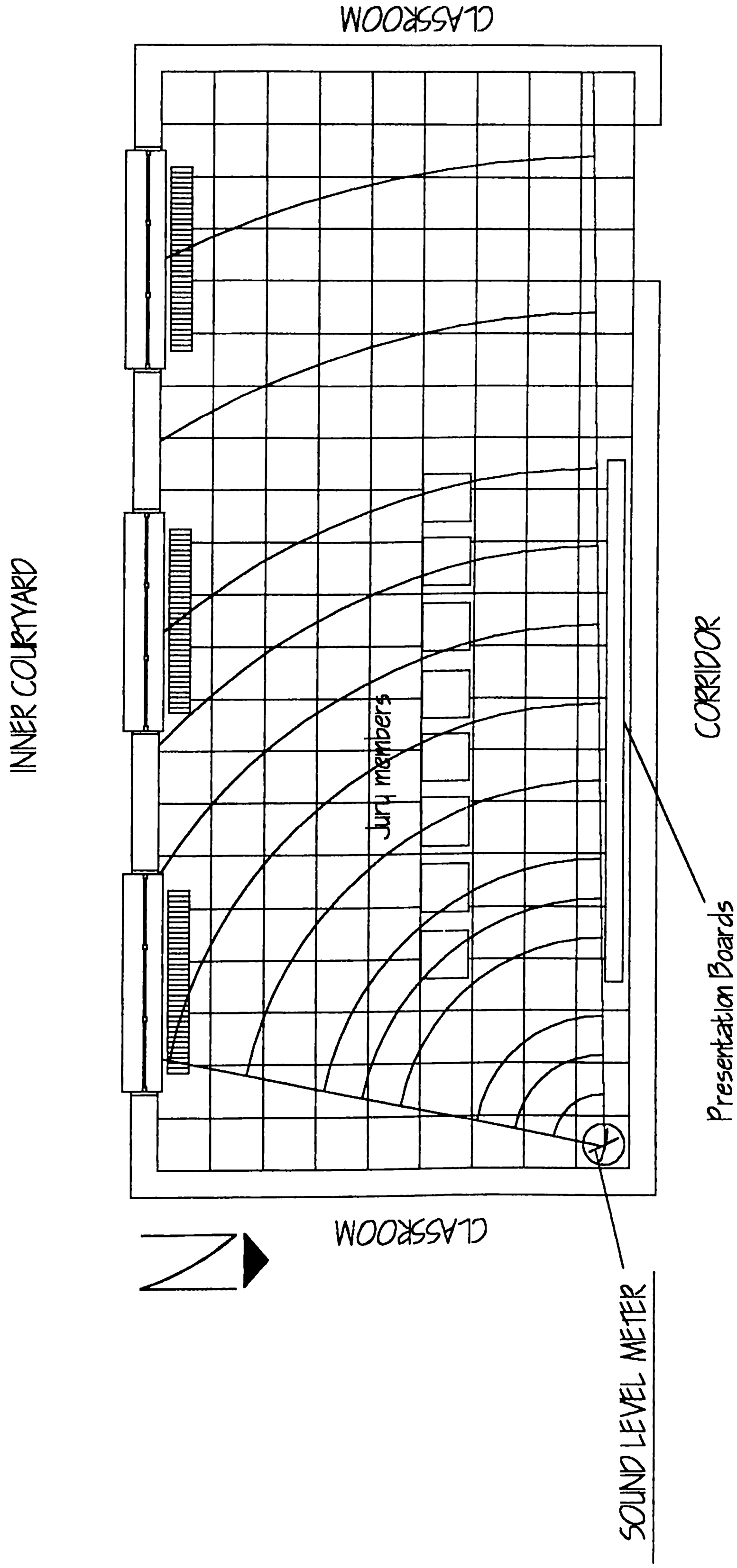


Figure 3.2.26 The Sound Pressure Level Measurements in FC 111 (3rd class) on May 25th, 1995

May 24, 1995 (FA 317-318): Nine measurements were realized in 1-hour periods between 11:00 and 20:00, with a mean attendance of 15-20 persons. In this time period, the lowest Leq value was found as 59.7 dBA (SEL: 93.9 -lowest) at 19:00-20:00 hours; while the mean Leq value came out to be 61.31 dBA; and the maximum Leq value was measured as 63.7 dBA (SEL: 98.8 - highest) at 12:00-13:00. At 14:00-15:00, a high 83.4 dBA of maximum (Max.) sound pressure level was recorded, while at 20:00, the background sound pressure level read 25.6 dBA.

Sample Number	Time	SEL (dBA)	Leq (dBA)	Min. (dBA)	Max. (dBA)
1	11:00-12:00	97.2	60.9	0.0	77.8
2	12:00-13:00	98.8	63.7	43.2	82.5
3	13:00-14:00	97.0	61.7	46.8	77.9
4	14:00-15:00	98.0	62.6	45.3	83.4
5	15:00-16:00	95.8	60.8	45.8	74.7
6	16:00-17:00	96.2	60.8	47.9	78.1
7	17:00-18:00	97.2	61.6	44.8	73.4
8	18:00-19:00	95.2	60.1	42.5	80.1
9	19:00-20:00	93.9	59.7	30.7	78.0

Table 3.2.14 The Sound Pressure Level Data of FA 317-318 (2nd class) on May 24th, 1995

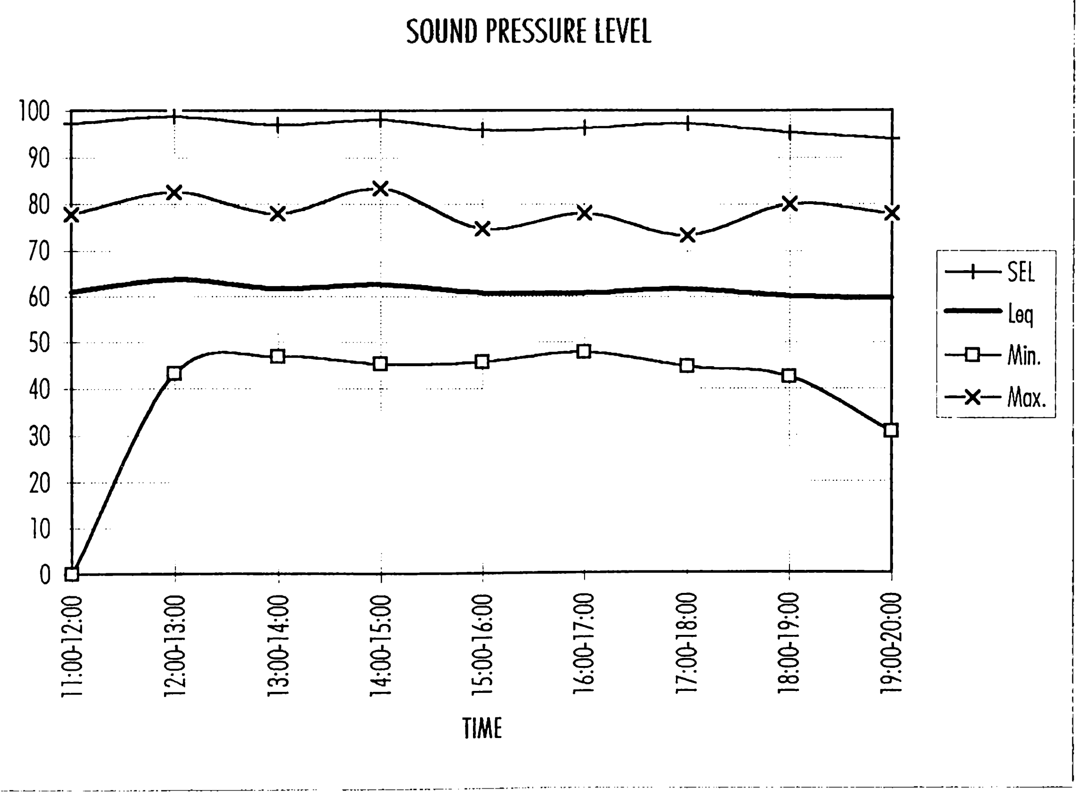


Figure 3.2.27 The Sound Pressure Level Data of FA 317-318 (2nd class) on May 24th, 1995

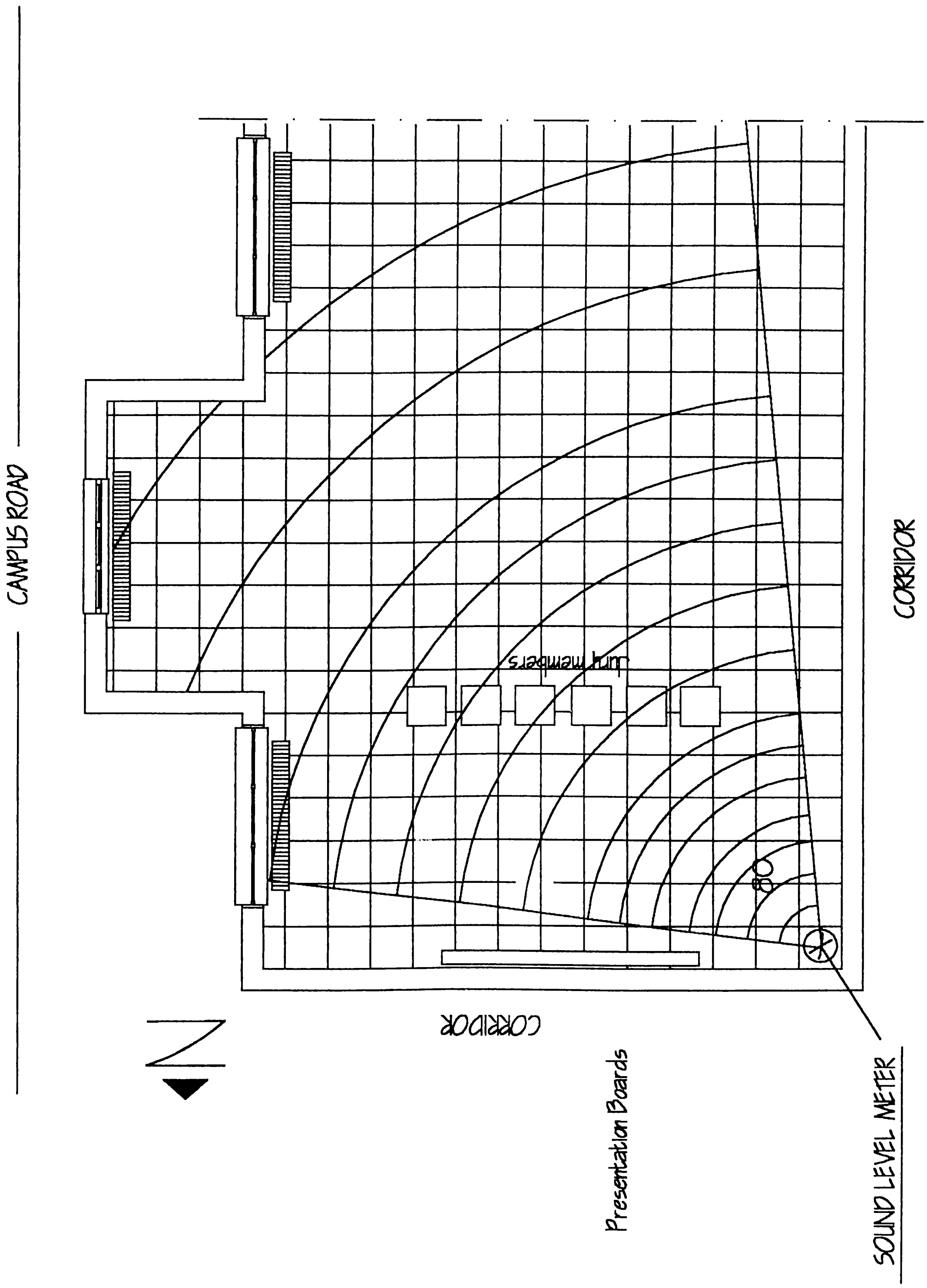


Figure 3.2.28 The Sound Pressure Level Measurements in FA 317-318 (2nd class) on May 24th, 1995

4. EVALUATION

4.1 Luminous Environment

Following the structure of the measurements, this chapter will be subdivided in the format of Chapter 3. Accordingly, even though both are within the realm of the luminous environment, luminance and illuminance measurements will be evaluated and discussed separately.

4.1.1 Luminance Measurements

In order to be able to make a sound analysis of the results of the luminance measurements, precise and reliable standards are required. Below are a set of standards on luminance by individual and international research groups, where available. No data on luminances were found in the Turkish lighting codes.

According to de Boer (71), ' an observer's field of view in an interior may include some or all of the following: faces, a task area, walls, ceiling, sky (seen through a window), luminaries. When recommending luminance values for each of these objects or areas it is customary to quote:

' Minimum values when referring to the luminance of the human features: 1 cd/m^2 for the features to be just recognizable, or 10 cd/m^2 - 20 cd/m^2 for the features to be just acceptably lit, i.e. recognizable without any special effort.

Optimum values when referring to the luminance of walls, ceiling, task area and the human features:

50 cd/m^2-150 cd/m^2 for walls,

100 cd/m^2-300 cd/m^2 for ceilings,

100 cd/m^2-400 cd/m^2 for the task area, and about

250 cd/m^2 for the human features

Maximum values when referring to the luminance of sky and luminaries:

2000 cd/m^2 marks the beginning of glare from the sky

1000 cd/m^2-10000 cd/m^2 (depending on illuminance level, type of luminaire, and room conditions) is the maximum luminance' (Boer, 71).

