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A COMPUTERISED ELECTRICAL INSTALLATION DESIGN TOOL

BY

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ABSTRACT

Lighting design and low-voltage building reticulation is often referred to as "bread and butter" work of the Electrical Consulting Engineers. The work is repetitive and does not vary much from a single level building to a multi-level building.

If software for a microcomputer could be developed to remove the tedium of repetitive calculations the following benefits could be derived : Improved accuracy of calculations, repeatability of calculations for 'What if' situations. Time savings would allow far more alternative designs to be considered. Once such calculations have been performed and acceptable results obtained within the project constraints, the software could provide details of the design, a bill of quantities and estimated cost of the work with only minor input from the operator.

It was with the intention of producing such a software package that this project was begun. The initial aim of the project was to develop a software package the would run on an MS-DOS based microcomputer to do the following :-

* Store luminaire photometric data and other allied information on a manufacturer independent 'luminaire' software based library.

* Store room dimensional data and lighting layout details in a PROJECT file.

* Utilise that data for lumen method lighting layout calculations and load estimations for distribution board feeder cable sizing

* Store data associated with the loads connected to each distribution and sub-distribution board.

* Utilise the previously stored data to interactively determine cable sizes in a radially connected network within the constraints of thermal current rating of the cable and voltage regulation drop permitted.

The software was subsequently developed within the constraints of the South African Bureau of Standards Code of Practice Ø114 : Interior Lighting and Code of Practice Ø142 (1981) : The wiring of premises and applicable Standards referred to therein.

An important consideration when software is to be used as a time saving tool is the interface it has with the operator. The aim was to provide a tool that would be simple to use and require nothing more than an ability to use floppy discs, a keyboard and a printer. Throughout the development

of the software one-line prompts have been provided for every input field so the operator is not left guessing what is required.

Using Turbo PASCAL as a programming language the five aims above were coded into a software programme. The software successfully implements these aims. The time savings that are achieved when using the programme to assist with detailed electrical installation designs is difficult to quantify. However some times are given for a test project which show significant time savings obtained when using the software compared to the time taken using the 'manual' method of design.

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CHAPTER ONE

INTRODUCTION

1.1 A MOTIVATION

The author spent two years working for a large multi-disciplinary consulting engineering practice involved primarily with low voltage industrial and commercial building reticulations and lighting design. The lack of sophisticated software which could be used on microcomputers to improve reliability and accuracy of design was surprising and having had a thorough grounding in computer architecture and software development it was apparent that a suite of programmes could be developed to fulfil the need. There are obvious advantages to using a computerised tool for engineering design, these include speed of calculation, reliable, repeatable and accurate results, neat readable paper print-outs and graphic presentations.

There should be a sound engineering reason for developing a new software programme. Recent developments in the Computer Aided Design/Engineering (CAD/CAE) fields, as reported in the technical press [1], have shown that the use of computers has resulted in an improvement in the quality of engineering design. In addition there should also be an economic saving that could be derived from the practical use of engineering software. Such savings may manifest themselves by savings in man-hours or reduction of human error. The amount of saving that could be derived from the use of CAE software is entirely dependent on the quality of the software, the ease with which data input is achieved, how readily input errors could be rectified, the clarity of output, and the speed of programme execution.

A survey (Appendix A) was carried out to determine how consulting engineering practices utilise their resources in terms of time spent on each of three phases of a building project and how that related to the income received. The three phases of a project referred to in the South African Association of Consulting Engineers Guide to Fees [2] are

* Project concept stage
* Detailed design stage
* Construction supervision stage

It was hoped that the survey would show that significant savings in design time could be achieved if CAE software was used as a design tool for low voltage building reticulation and hence improve the profitability of the project.

The bar charts showing the results of the survey (see Appendix A) show that in general if the bars representing the time spent on each stage could be made to bunch up to the left of the X-Axis (i.e. reduce the time) and if the bars representing the amount of income could be bunched up towards the right (i.e. increase the income received) then the industry would head in a more profitable direction.

The information displayed on the bar charts in Appendix A is summarised here :

> Project Concept Stage: the amount of time spent on this stage could be only marginally reduced. This time is often a risk investment in the hopes of securing an appointment. However if the appointment is successful the indications are that this stage is profitable with 69% of the respondents receiving 20% of the total project income, while generally spending less than 20% of the total project time on the concepts.
>
> Detail Design Stage: with 64% of the respondents receiving 40% of the total project fee income and only 56% spending 40% or less of the total project time on the detail design, it is apparent that there is scope for reducing the time spent on detailed design. This is possibly the only stage of the project where the design engineer has minimum interference from other parties and is usually left undisturbed to complete the design. He would therefore have more control on the time that is spent on the design.
>
> Construction Supervision Stage: the time spent on this stage is dependent on the quality of design, capability of the contractor and the distance of the site from the office. Here time is less closely related to costs incurred than in the first two stages. Construction supervision is not an area where computerisation can readily reduce time spent on site, except indirectly by producing high quality unambiguous designs.