Below is the compact data table from the Philips Lighting Manual of 1988 (47). The table also includes approximate horizontal illuminance values, in order to supplement the designer with illuminances necessary to achieve the luminance values indicated.

	Luminance (cd/m^2)	Horizontal Illuminance (lx)
Features of human face just discernible reflectance= 0.1	1	20
Features of human face satisfactorily discernible reflectance= 0.1	10-20	200
Optimum viewing conditions in normal working interiors reflectances between 0.2 to 0.8	100-400	2000
Task luminance for surfaces, reflectances above 0,15	1000	20000

Table 4.1.1 Recommended luminances and corresponding levels of horizontal illuminance

As can be noticed in both of the references cited, there is a distinct inclination towards defining ranges rather than specific values of luminances. The intention here is to give the designer recommended ranges which are to be arranged by him to form a scale of luminance for the interior. Figure 4.1.1 below will serve the designer as a quick reference to luminance measurements within an interior space.

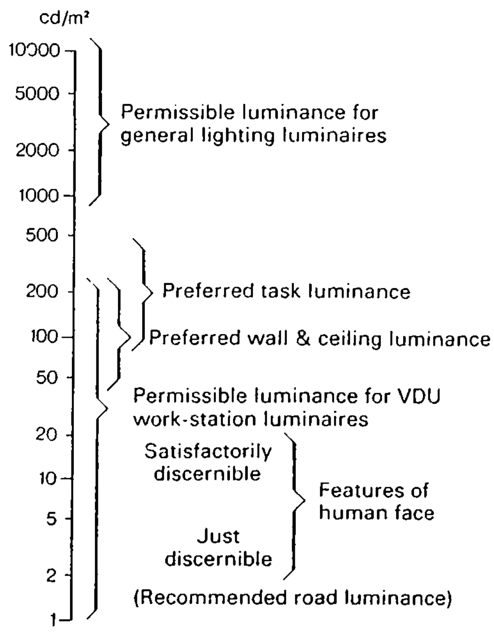


Figure 4.1.1 Recommended scale of luminance for interiors

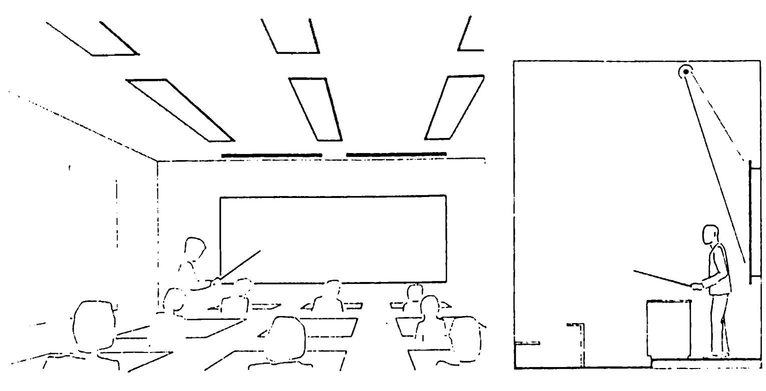


Figure 4.1.2 Additional Lighting for the Presentation Board

Summary of Measurement Data

Studio No	Min. A (cd/m^2)	Min. B (cd/m^2)	Av. A (cd/m^2)	Av. B (cd/m^2)	Max.A (cd/m^2)	Max. B (cd/m^2)
FCZ 23	31.89	28.73	82.27	80.17	118.2	137.4
FA 214-215	83.62	100.8	130.9	163.69	167.8	286.8
FC 111	82.13	66.34	125.18	120.94	170.6	189.4
FA 317-318	78.74	80.84	108.06	121.42	139.8	150.3

Table 4.1.2 A Summary of the Luminance Measurements

Evaluation

The FA 214-215 studio, facing south without any obstructing buildings around (Appendix B), gave the highest values for all categories. The presentation boards were next to the high windows (Figure 3.2.4), which provided daylight from the unobstructed sky. Here, luminance values rose as high as 286.8 cd/m^2 at 11:00, constituting the maximum for the four studios. The afternoon luminance values showed a decreasing trend, due to the fact that the jury wall was on the south-east wall of the studio. Therefore, the effect of daylight which entered the studio was higher in the morning, in terms of luminance on the presentation boards.

The FC 111 studio, having the same orientation with the FA 214-215 studio, could not come up with similar results for two reasons. One was that the studio's south-west side was obstructed by the west wall of the FB building (Appendix B). This factor greatly decreased the luminance level provided by the morning sun. The other reason was the jury wall's distance to the windows was greater than the FA 214-215 studio. Here, the light gradient factor - a result of inverse square law- was effective; that as the distance from the light source increased, the amount of light reaching the depths of the room decreased (Figure 3.2.6).

The FA 317-318 studio, with its eastern exposure, ranked third among the four studios. This studio seemed to make advantage of its opening to the east until noon, since it received direct horizontal sunlight in the morning. However, it should be noticed that the jury members needed to turn on the supplementary lighting system at 14:30 which shows that together with the partial cloudy sky of May

24, 1995, the movement of the sun towards the west left the studio unattended by the direct effect of sunlight and daylight from the sky. This caused a remarkable down-shift in the luminance level of the presentation boards. Even though the luminance values of the FA 317-318 studio, after 14:30 hours, were close to the values of the FA 111 studio, the teachers needed to turn on the lights due to the sudden decrease in the luminance level. This event is an indication of the subjectivity of lighting, which will be discussed in the fifth chapter.

Finally, the huge FCZ 23 studio listed last with its northern exposure and great light loss due to the light gradient factor. Looking to the plan of the studio (Fig 3.2.2), one might immediately notice that a vast majority of the juries were held on presentation boards placed away from the daylight sources. This made it a necessity to turn on the lighting system as early as 12:30 hours. In this studio, the jury began from the north-west wall, looking slightly towards the east, which received more northern daylight than the rest of the jury walls. Gradually, as the jury moved towards the darker corners of the studio, due to the lack of sufficient light, the need for supplementary light emerged, and the lights were turned on.

Considering that the optimum viewing conditions in normal working interiors require luminance values between 100-400 cd/m^2 (Philips 47; Boer 71), it can be seen that the FCZ-23 studio was far from satisfying this requirement, even after the supplementary lighting system was activated. In addition, the Philips Lighting Manual (79) indicates that 100 cd/m^2 is the normal wall luminance value in the classroom, while the whiteboard requires additional lighting (Figure 4.1.2). This would mean that the luminance value of a wall-mounted architectural drawing presentation board will require a luminance level way above 100 cd/m^2, even though specific values are not given. In this context, only the average B value of the FA 214-215 studio could fall within an acceptable lower luminance limit. Meanwhile, it was realized that, when activated, the supplementary lighting systems of the FA 317-318 and the FCZ 23 studios could shift the luminance level slightly above minimum. Keeping in mind the great change of the quality and quantity of daylight due to the path of the sun throughout the day and the year, it can be deduced that the studios measured were far from meeting the physical requirements of its occupants- even during late spring and early summer's good daylight conditions. Figure 4.1.3 is a clear representation of this situation.

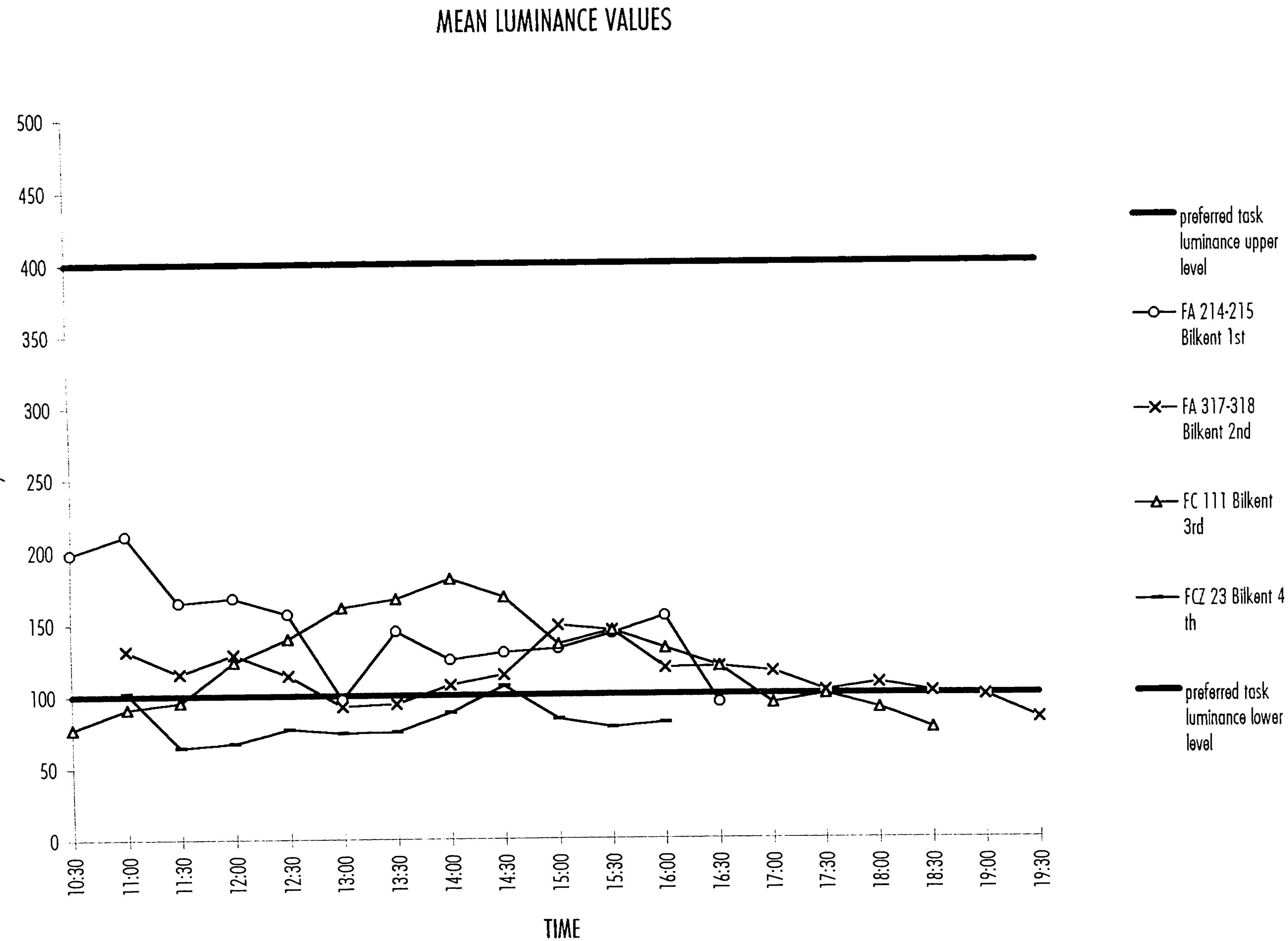


Figure 4.1.3 Mean Luminance Values of the Four Studios

4.1.2 Illuminance Measurements

As will be explained in the next chapter, factors shaping luminance and illuminance are identical, if not the same. Therefore, in evaluating illuminance, those physical characteristics of the studios which affected the luminance measurements are not repeated.

In order to be able to make a sound analysis of the results of the illuminance measurements, precise and reliable standards are required. Below are a set of standards on illuminance by individual and international research groups, where available.

The Illumination Engineering Society of North America has classified recommended illuminance categories and illuminance ranges for interior lighting designers in terms of generic-type activities (10). These are indicated below, in Table 4.1.3.

Type of Activity	Illuminance Category	Range of Illuminance (Lux)	Reference Work-plane
Public spaces with dark surroundings	A	20-30-50	General
Simple orientation for short temporary visits	B	50-75-100	lighting throughout
Working spaces where visual tasks are only occasionally performed	C	100-150-200	spaces
Performance of visual tasks of high contrast or large size	D	200-300-500	**Illuminance**
Performance of visual tasks of medium contrast or small size	E	500-750-1000	**on**
Performance of visual tasks of low contrast or very small size	F	1000-1500-2000	Task
Performance of visual tasks of low contrast and very small size over a prolonged period	G	2000-3000-5000	Illuminance on task, obtained by a
Performance of very prolonged and exciting visual task	H	5000-7500-10000	combination of general and
Performance of very special visual tasks of extremely low contrast and small size	I	10000-15000-20000	local (supplementary) lighting

Table 4.1.3 Illuminance Categories and Ranges for Interior Lighting Design

IESNA provides data in the form of the illuminance categories as specified in Table 4.1.3 for specific activities in educational facilities (10-1). These are as follows:

Drafting

Mylar

High contrast media; India ink, plastic leads,

soft graphite leads ....E (500-1000)

Low contrast media; high graphite leads ....F (1000-2000)

Vellum

High contrast ....E (500-1000)

Low contrast...F (1000-2000)

Tracing paper

High contrast ....E (500-1000)

Low contrast ....F (1000-2000)

Overlays

Light table ....C (100-200)

Prints

Blue line ....E (500-1000)

Blueprint ....E (500-1000)

Sepia prints ....F (1000-2000)

Another leading institution in the field of interior lighting is the Chartered Institution of Building Services Engineers (CIBSE). The 1984 Code for Interior Lighting of CIBSE provides designers with lighting recommendations for specific interiors and activities. Among are standard service illuminance values for educational institutes, as shown below (52-3) :

	Standard Service Illuminance
Education	(lx)
Assembly Halls	300
Teaching spaces	300

Lecture theaters	
General	300
Demonstration benches	500
Seminar rooms	500
Art rooms	500
Needlework rooms	500
Laboratories	500
Libraries	300
Music rooms	300
Sports halls	300
Workshops	300

Additional emphasis is put on the requirement that no matter what the light source is, the illuminance on any point on the working plane should be a minimum of 150 lx. For the same interior, a service illuminance of not less than 300 lx -where fluorescent lamps are used- and where the lighting of a space is achieved by a combination of daylight and electric light a service illuminance of not less than 350 lx will usually be necessary (52).

A third set of standards are obtained from the Ministry of Public Works of the Turkish Republic. However, these are unofficial documents, which are hand-distributed to the technical offices of the

Ministry, presumably published in 1977, and not revised until then. These unofficial documents resemble their European and American precedents in the way they are arranged. A summary of the relevant data are listed below.

	Required Illuminance Level (lx)
Offices	
Mechanic and Architectural Drafting	750
Sketch and Decorative Drafting	500
Schools	
Kindergarten Schools	100
Primary Schools	
Classrooms	200
Corridors	100
Secondary Schools	
Classrooms	250
Laboratories	300
Meeting rooms	150
Corridors	150
Technical Schools	
Classrooms	250
Drafting rooms	400
Workshops	250

These standards are somewhat awkward and hard to rely on, in the sense that they show a direct proportion between age and illuminance level. According to these standards, kindergarten and primary school students have better perception than secondary and higher school students. That is, for the same task, i.e. reading, small children are superior to adolescents.

Summary of Measurement Data

Studio No	Min.A(lx)	Min.B(lx)	Av.A(lx)	Av.B(lx)	Max.A(lx)	Max.B(lx)
FCZ 23	190	327	349	416.6	448	600
FA 214-215	348	758	561.1	1071.4	700	1430
FC 111	252	225	445.1	463.6	624	672
FA 317-318	358	457	512.6	768.5	639	1210

Table 4.1.4 Summary of the Illuminance Measurements

Evaluation

The results gained in the illuminance data showed great resemblance with the results of the luminance data. The FA 214-215 studio ranked at the top again, due to its uninterrupted southern exposure to daylight from an unobstructed sky. This time, the FA 317-318 studio came second, as a result of its physical opening to eastern light -until noon- and the location of the jury wall. According to the compilation on the illuminance ranges of design studios, an illuminance level of 500 to 1000 lux can be observed as recommended. Accordingly, the FA 214-215 and FA 317-318 studios were the only two where the averages fell within this range. The FC 111 and FCZ 23 were very much below this level, the FCZ 23 still holding its positions as the poorest studio in terms of light. The FC 111, on the other hand, gave quite low results as a result of the light gradient loss and the fact that the jury members and those watching the jury were actually blocking daylight. This is interesting in the sense that the jury members never felt the need to turn on the lights, even though the illuminance value reached levels below standards. As a conclusion, only two of the studios were -barely- sufficient enough, in terms of illuminance, to meet the physical needs of the jury members and the students for the duration of the juries. In the other two studios, it was seen that daylighting was not enough to bring illuminance to required levels while the supplementary lighting systems located on the ceilings high above were far away from fulfilling the requirements for which they were installed. The standing of the four studios measured can be clearly analyzed in Figure 4.1.4 in the following page.

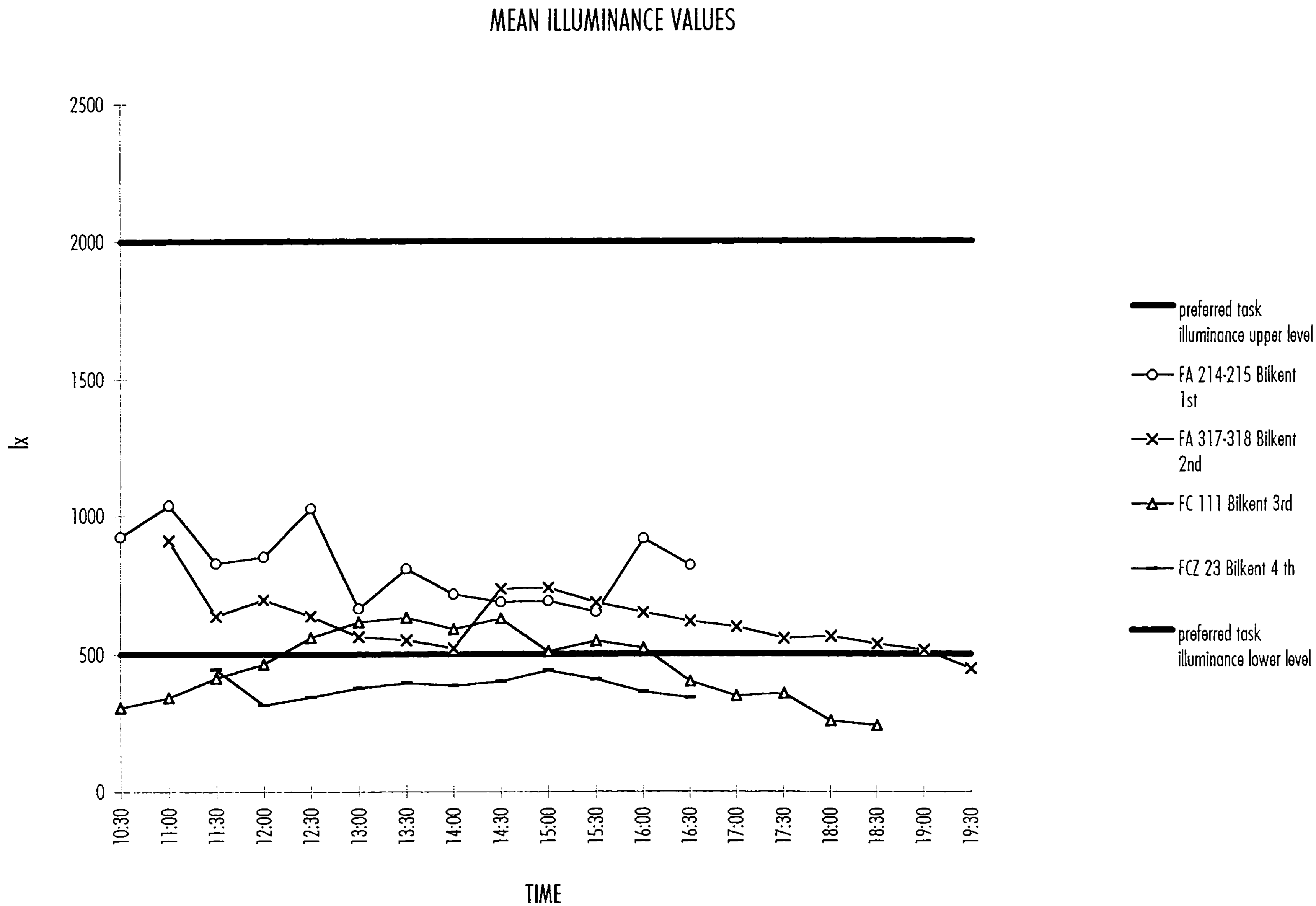


Figure 4.1.4 Mean Illuminance Values of the Four Studios

4.2 Sonic Environment

In order to be able to make a sound analysis of the results of the sound pressure level measurements, precise and reliable standards are required. Below are a set of standards on sound pressure level by individual and international research groups, where available.

Egan has defined interior spaces which require quiet ambient backgrounds as places which need to be located far away from noise sources or be shielded by noncritical *buffer* spaces such as storage rooms and the like (272). It is also mentioned that window openings of quiet spaces should be placed on building exposures which face away from environmental noise sources. Below is a list of the types of spaces classified according to their characteristics related to noise source and quiet ambient background.

Types of Spaces	Noise Source	Quiet Ambient Background
Auditoriums, theaters, radio/TV studios, music practice rooms, large meeting rooms, classrooms, audiovisual facilities, conference rooms	Yes	Yes
Residences, apartments, hotels, motels, reception areas, churches, chapels, courtrooms, large offices	Sometimes	Yes
Private offices, libraries, bedrooms hospital patient rooms	No	Yes
Retail shops and stores, cafeterias, kitchens, laundries, school and industrial shops, computer equipment rooms, mechanical equipment rooms	Yes	No

Table 4.2.1 Classification of Rooms for Noise Control

A similar chart is also introduced by Egan on noise criteria for rooms. Noise criteria curves can be used to evaluate existing situations by measuring sound levels at the loudest locations in rooms, preferably at user ear height (233). They also can be used to specify the steady, or continuous, background noise levels. The table below presents recommended noise criteria ranges for various indoor activity areas (233).

Type of Space (and Listening Requirements)	Preferred Range of Noise Criteria	Equivalent dBA Level
Concert halls, opera houses, broadcast and recording studios, large auditoriums, large churches, recital halls (for excellent listening conditions)	< NC-20	<30
Small auditoriums, theaters, music practice rooms, large meeting rooms, teleconference rooms, audiovisual facilities, large conference rooms, executive offices, small churches, courtrooms, chapels (for very good listening conditions)	NC-20 to NC-30	30 to 38
Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, motels (for sleeping, resting, relaxing)	NC-25 to NC-35	34 to 42
Private or semiprivate offices, small conference rooms, classrooms, libraries (for good listening conditions)	NC-30 to NC-35	38 to 42
Large offices, reception areas, retail shops and stores, cafeterias, restaurants, gymnasium (for moderately good listening conditions)	NC-35 to NC-40	42 to 47
Lobbies, laboratory work spaces, drafting and engineering rooms, general secretarial areas, maintenance shops such as for electrical equipment (for fair listening conditions)	NC-40 to NC-45	47 to 52
Kitchens, laundries, school and industrial shops, computer equipment rooms (for moderately fair listening conditions)	NC-45 to NC-55	52 to 61

Table 4.2.2 Noise Criteria for Rooms

As previously mentioned in the second chapter by Egan, it is concluded that in a classroom, reverberation times should be less than 0.8 seconds (88). Otherwise, long reverberation times will occur, resulting in the reduction of the intelligibility of speech the same way noise masks speech signals. Below is a chart from

Egan which demonstrates the numerical designation of *noise criteria* NC curves prepared by taking the arithmetic averages of the sound pressure levels at 1000, 2000, and 4000 Hz, which are extremely important frequencies for speech perception (235). Even though they weren't measured in this study, the NC rating for a measured noise can be found by comparing its plotted sound spectrum to the NC

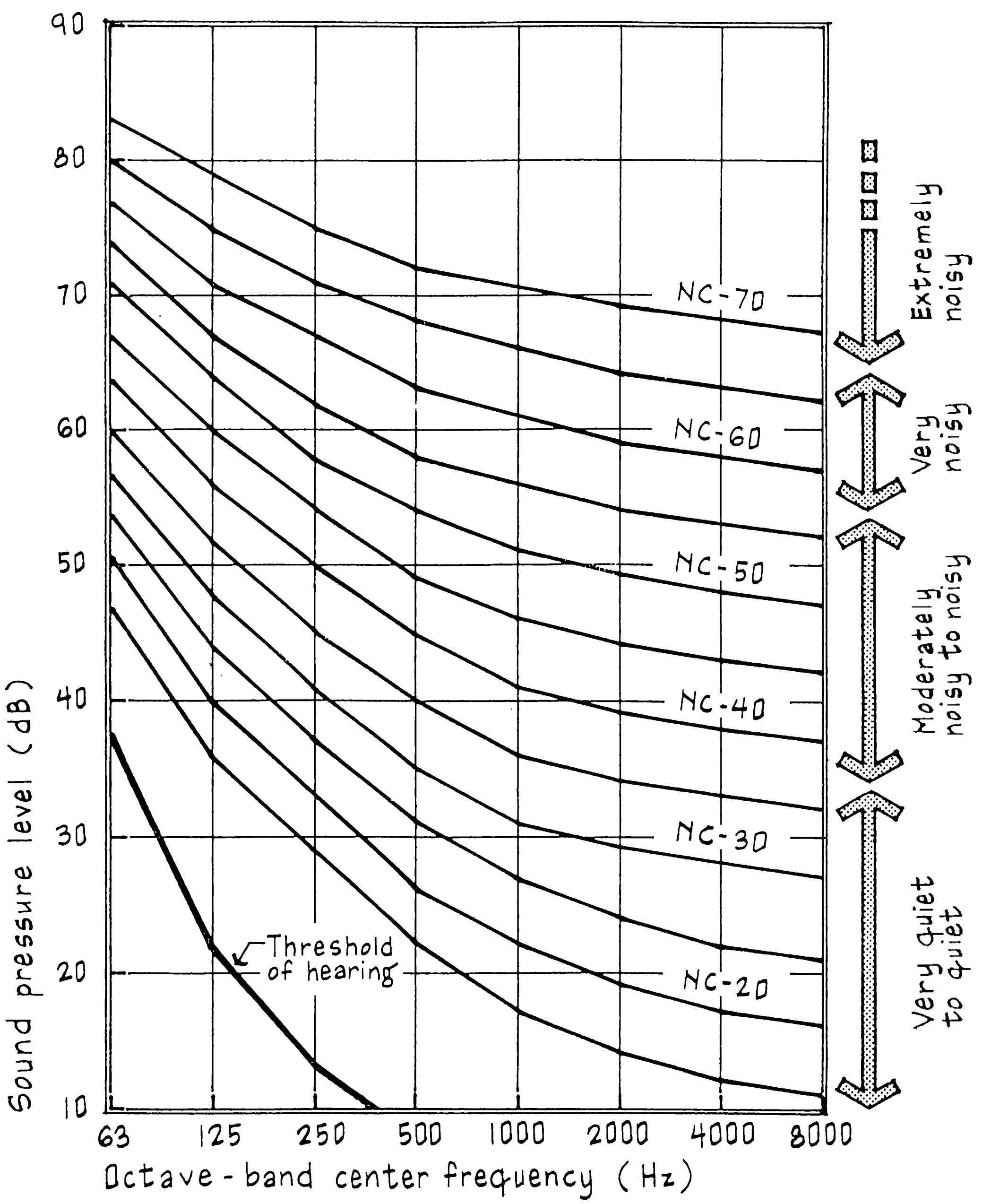


Figure 4.2.1 Noise Criteria Curves

Another source of information for standards on sound pressure level, by Templeton (68), states that 'reverberation times inside the classroom conditions should be controlled to 0.75 seconds at middle frequencies and 40 dB average separation between reading areas.' He goes on to add that in a space with good room acoustics for speech (reverberation time 0.5-0.75s) -like a design studio during juries and presentations- the following guides apply (72):

- up to 15m	relaxed listening
- 15-20m	good intelligibility
- 20-25m	satisfactory
- 30m	limits of acceptability

Templeton advises that reading lip movements helps intelligibility, which is of assistance up to 15m (72). A speech reinforcement system is recommended when the distance between the speaker and the farthest listener exceed 10-15m.