Analysing the answers to question three of the questionnaire, a total of 30 answers were received. Only 20% of the respondents did not use any form of computer aid in the office and these respondents spent a greater percentage of the total project time doing detail design compared with the percentage of the total project fee income received for the work. It is this group of practices that could benefit by the use of the software programme that is the subject of this dissertation. Only 7% of the respondents did not use computer aids but did manage to spend a smaller percentage of the total project time than the percentage of total fee income received. Sixty six percent of the respondents did use computer aids in the office and these practices showed that they received a greater percentage of the fee income for a smaller percentage of time spent on the detailed design. The latter group show a tendency that computer aids help reduce the time spent on detail design of a project.

As costs keep escalating and the present depressed building climate persists, the consulting engineer who can improve his productivity and quality of work on a project will be in a stronger position to keep his place in the market. Maintaining profit margins in difficult economic climate means reducing the costs of producing the profit.

Good productivity means that the designs produced are accurate, the specification documentation is unambiguous and the drawings contain clear precise information and that these ideals are achieved in an efficient manner. The process by which these ideals are achieved must itself be accurate so as to eliminate redesign caused by design errors. The design process must contain a system for error trapping and correction which must be activated in good time. If such an ideal design process could be achieved then the efficiency and subsequently the productivity of the consulting engineer would be at it's optimum during the detailed design stage of the project.

It is proposed here that the microcomputer with relevant software could provide the solution to the problem of obtaining an accurate design process through which the specifications and drawings could be produced accurately and quickly. A design process which will not inadvertently omit anything. Tedious calculations would be performed in a matter of seconds as opposed to the time consuming manual method. Results would be accurate and dependable (providing only that the input data itself was accurate and dependable). By designing the software to accept only sensible input within boundary conditions defined for each input field the occurrence of incorrect input data could be reduced and hence reliability would improve. For example, an input field requiring a numeric input between the values of zero and one would only accept characters 'Ø'..'9','.', and '-' from the keyboard such that the value of the input remained within the limits set for the particular field, in this case zero and one.

The speed at which the microcomputer can perform mathematical manipulations and calculations allows the designer to interactively change inputs to test various input options. The overall benefit of testing alternative input situations is that intuitive ideas, educated guesses and imaginative 'what if' situations can all be tested to obtain the most suitable design within the overall project constraints. The time overhead attached to alternative designs frequently prevents their investigation, particularly when the design stage is short. Therefore if the time overhead could be reduced, a certain amount of the time saved could be spent on exploring alterative solutions to design problems.

The envisaged computerised design tool could not only act as an aid to the designer by means of the computer's superior calculating speed, but also be a repeatable design method which would take the engineer step by step through all requirements of the design. This dissertation is therefore not only a computer based design aid but also a proposal for a systematic design procedure. A design ~~design~~ procedure that has been developed in practice in consultation with more experienced consulting engineers. The design procedure has been built into the software which will be described in the following chapters.

1.2 SIMILAR WORK, BOTH LOCAL AND INTERNATIONAL

Control Data [3] have developed a software package marketed under the name of Cybernet Express Power Systems. The software is delivered on 16*5-1/4 inch floppy discs and requires an IBM PC-compatible microcomputer with an Intel 8087 processor, 512KBytes of RAM, a colour monitor, a graphics quality dot-matrix printer and a 10-megabyte Winchester drive as a minimum workable hardware configuration. The design and analysis procedures used in the package are initially configured to comply with the National Electrical Code, USA. However it is claimed that the package can be re-configured to comply with local codes or individual design standards. It was not possible, however, due to the distances involved between Cape Town and the South African agents in Johannesburg for the package to be demonstrated in Cape Town so as a full evaluation of its capabilities could be made. Cybernet Express Power Systems is described as " an integrated set of microcomputer based applications for design, analysis and management of electrical power distribution systems."

The Cybernet Express Power Systems is a sophisticated electrical engineering design tool which is marketed at $8 000,00 in the USA and R20 800,00 in South Africa. It encompasses features that are beyond the scope of this dissertation. What is not clear however is the method of load data entry and subsequent analysis of the connected loads for the purpose of sizing feeder cables and transformers. There are certain similarities with the software developed for this dissertation such as the use of libraries based on mass storage devices. In both cases data related to the commercially available products are stored in these libraries. What Cybernet Express does not provide however is an illumination design procedure, which is a major part of this dissertation.