Summary of Measurement Data

The studio	Av. Persons	Min. Leq (dBA)	Av. Leq (dBA)	Max.Leq (dBA)	Max.SPL (dBA)	Background SPL (dBA)
FA 217-218	35-45	62.0	67.08	71.1	90.4	22.7
FCZ 23	10	60.5	63.31	65.6	87.3	31.7
FCZ 23	15-20	59.0	61.37	63.7	89.0	35.9
FA 214-215	8-12	57.4	60.97	64.1	88.8	37.3
FC 111	15-20	57.9	61.82	64.7	85.1	27.2
FA 317-318	15-20	59.7	61.32	63.7	83.4	25.6

Table 4.2.3 Summary of the Sound Pressure Level Measurements

Evaluation

Being the most crowded and noisy jury, the results of the FA 217-218 studio showed to have the highest values for Min. Leq, Av. Leq, Max. Leq, and Max. SPL. On the other hand, the same studio had the lowest background sound pressure level, which was measured at 21:15, the latest hour of the sound pressure level measurements of the six days.

The FCZ 23 also showed very high values for all categories. The interesting point about the FCZ 23 studio was that even though the May 29 jury was more crowded, the results of the June 1 jury had higher values. The reason for such a situation can be explained by the difference in the input of the background sound pressure level to the Leq throughout the measurement period. However, it will be noticed that the background noise of the May 29 jury was higher than the June 1 jury. Even though this data may seem to dispute the above statement, the results have pointed out that as time proceeds, background pressure level decreases (Fig. 4.2.2). That is, since the background sound pressure level measurement of May 29 was taken at an earlier time than June 1, its resulting value appeared to be higher (Table 4.2.4)

The studio	Time	Background SPL
FA 217-218	21:15	22.7 (dBA)
FA 317-318	20:00	25.6 (dBA)
FC 111	19:00	27.2 (dBA)
FCZ 23	18:45	31.7 (dBA)
FCZ 23	18:00	35.9 (dBA)
FA 214-215	17:00	37.3 (dBA)

Table 4.2.4 Time vs. Background Sound Pressure Level

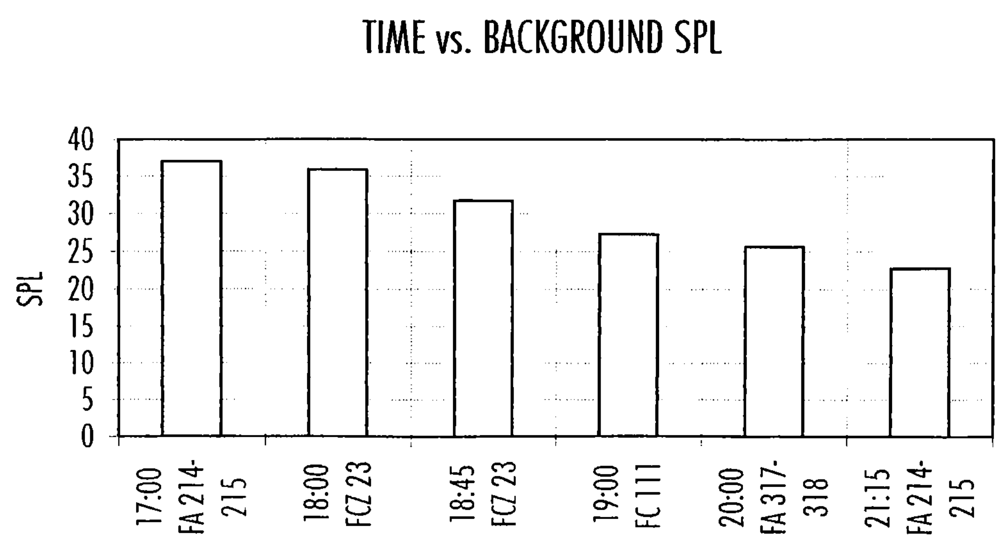


Fig. 4.2.2 Time vs. Background Sound Pressure Level

The FC 111 studio had presented results away from the expected. Even though this studio seemed to be secluded from noise generating sources like cars, its relatively small size and the relatively crowding number of students per square meter watching the juries were enough to produce high sound pressure levels inside this studio.

The FA 317-318 studio proved to be more quiet than the FA 217-218 below. This was due to the difference in the number of students attending the juries, the less traffic on the corridors, and the higher elevation -top floor of the building- of the FA 317-318 studio.

Finally, the FA 214-215 studio was relatively more quiet in terms of Min. Leq and Av. Leq values. The high background noise was a result of the working construction site, but it was not very much effective on the Av. Leq values. Another contributing factor was the small quantity of persons watching the juries in this studio.

Evaluation

The above conclusions have common characteristics. All the studios measured were far more noisy than the desired value for a classroom, which is about 38-42 dBA (Egan 233). The peak sound pressure levels were very surprising and scaring, remembered that maximum values went up to 90 dB and above in the FA 217-218 studio and close-by in the FCZ 23 and FA 214-215 studios. Problems of high background noise level were primarily a result of campus roads adjacent to the buildings, construction sites inside and nearby the campus, noise from corridors and campus pedestrian walkways surrounding the studios. It was also recorded that at night, after all the above mentioned noises had disappeared, there was a high background noise coming from the city of Ankara. Within the studios, as the number of students attending a jury increased, complaints of difficulty of hearing the students presenting their work by the jurists increased as well.

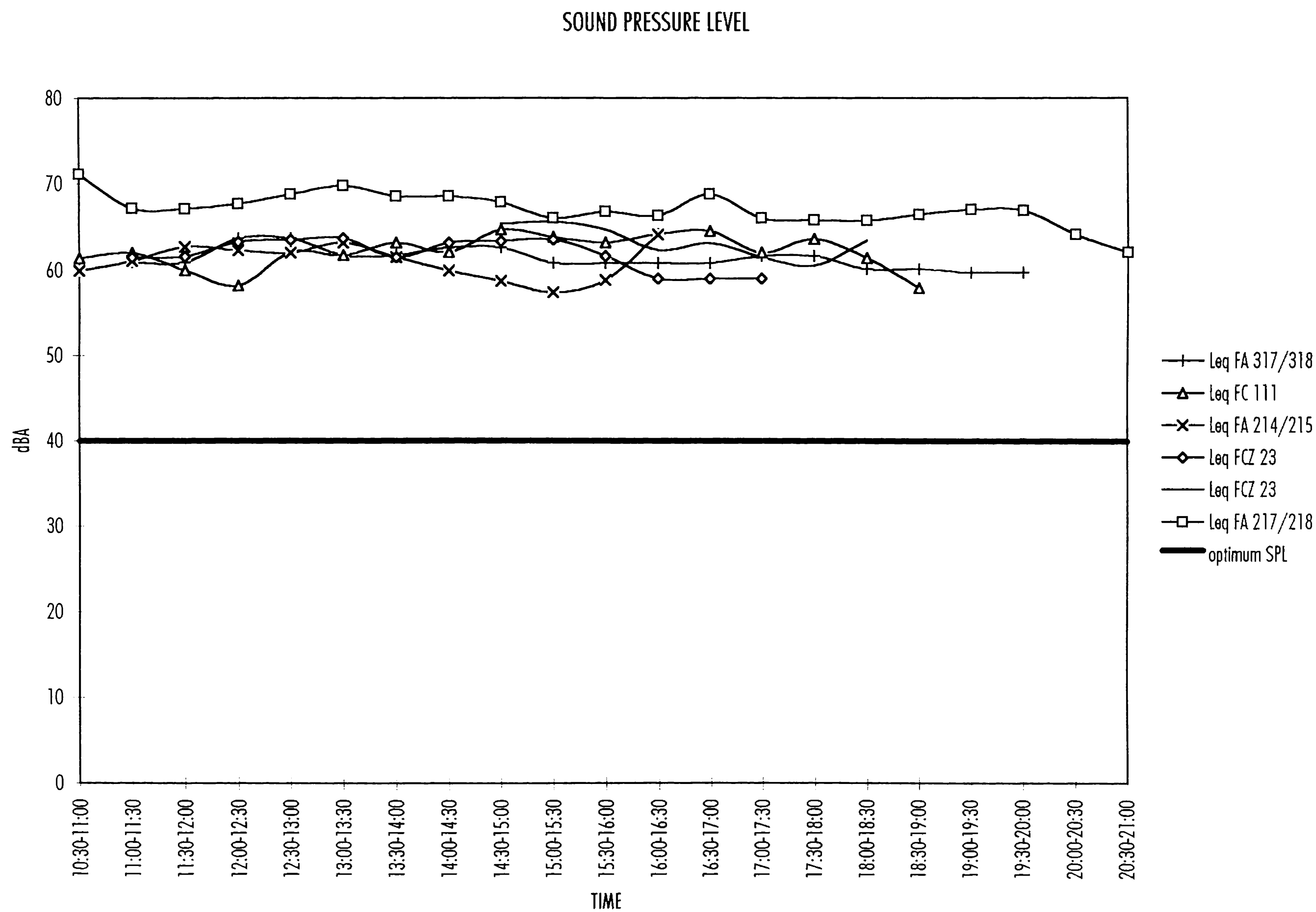


Figure 4.2.3 Mean Sound Pressure Level Values of the Four Studios

5. CONCLUSION

5.1 General Commentary

Before proceeding with the lighting and acoustics conclusions, there are a number of points that need to be emphasized. The most important of these points is the issue of subjectivity. It is common knowledge that human sensory systems do not respond to different stimulus with a constant reaction, but vary from person to person due to physical well-being, inborn characteristics, geographical and cultural backgrounds, age, personal habits and the like. Accordingly, different persons have different reactions towards the same environmental conditions. This is the subjectivity of human perception and has certain implications on the outcomes of the study.

Studies concerning acoustics and lighting are not designed to physically and psychologically satisfy all the occupants of a space, since this is very rarely possible. Rather, as a result of biological variance, the aim is to create an environment which is optimally comfortable for the highest possible percentage of the occupants. Therefore, the standards, numeric data and principles pertaining to light and sound mentioned in this text should be viewed accordingly. In a similar manner, human perception is also a subjective judgment. As it varies from person to person, its accuracy can change momentarily due to factors like disruption of concentration on task, changes in the environment, hunger, fatigue, and the like.

There were several observations noted by the researcher during the measurement-taking phase on the subjective criteria of lighting and acoustics, due to differences in humans beings:

The FCZ 23 and FA 317-318 were the two studios where the supplementary lighting systems were turned on. The FCZ 23 studio, as explained previously in the third and fourth chapters, is the studio with the worst lighting conditions. The lighting system was activated at 12:50. The reason was a drastic downshift in the luminance (A=71.62 cd/m^2, B=77.84 cd/m^2) and illuminance (A=114 lx, B=105 lx) levels. Likewise, the FA 317-318 studio went through a similar trend with its luminance (A=90.41 cd/m^2, B=104.1 cd/m^2) and illuminance (A=324 lx, B=533 lx) values at 14:00. The subjectivity of human perception appears in the comparison of the two studios. It can be noticed that the illuminance values of the FA 317-318 studio was three times as much for A and five times as much for B values of the FCZ 23 studio at the time the jury members decided to turn on the lights. Obviously, both the luminance and illuminance values of the FCZ 23 studio were below acceptable standards throughout the day. However, the jury members decided to turn on the lights only when there were sudden decreases in the luminance and illuminance levels. This is the subjective adaptation process of the human sensory system to the surrounding environment. That is, even though the luminance and illuminance values were under desired levels, the eye tended to harmonize with the existing conditions of the environment, until an unacceptable discomfort had occurred. The reaction of the jury members and the students in the FA 111 studio behaved similarly with this observation. The values of the FA 111 studio shows that both the luminance and the illuminance values started to rise at 10:30 in the morning, reached their peak at 14:00 hours and from then on, entered a declining phase. During the morning and late afternoon, the luminance and illuminance values were below desired conditions. However, as again, the eyes had adapted to the luminance and illuminance levels in the very beginning. Since no extreme increases or decreases were recorded throughout the day, the eye's adaptation limits were not exceeded and no lights were turned on.

Another observation revealed the truth that age was an important consideration in designing for lighting. In the two studios mentioned above where the lights were turned on, the need for more light came from the jury members, not the students. Moreover, in both of the studios, the lights were turned on by the most elderly member of the jury without the consent of the other jury members, but simply as a result of personal demand. It was noticed that these attempts did not receive any objections from the other members of the jury.

From these observations, certain designing principles can be deduced. One is that while selecting luminance and illuminance standards for design studios, planning should be made considering the upper age level of the users of the design studio as well as those of the students. Another point to keep in mind is when planning different zones with different functions inside the studio, the luminance and illuminance levels of adjacent zones should not show drastic differences. Otherwise, the adaptation limits of the eye will be outran, resulting in fatigue.

The topic of subjectivity also shows up in the field of acoustics. Again, it was observed during the juries that the factors of personal attitude towards the sound generator or noise, mood of the listener, duration of sound event and sound character determined the reactions of the jurists and the students in the design studio. That is, while instructors constantly complained about not being able to hear the student being examined because of sound generated constantly by mumbling students, neither of the students came up with such complaints of difficulty of hearing. This was a result of the age of the instructor, the limit of tolerance of an instructors to a student and of a student to another one.

The subjective criteria of lighting and acoustics is very difficult to deal with. Actually, they are outside the scope of the designer. Even though these are not predictable, a designer should be aware of their existence and positive and negative influences on the perception of the qualities of a space.

5.2 Lighting Conclusion

One of the conclusions derived from the measurement phase was that the changes occurring in the luminous environment affected luminance and illuminance values simultaneously. No matter what the orientation of the studios were, the juxtaposition of corresponding luminance and illuminance charts produced very close curves. The comparison of luminance and illuminance curves for each studio are shown in Figure 5.2.1 to Figure 5.2.4.

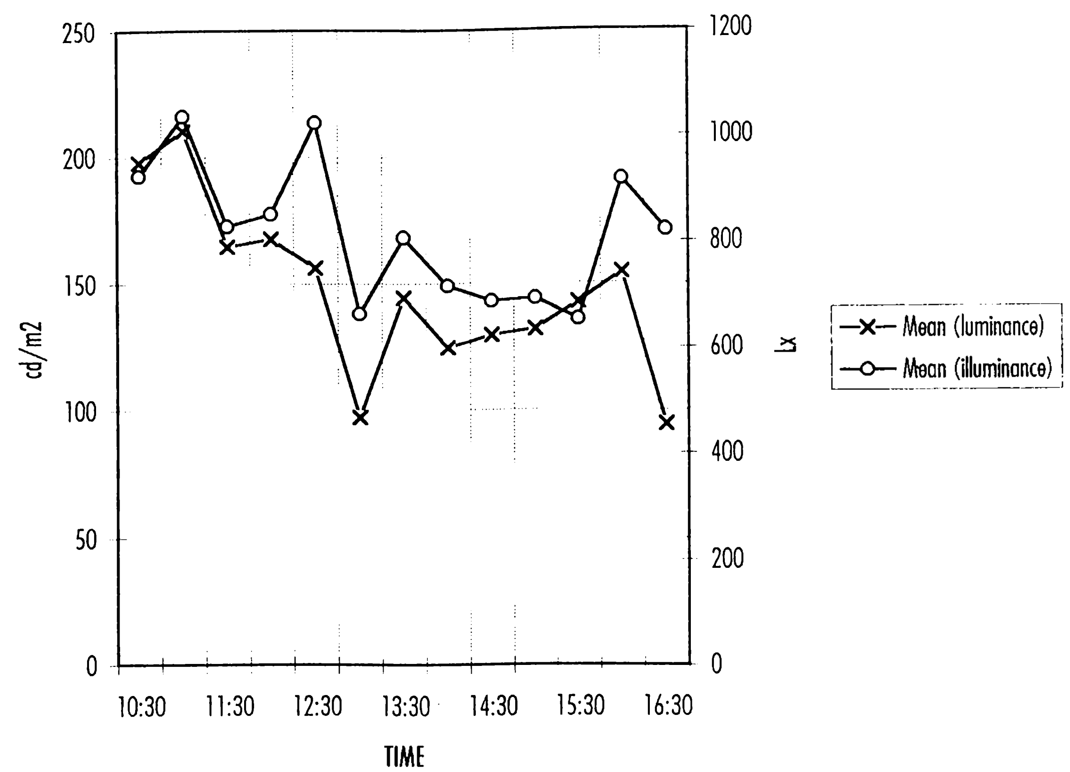


Figure 5.2.1 Luminance - Illuminance Values of FA 214-215 (Bilkent 1st)

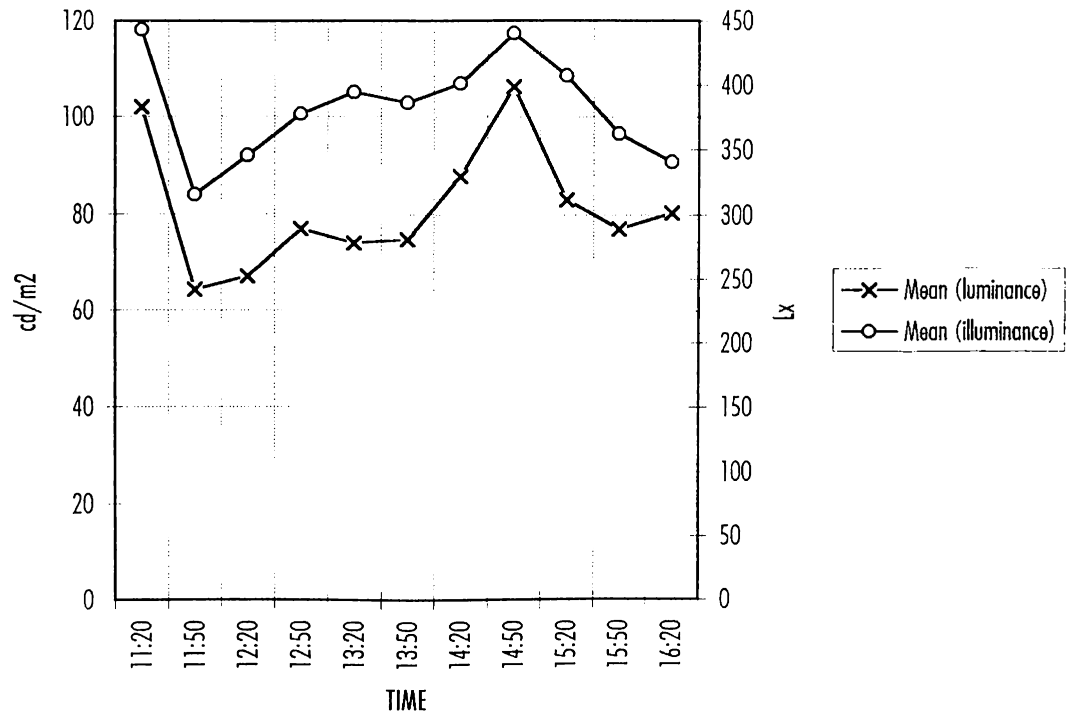


Figure 5.2.2 Luminance - Illuminance Values of FCZ 23 (Bilkent 4th)

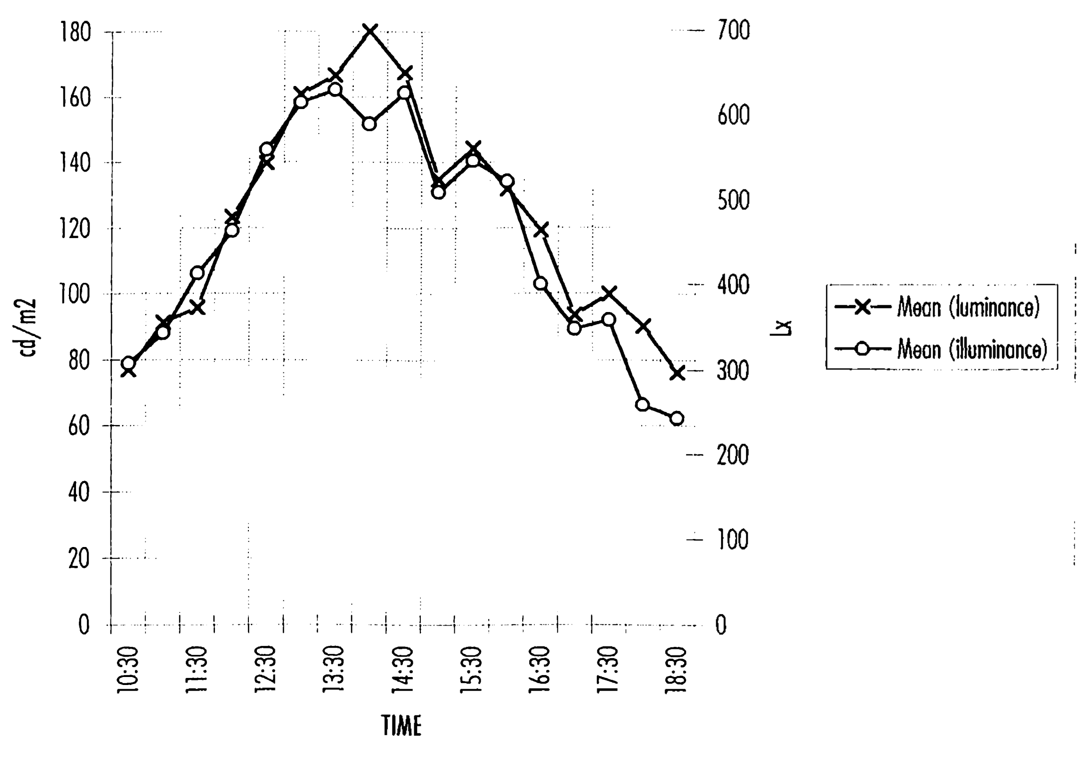


Figure 5.2.3 Luminance - Illuminance Values of FC 111 (Bilkent 3rd)

Figure 5.2.4 Luminance - Illuminance Values of FA 317-318 (Bilkent 2nd)

The measurements showed that each studio behaved differently to light as a result of its orientation, shape, size, elevation, location, adjacencies and performance. In terms of lighting, each design studio appears to be unique in itself. This singularity demands that at the very beginning of the process of designing schools of architecture, each studio should be studied separately, in the way their lighting needs are specified. Accordingly, appropriate lighting design solutions should be produced for each design studio. Even though such an approach might seem somewhat utopic and costly, it should be realized that the multi-functionality of the design studio calls for such a specialized lighting approach.

From the standpoint of this thesis, each design studio has been evaluated separately and in direct relation with its near surroundings. Comparisons between studios has been made, in hope to find clarifying explanations to the similar or unlike events taking place. However, the conclusion paragraphs of the subject of lighting will put emphasis alone on general points for the amelioration of the quality and quantity of light inside the design studios of the Department of Interior Architecture and Environmental Design.

There are several solutions for creating well-illuminated interiors within the design studios at Bilkent University. In order to increase the level of illuminance, the number of luminaries on the ceiling can be increased. Keeping the number of the luminaries constant, while bringing down the whole system of the luminaries can be considered, since height of the ceilings permit such an attempt. However, as the ceiling is lowered towards the task surfaces, the number of luminaries should not be decreased, as this will not provide a better condition of lighting. An example of this mistake can be observed in the FA 217-218 studio. Another misleading approach which should be avoided is to use task lighting to compensate for low illuminance levels. This will increase task-environment contrast ratio, resulting in discomfort and fatigue in the eyes of not only users but also produce glare in the eyes of the students working at the nearby tables. Another mistake with the use of the task light is to think of the direction of light only for the student working with the lamp but not of its possible negative effects on the surrounding students. Supplementary task lighting can be used together with increased number and quality of luminaries, providing for further perception of fine detail and elimination of unwanted shadows on the work surface. In addition, the maintenance of the luminaries is of utmost importance. Replacing broken luminaries instantly and keeping their surfaces clean will significantly improve the illuminance levels inside the studios. However, the choice of the luminaries should not be left to chance, as is the case with the design studios measured. The fluorescent lamps used in the studios measured had very low color rendering indexes, which shows that no care was shown for their selection. As mentioned previously, sufficient quantity of lighting alone will not be of much value if the demanded quality of lighting is not achieved. A proposition for the betterment of the luminance levels of the presentation walls is to provide additional luminaries directed from the ceiling onto the presentation boards. Finally, the controls of the lighting system should be flexible -either with the use of dimmers or having control on each lamp individually- in order to support the multi- functional demands of the design studio.

5.3 Acoustics Conclusion

Concerning acoustics, only sound pressure level measurements were realized. Accordingly, what is to be said on acoustics will be mostly based on observation and common sense. In the first place, the orientation of the design studios and the nearby landscape were not planned as to avoid external noises. Therefore, a great amount of noise entered the studios from the surroundings. Moreover, the planning and material assignments of the studios were not done with acoustical concerns. The reflectances of the floors, walls, ceilings, work surfaces and the location of these surfaces in relation to each other resulted in flutter echoes throughout the studios. It was noticed that in all the studios, facing walls were parallel to each other, which is an undesired design solution when echoes are to be avoided. None of the studios housed any sound-absorbing materials. As a result, the slightest murmur between students disturbed the course of work inside the studio. Only the FCZ 23 studio was furnished with ceiling-hanging banners which acted as sound-absorbing barriers. Otherwise, the huge, corridor-like FCZ 23 studio would become an intolerable place from a noise point of view.

The high noise levels inside and outside the design studios call for several precautions to be taken. It can be said that covering the floors with carpeting will considerably reduce the reverberation times inside the studios. Certain hanging ceiling applications with sound-absorbing finishes can help prevent the buildup of noise. Acoustical applications should be studied separately in each studio, as is the case with lighting. However, in all the studios, the parallelity of the walls should be changed. Very long studios like the FCZ 23, FA 317-318, FA 214-215 can be subdivided into cubicles with partition walls which do not block vision. These will act as local screening elements which will play an important role in the reduction of noise inside the design studio. Use of absorptive materials on the walls or thick curtains on the windows will help to reduce external noises and flutter echoes. Tree plantations near the roads will, in the long run, diminish noise from cars. In general, a sound pressure level of 38-42 dBA should not be exceeded, for higher noise levels will significantly mask speech intelligibility and diminish concentration on work and productivity.

REFERENCES

Burberry, Peter. Environment and Services. London: The Mitchell Publishing Company Ltd, 1988.

Chatered Institution of Building Services Engineers. Code For Interior Lighting 1984. London: Yale Press Ltd, 1989

Cullen, John. The Lighting Handbook. London: Pelham Books Ltd, 1986.

De Boer, J.B., and D. Fischer. Interior Lighting. Antwerpen: Kluwer Technische Boeken B.V., 1981.

Egan, David M. Architectural Acoustics. New York: McGraw Hill,Inc., 1988.

Fitch, James Marston. American Building: The Environmental Forces That Shape It. Boston: Houghton Mifflin Company, 1972.

Flynn, John E., Arthur W. Segil, and Gary R. Steffy. Architectural Interior Systems. New York: Van Nostrand Reinhold Company, 1988.

Governmental Noise Committee, " Noise Control Regulations," Turkish Official Newspaper 11 Dec. 1986, number 19308.

Grandjean, Etienne. Ergonomics of the Home. London: Taylor & Francis, 1973.

Illumination Engineering Society of North America. IES Lighting Handbook 1987: Application Volume. New York: IESNA, 1987.

Illumination Engineering Society of North America. IES Lighting Handbook 1984: Reference Volume. New York: IESNA, 1984.

Illumination Engineering Society of North America. American National Standard: Guide for Educational Facilities Lighting. New York: IESNA, 1988.

Illumination Engineering Society of North America. American National Standard: Nomenclature and Definitions for Illuminating Engineering. New York: IESNA, 1987.

Illumination Engineering Society of North America. IES Design Considerations for Effective Building Lighting Energy Utilization. New York: IESNA, 1987.

IES Education Committee. IES Education Series: Introductory Lighting. New York: IESNA, 1988.

Philips. Lighting Manual. Netherlands: N.V. Philips' Gloeilampenfabrieken, 1986.

Philips. Lighting Manual. Netherlands: Philips Lighting B.V., 1993.

Pressman, Andy. Architecture 101. New York: John Wiley & Sons, Inc., 1993.

Rea, Mark S. ed., Selected Papers on Architectural Lighting. Washington: SPIE Optical Engineering Press, 1992.

Steffy, Gary R. Architectural Lighting Design. New York: Van Nostrand Reinhold Company, 1990.

Szokolay, S.V. Environmental Science Handbook. Lancaster: The Construction Press Ltd, 1980.

Templeton, Duncan, ed. Acoustics in the Built Environment. London: Butterworth Architecture, 1993.

Templeton, Duncan, and David Saunders. Acoustic Design. London: The Architectural Press, 1987.

APPENDICES

APPENDIX A

MEASURING RANGE:

FSD[1]	Measuring Range		
	Lower limit for S/N ratio >5 dB (A-weighting)	Max. peak level[3]	Upper limit for signals of crest factor =10 (20 dB)[3]
70	24	83	63
80	24	93	73
90	30	103	83
100	40	113	93
110	50	123	103
120	60	133	113
130[2]	70	143	123
140[2]	80	153	133

[1] FSD on quasi analogue display

[2] Only with attenuator ZF 0020 employed

[3] Values may diverge slightly from nominal value depending on microphone K_0 factor

FREQUENCY RESPONSE:
See Figs.3 and 4

FREQUENCY WEIGHTING:
A, C weighting to IEC 651 Type 1
Linear (20 Hz -20 kHz)
All-pass (10 Hz -50 kHz)

DETECTOR:
Characteristics: RMS, peak
Linearity range: 70 dB
Pulse range: 73 dB
Crest factor capability: 13 dB at FSD

TIME WEIGHTING CHARACTERISTICS:
"I": to IEC 651 Type 1
"F": to IEC 651 Type 1
"S": to IEC 651 Type 1
"Peak": rise time <50 μs
Max. Hold decay rate: 0 dB/s (digital)

L_{eq} RESPONSE TIME FOR CONSTANT INPUT SIGNAL:
1 s after reset

MAXIMUM MEASUREMENT PERIOD:
Only limited by battery life

DISPLAY:
Digital: 4 digits 7 segments, liquid crystal, 8 mm high, resolution 0,1 dB
Quasi-analogue: 60 dB scale with 2 dB resolution for monitoring current SPL
Additional functions: Overload occurring: ↑, Overload has occurred: ^, Battery near low level: BAT flashing, Battery low level: BAT (flash.) ↑ (non-reset.), Illegal setting: ↑

AC OUTPUT:
1 V RMS for full scale, output imp. ≤120 Ω, short circuit protected, mini-jack socket

DC OUTPUT:
3 V for full scale, 0 V bottom scale, 50 mV/dB, output impedance ≤500 Ω, short circuit protected, mini-jack socket

RESET FUNCTION:
Automatic reset all occurs when changing FSD setting.
Reset all: Max./min. detectors, L_{eq}, $L_{EA,T}$ and overload detector are reset
Reset max./min.: Only max./min detectors are reset

MICROPHONE:
Type: ½ inch B & K Prepolarized Condenser Microphone Type 4155
Sensitivity: 50 mV/Pa
Capacitance: 15 pF
Windscreen effect: <0,9 dB up to 10 kHz

CALIBRATION:
Acoustical: With Sound Level Calibrator Type 4230, Pistonphone Type 4220 or Multi-function Acoustic Calibrator Type 4226
Electrical: With internal reference source by potentiometer adjustment

REFERENCE CONDITIONS FOR ACOUSTICAL CALIBRATION WITH TYPE 4230:
Type of Sound Field: Free
Reference Incidence Direction: Perpendicular to microphone diaphragm
Reference SPL: 94 dB (re 20 μPa)
Reference Frequency: 1 kHz
Reference Temperature: 20°C
Reference Measuring Range: 110 dB FSD

WARM-UP TIME:
<5 s for 0,5 dB; <10 s for 0,1 dB

EFFECT OF HUMIDITY (AT 40°C/1000 Hz):
<0,5 dB for 30%<RH<90%

EFFECT OF TEMPERATURE:
Microphone: −0,006 dB/°C typically
Complete instrument:
<0,5 dB −10 to +50°C
Operating range: -10 to +50°C (+14 to 122°F)
Storage without batteries: -20 to +70°C (-4 to 158°F)

EFFECT OF MAGNETIC FIELD:
80 A/m (1 Ørsted) at 50 Hz gives:
<25 dB (A) or <44 dB (Lin)

VIBRATION SENSITIVITY:
72 dB max. at 40 Hz and 1 ms^{-2}.

BATTERIES:
Type: Four 1,5 V Alkaline cells IEC type LR 6 (B&K order No. QB 0013)
Life: approx. 8 hours

OVERALL DIMENSIONS AND WEIGHT:
370 × 85 × 47 mm (14,7 × 3,3 × 1,8 in)
860 g (1,9 lb) with batteries

ACCESSORIES INCLUDED:
Microphone Type 4155
2,5 mm mini-jack plug (×2) .... JP 0213
Windscreen .... UA 0237
Input Adaptor .... JJ 2614
Screwdriver .... QA 0001
Cells (×4) .... QB 0013
20 dB Attenuator .... ZF 0020
Instruction Manual

ACCESSORIES AVAILABLE:
Carrying case .... KE 0226
Tripod .... UA 0801
Sound Level Calibrator .... Type 4230
Level Recorder Cable .... AO 0173
3 m Microphone Extension cable ..... AO 0027
Power Supply .... ZG 0254
Interface Module .... ZI 9101
Service Manual

INPUT (ZR 0035):
Voltage input -0,05 V to +10,19 V
Input impedance 1,0 MΩ
DC offset adjustment ~ ±125 mV

CALCULATED VALUES (ZR 0035)
SPL, L_{eq}, Max., and Min.
Sampling rate
of DC signal: 256 samples per second
Measurement periods
without filtering: 1, 5, and 15 min.
with filtering : Dwell time on each filter is controlled to give RMS read-out error less than 0,5 dB

PRINTING SYSTEM:
Thermal dot-matrix printing, 7-dot single-column matrix, on heat sensitive paper

PRINTING RATE:
0,8 lines per second

PAPER ROLL:
Length: ~15 m (~49 ft)
—sufficient for ~4000 lines
Width: 58 mm (2,28 in)
Diameter: <40 mm (<1,6 in)
(to fit magazine)

POWER SUPPLY:
4 × 1,25 V rechargeable cells, 0,5 Ah capacity

CURRENT CONSUMPTION:
Printing: < 1,0 A average/3,75 A peak
Standby: < 25 mA (± 5 V interface)
< 40 mA (± 10 V interface)

BATTERY LIFE:
At least 1000 lines, typically 2000 lines, at 25°C (77°F)

OPERATION TEMPERATURE:
+ 5°C to + 45°C (+ 41°F to + 113°F)

HUMIDITY (MAX.):
Storage: 95% RH at 45°C
Operation: 90% RH at 30°C

ELECTROMAGNETIC COMPATIBILITY:
Complies with Class B of the American FCC (Federal Communications Commission) rules

DIMENSIONS:
Length: 202 mm (7,95 in)
Width: 85 mm (3,35 in)
Height: 52 mm (2,05 in)

WEIGHT:
~ 1 kg (2,2 lb) with ZR 0035, battery pack, paper, and leather case

ACCESSORIES INCLUDED:
Integration and Filter-control Module ..... ZR 0035
Signal Cable ..... AO 1355
Control Cable ..... AQ 0497
Power Supply ..... ZG 0254
Recording Paper (4-roll pack) ..... QP 0021
Leather Carrying-case ..... KE 0273
Instruction Manual

ACCESSORIES AVAILABLE:
Serial Interface Module ..... ZI 0054
Recording Paper (4-roll pack) ..... QP 0021
Service Manual

Brüel & Kjaer Graphics Printer 2318

Type: Spot luminance meter

Receptor: Sillicon photocell filtered to closely match the CIE Relative Photopic Luminosity Response

Calibration: PRESET for Minolta standard calibration
VARI. for user-selected calibration standard

Measuring modes: ABS. for measuring absolute luminance
% for determining percent luminance in relation to a reference luminance in memory

Other measuring functions: PEAK function to display highest value of absolute or percent luminance measured while measuring trigger held in; C.C.F. (color-correction factor) to correct meter response when measuring colored subjects or using close-up lenses

Optical system: 85mm f/2.8 lens; TTL (through-the-lens) viewing system; influence of flare on measurement less than 1.5%

Acceptance angle: LS-100: 1°
LS-110: 1/3°

Field of view: 9° (with circular measurement-area indication)

Focusing distance: 1014mm to infinity (205mm minimum using close-up lens)

Minimum target area: LS-100: φ14.4mm at 1014mm (φ1.3mm at 205mm using close-up lens
LS-110: φ4.8mm at 1014mm (φ0.4mm at 203mm using close-up lens

Luminance units: cd/m^2 or fL selectable; calibration and reference luminance values in memory automatically converted

Measuring range: LS-100: FAST: 0.001 to 299900 cd/m^2 (0.001 to 87530 fL)
SLOW: 0.001 to 49990 cd/m^2 (0.001 to 14590 fL)
LS-110: FAST: 0.01 to 999900 cd/m^2 (0.01 to 191800 fL)
SLOW: 0.01 to 499900 cd/m^2 (0.01 to 145900 fL)

Accuracy: LS-100: 0.001 to 0.999 cd/m^2 (or fL): ±2% ±2 digits of measured valuve
1.000 cd/m^2 (or fL) or more: ±2% ±1 digit of measured valuve
LS-110: 0.01 to 9.99 cd/m^2 (or fL): ±2% ±2 digits of measured valuve
10.00 cd/m^2 (or fL) or more: ±2% ±1 digit of measured valuve
(Measuring conditions: Subject: Standard Illuminant A; ambient temperature: 20 to 30°C/68 to 86°F)

Short-term repeatability: LS-100: 0.001 to 0.999 cd/m^2 (or fL): ±0.2% ±2 digits of measured valuve
1.000 cd/m^2 (or fL) or more: ±0.2% ±1 digit of measured valuve
LS-110: 0.01 to 9.99 cd/m^2 (or fL): ±0.2% ±2 digits of measured valuve
10.00 cd/m^2 (or fL) or more: ±0.2% ±1 digit of measured valuve
(Measuring subject: Standard Illuminant A)

Displays: External LCD panel shows measured value plus operation and error indications; viewfinder LCD panel shows measured value

Data output: 1-bit serial, ASCII code, ± 5V, 4800 baud; output via Hirose RP17-13RA-12SD connector; remote control possible

Power source: One 9V battery (Eveready 216 or equivalent); external power supply may be used via data-output terminal

Operating temperature range: 0 to 40°C (32 to 104°F)

Storage temperature range: −20 to +55°C (−4 to +131°F)

Dimensions: 208 x 79 x 150mm (8-3/16 x 3-1/8 x 5-7/8 in.)

Weight: 850g (30 oz.) without battery

Standard accessories: Lens cap, eyepiece cap, ND eyepiece filter, data-output terminal cover, 9V battery, case

Optional accessories: Close-up lenses, data printer, long eye-relief eyepiece

Minolta Luminance Meter LS-110

Type:	Multi-function illuminance meter with microprocessor and liquid-crystal display for continuous and flickering light sources
Receptor:	Silicon photocell; receptor head detachable
Spectral response:	400 to 760mm within ±2% (integrated) of C.I.E. photopic luminosity curve
Acceptance-angle error:	Within ±2% at 30°, ±7% at 60°, ±25% at 80° of ideal curve
Response speed:	"FAST" setting: 1 msec. (0.001 sec.); "SLOW" setting: 1 sec.
Measuring functions:	Illuminance in lux (lx) or footcandles (fcd); integrated illuminance in lux-hours (lx·h) or footcandle-hours (fcd·h); integration time in hours (h)
Measuring ranges:	Illuminance: 0.01 to 99,900 lx (0.01 to 300,000 lx*) 0.001 to 9,990 fcd (0.001 to 300,000 fcd*) * analog-output ranges 5 ranges in Manual mode Integrated illuminance: 0.01 to 999,000 lx·h 0.001 to 99,900 fcd·h Infinite integration
Accuracy:	±2% of C.I.E. standard, ±1 digit in last changing display position
Analog output:	1 mv per digit; 3v at maximum reading; 10 kilo ohms impedance
Power source:	One self-contained 9v battery (Eveready 216 or equivalent) or external 9v 7mA DC current
Accessories:	Included with unit: Receptor cap, web neck strap, analog-output plug, belt case Available optionally: Adapter Cord MA-1 (2m or 6.6ft.), MA-2 (1m or 3.3ft.), MA-3 (5m or 16.4ft.) and MA-4 (10m or 32.8ft.)
Dimensions:	170 x 72 x 33mm (6-11/16 x 2-13/16 x 1-5/16 in.)
Weight:	220g (7-3/4 oz.) without battery

Minolta Illuminance Meter

Type: Battery-powered data printer with analog-output jacks for use with Minolta Luminance Meters LS-100 and LS-110

Printer

TYPE: 24-character thermal-dot

PRINTED DATA: Measurement number, measured value, elapsed time since first measurement

Interval Timer

INTERVALS: 10 sec., 30 sec., 2 min., and 10 min.

Analog Output

MEASUREMENT RANGES: 10, 10^2, 10^3, 10^4, 10^5, 10^6 (cd/m² or fL); manually selected

OUTPUT VOLTAGE: 0.0 to 1000.0mV in 0.1mV steps; error indicated by output of approximately 1100mV

TIME DELAY: 300 msec.

TEMPERATURE DRIFT: 0.02mV/°C

ACCURACY: ±0.4%, ±0.2mV (based on Minolta's standard test methods)

Power Source: 6 AA-size alkaline-manganese or carbon-zinc (1.5V) or nickel-cadmium (1.2V) batteries, or optional AC Adapter AC-A10 (9V/0.7A) connected to AC power source

Temperature Range

OPERATION: 0 to 50°C (32 to 122°F)

STORAGE: −20 to 55°C (−4 to 131°F)

Dimensions: 186 x 53 x 102mm (7-5/16 x 2-1/16 x 4 in.)

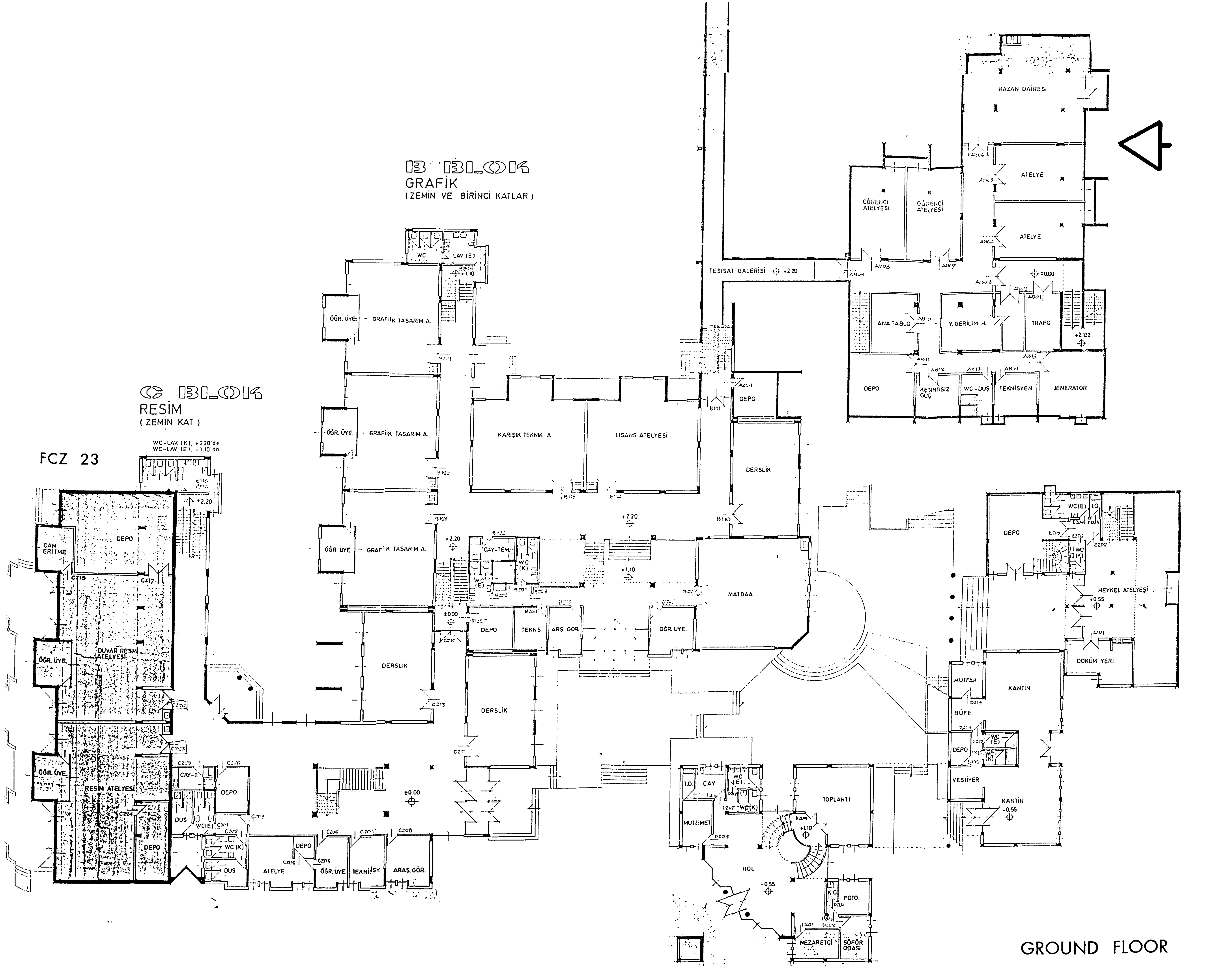
Weight: 440g (11 oz.) without batteries or thermal paper

Standard accessories: Battery holder, Thermal paper (one roll), Data Cable LS-A10, Carrying strap, Banana plugs (2), AA-size alkaline-manganese batteries (6)

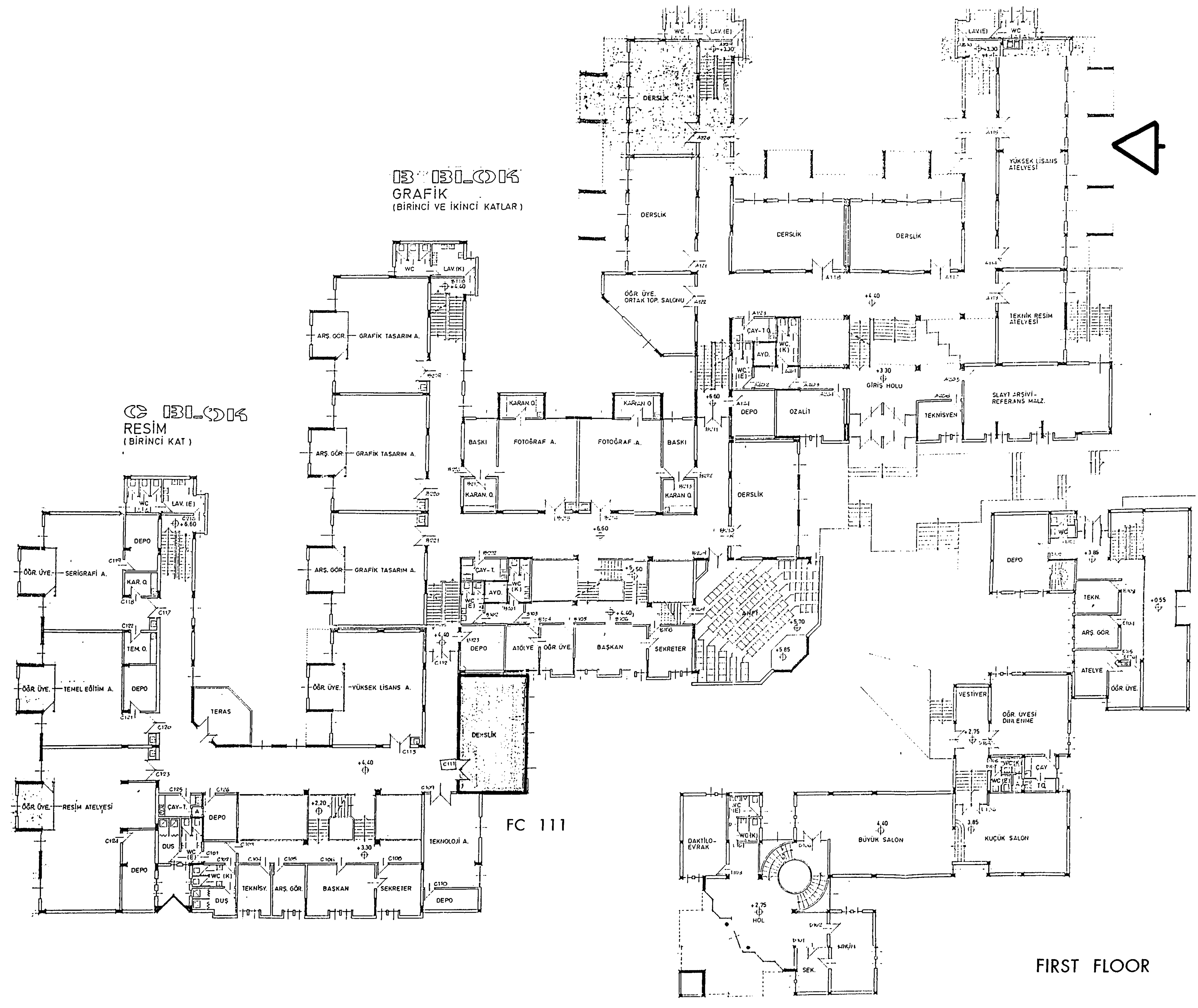
Optional accessories: Thermal paper (package of ten rolls), AC Adapter AC-A10

Minolta Data Printer DP-10

APPENDIX B

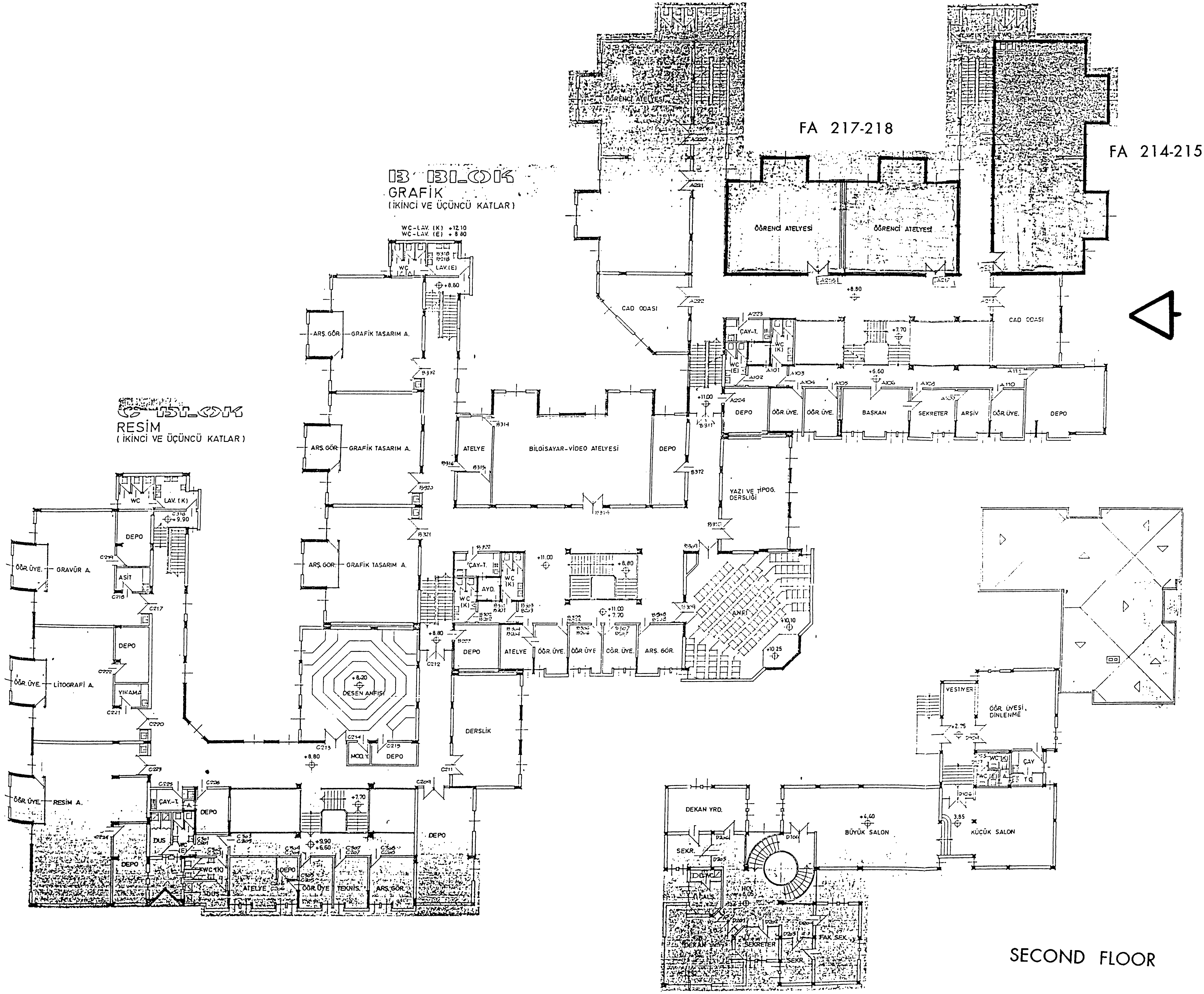


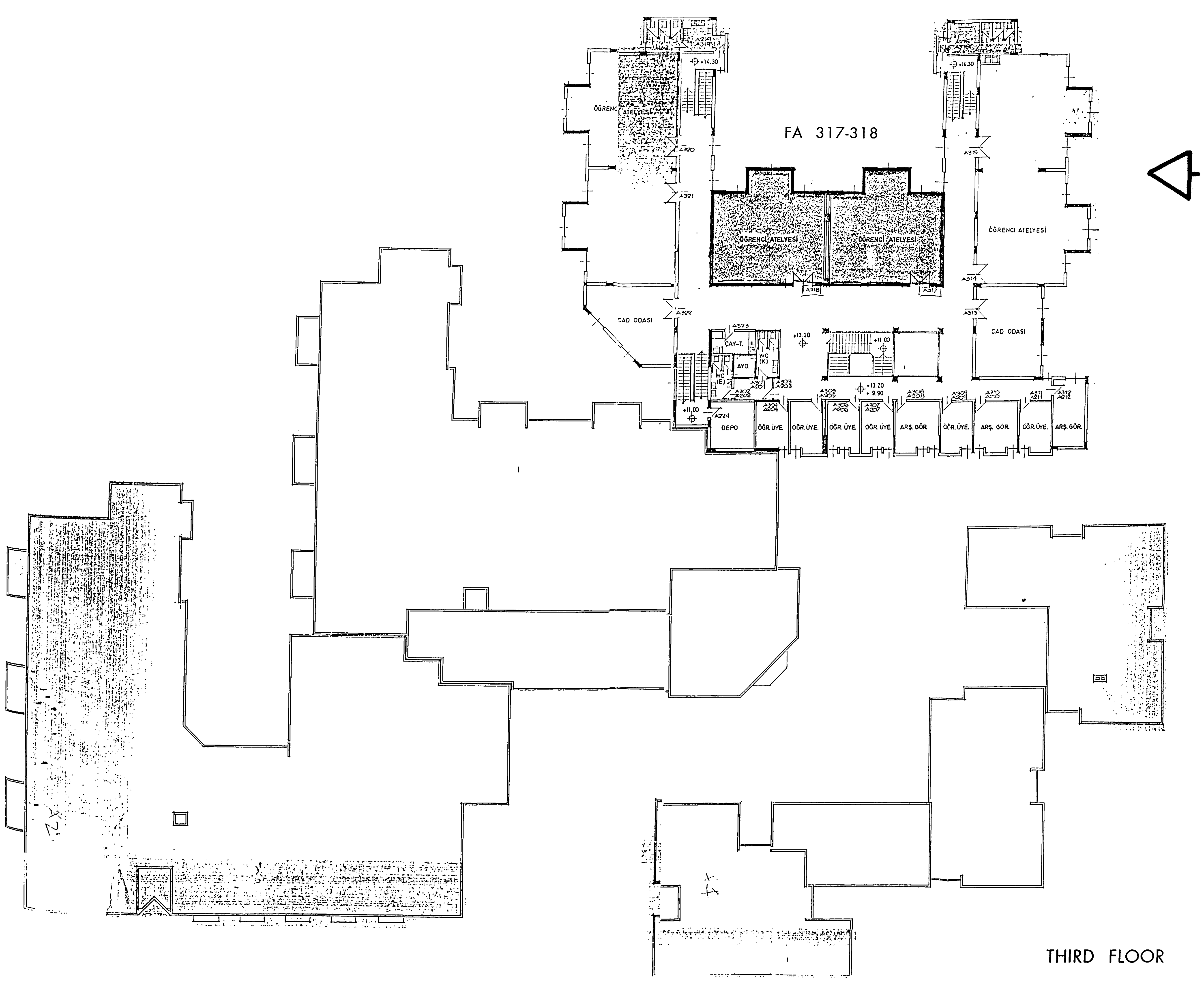
B BLOK
GRAFİK
(ZEMİN VE BİRİNCİ KATLAR)
C BLOK
RESİM
(ZEMİN KAT)
FCZ 23
WC-LAV (K), +2.20'de
WC-LAV (E), -1.10'da
KAZAN DAİRESİ
ATELYE
ATELYE
ÖĞRENCİ ATELYESİ
ÖĞRENCİ ATELYESİ
TESİSAT GALERİSİ
ANA TABLO
Y. GERİLİM H.
TRAFO
DEPO
KESİNTİSİZ GÜÇ
WC-DUŞ
TEKNİSYEN
JENERATÖR
WC
LAV (E)
ÖĞR. ÜYE.
GRAFİK TASARIM A.
KARIŞIK TEKNİK A.
LİSANS ATELYESİ
DEPO
DERSLİK
CAM ERİTME
DEPO
DUVAR RESMİ ATELYESİ
ÇAY-TEM.
MATBAA
DEPO
TEKNS.
ARS. GÖR.
ÖĞR. ÜYE.
HEYKEL ATELYEŞİ
DÖKÜM YERİ
MUTFAK
BÜFE
KANTİN
VESTİYER
RESİM ATELYESİ
DEPO
DUŞ
ATELYE
ÖĞR. ÜYE.
TEKNİSY.
ARAŞ. GÖR.
T.O.
ÇAY
MUTEMET
TOPLANTI
HOL
FOTO.
NEZARETÇİ
ŞOFÖR ODASI
GROUND FLOOR



FC 111

FIRST FLOOR


FA 217-218
FA 214-215
B BLOK
GRAFİK
(İKİNCİ VE ÜÇÜNCÜ KATLAR)
C BLOK
RESİM
(İKİNCİ VE ÜÇÜNCÜ KATLAR)
ÖĞRENCİ ATELYESİ
ÖĞRENCİ ATELYESİ
ÖĞRENCİ ATELYESİ
CAD ODASI
CAD ODASI
DEPO
ÖĞR. ÜYE.
ÖĞR. ÜYE.
BAŞKAN
SEKRETER
ARŞİV
ÖĞR. ÜYE.
DEPO
ARŞ. GÖR.
GRAFİK TASARIM A.
ARŞ. GÖR.
GRAFİK TASARIM A.
ARŞ. GÖR.
GRAFİK TASARIM A.
ATELYE
BİLGİSAYAR-VİDEO ATELYESİ
DEPO
YAZI VE TİPOG. DERSLİĞİ
ANFİ
DEPO
ATELYE
ÖĞR. ÜYE.
ÖĞR. ÜYE.
ÖĞR. ÜYE.
ARŞ. GÖR.
DESEN ANFİSİ
MOD. Y.
DEPO
DERSLİK
DEPO
ÖĞR. ÜYE.
GRAVÜR A.
DEPO
ASİT
ÖĞR. ÜYE.
LİTOGRAFİ A.
DEPO
YIKAMA
ÖĞR. ÜYE.
RESİM A.
ÇAY.-T.
DEPO
DEPO
ATELYE
ÖĞR. ÜYE
TEKNİS.
ARŞ. GÖR.
VESTİYER
ÖĞR. ÜYESİ DİNLENME
DEKAN YRD.
SEKR.
BÜYÜK SALON
KÜÇÜK SALON
DEKAN
SEKRETER
SEKR.
FAK. SEK.
SECOND FLOOR


FA 317-318
ÖĞRENCİ ATELYESİ
ÖĞRENCİ ATELYESİ
ÖĞRENCİ ATELYESİ
ÖĞRENCİ ATELYESİ
CAD ODASI
CAD ODASI
ÇAY-T.
AYD.
WC (K)
WC (E)
DEPO
ÖĞR. ÜYE.
ARŞ. GÖR.

THIRD FLOOR

APPENDIX C

TERMINOLOGY

absorption	:the ability of a material to intercept the propagated sound waves in and change them into heat energy.
acoustics	:(1) the science of sound, dealing with the control, production, transmission, reception and effects of sound waves. (2) The qualities that determine the ability of an enclosure to reflect sound waves in such a way as to produce distinct hearing.
adaptation	:the process by which the visual system becomes accustomed to more or less light or light of a different color than it was exposed to during an immediately proceeding period. It results in a change in the sensitivity of the eye to light.
candela, cd	:(formerly candle) the unit of luminous intensity.
color rendering	:general expression for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.

decibel	:(dB) a unit for expressing the relative intensity of sounds on a scale from zero for the threshold of hearing of about 130 dB for the threshold of pain value. It is a logarithmic scale of a particular sound pressure level depending on a standard reference value.
direct glare	:glare resulting from high luminances or insufficiently shielded light sources in the field of view or from reflecting areas of high luminance. It usually is associated with bright areas, such as luminaires, ceilings and windows that are outside the visual task or region being viewed.
echo	:the delayed reflection loud enough to be perceived as a separate sound which disturbs the listener.
flutter echo	:a rapid succession of reflected sound waves resulting from a single initial sound pulse.
general lighting	:lighting designed to provide a substantially uniform level of illuminance throughout an area.
glare	:the sensation produced by luminance within the visual field that are sufficiently greater than the luminance to which the eyes are adapted to cause

	annoyance, discomfort or loss in visual performance and visibility.
illuminance	:the density of the luminous flux incident on a surface; it is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated.
illuminance meter	:an instrument for measuring illuminance on a plane.
illumination	:the act of illuminating or state of being illuminated.
L_{eq}	:the sound pressure level averaged over the measurement period.
lamp	:a generic term for a man-made source of light. By extension, the term is also used to denote sources that radiate in regions of the spectrum adjacent to the visible.
light	:radiant energy that is capable of exciting the retina and producing a visual sensation.
loudness	:the subjective judgment by an individual which tends to be influenced by sound pressure and frequency.

luminaire	:a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.
luminance	:(photometric brightness) the luminous intensity of any surface in a given direction per unit area of that surface as viewed from that direction. All things visible have some luminance.
lux	:(lx) the International System (SI) unit of illuminance. It is the illumination on a surface one square meter in area on which there is a uniformly distributed flux of one lumen, or the illumination produced at a surface all points of which are at a distance of one meter from a uniform point source of one candela.
noise	:any sound that is unwanted or interferes with one's hearing of something.
portable lighting	:lighting by means of equipment designed for manual portability.
quality of lighting	:pertains to the distribution of luminance in a visual environment. The term is used in a positive sense and implies that all luminances

	contribute favorably to visual performance, visual comfort, ease of seeing, safety, and aesthetics for the specific visual tasks involved.
reflectance	:**(sound)** sound energy returned after hitting a surface, rather than being absorbed as heat energy within the surface.
reflectance	:**(light)**(of a surface or medium) the ratio of the reflected flux to the incident flux.
reflected glare	:glare resulting from specular reflections of high luminances in polished or glossy surfaces in the field of view. It usually is associated with reflections from within a visual task or areas in close proximity to the region being viewed.
reflection	:a general term for the process by which the incident flux leaves a surface or medium from the incident side.
reverberation	:the continuation, build up of sound in an enclosed space, because of multiple reflection from surrounding enclosing walls, floors, and ceiling, after the sound source is switched off.
reverberation time	: the time taken for a sound intensity to decay by 60 dB after the sound source is switched off.

SEL :sound exposure level is the constant level which if maintained for a period of 1 second would have the same acoustic energy as the A-weighted measured noise event.

sound :the sensation perceived by the sense of hearing which results from rapid variations in air pressure.

sound pressure :the variation from normal atmospheric pressure caused by the flow of sound energy as a motion of molecules in the air.

supplementary light: lighting used to provide an additional quantity and quality of illumination that cannot readily be obtained by a general lighting system and that supplements the general lighting level, usually for specific work requirements.

task lighting :lighting directed to a specific surface or area that provides illumination for visual tasks.

visibility :the quality or state of being perceivable by the eye.

visual task :conventionally designates those details and objects that must be seen for the performance of a given activity, and includes the immediate background of the details or objects.

work-plane :the plane at which work usually is done; and at which the illuminance is specified and measured.