Other software developments in the electrical power systems engineering field have taken place in central and eastern Europe, but due to a language barrier no further information about such developments has been obtained.

In South Africa development is in progress at the University of Stellenbosch under the supervision of R Herman [4],[5]. Herman's development is directed along the line of power systems analysis using Gauss-Seidel routines. Herman's work was presented at a recent workshop held under the auspices of the South African Institute of Electrical Engineers, Cape Western Center. It was clear that the human interface between the programme and the operator had been neglected and that the programme was in fact a power system analysis tool. Yodaiken [6] has developed a L.T. Distribution Cable Sizing program which is written under MS-Dos. Again the problem of distances has prevented a demonstration of the programme. From the literature it is clear that no attempt has been made to develop the software to be simple and easy to use. It would appear that the entry of network parameters is sequential with no capability of back stepping through input data for error correction. The output generated by the programme is excessive and poorly presented making it difficult to read. Yodaiken's software, at R1 300,00, apparently represents the only locally developed cable sizing programme available on the South African market.

1.3 THE SOUTH AFRICAN BUREAU OF STANDARDS

The software developed for this dissertation has rigidly kept within the design criteria applicable to low voltage installations and lighting design practices as published by the Council of the South African Bureau of Standards (SABS). The only deviation from these standards has been in areas which the SABS has not covered.

It has been the author's experience that any new product that adheres to the SABS standards gains acceptance in the market place more rapidly than a similar product that has not adhered to the SABS standards, but may be adequately suitable for its intended purpose. For this reason no simplifications have been made in implementing the requirements of the Code of Practice. The results obtained from this programme can be obtained by hand calculation methods recommended by the respective Codes of Practice.

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CHAPTER TWO

PROGRAMME CONCEPTS

2.1 CHOICE OF PROGRAMMING LANGUAGE.

Three languages were investigated during the initial period of the programme development. The three languages investigated were HP-BASIC (VER 3), GWBASIC and Turbo PASCAL. The draw back of the two versions of BASIC was their inability to support complex data structures. The extra code required to define the required data structure in BASIC leads to complex algorithms for the manipulation and storage of the data. Turbo PASCAL [1], which is a super-set of Standard PASCAL, supports user defined data structures which not only simplifies the programme code but also generates self documenting code.

Turbo PASCAL is a structured compiled language which has an advantage of faster executing code compared to the interpreted BASIC languages mentioned above, which are converted to machine code at run time. The speed of programme execution only becomes significant, however, when numerous mathematical calculations have to be performed in an interactive mode such as voltage drop calculations of large radial networks. The Turbo PASCAL Compiler which is a single pass compiler has the advantage of fast compilation compared with other two pass compilers, however it does have the draw back of not having linkable object code. Turbo PASCAL uses 'Include' Files to overcome this draw back, allowing source codes greater than 64KBytes to be compiled in "chunks" of source code less than 64KBytes. However as the source code grows the compilation time naturally increases because all the Include source files must be compiled each time. Thus any advantage of speed that Turbo's compiler has is lost. Careful planning of the programme structure and use of the chaining facility can reduce the compilation time. Completed self contained modules of the programme may be separately compiled and chained into the main programme at run time.

Turbo PASCAL is not simply a compiler. It is supplied with an integrated text editor which is based on the WordStar commands, but it has a few built in enhancements that make the text editor a sophisticated software development tool complete with a debugging facility that locates syntax errors, run-time errors and I/O errors. Software development time using Turbo PASCAL is reduced when compared to development time when using the interpreted versions of BASIC discussed above. The debugging facility quickly locates errors and returns the user to the source code at the point of the first occurrence of the error.

Pascal lends itself to self documentation. As a high level language it uses English type commands and allows identifiers of up to 80 characters. However the Pascal Standard states that the meaning of a programme shall not be changed if its identifiers are truncated to eight characters [4]. Turbo Pascal as a super-set of Standard Pascal limits the length of an identifier to the line length of 127 characters, all characters being significant. This provides tremendous scope for declaring identifiers that fully describe the variable.

Throughout this dissertation the important programme procedures and functions are presented in Pseudo-code. Pseudo-code is a collection of Pascal like statements which do not comply with correct Pascal syntax. The purpose of the pseudo-code is to present the programme flow in a readable form. To avoid confusion when nested or more than one procedure is shown in the same diagram the last procedure should be read as the controlling procedure from which the other procedures in the diagram are called.

2.2 GENERAL DATA STRUCTURES

Turbo PASCAL has a full range of Structured Types which are explained in the reference manual [2]. The Standard Types are similar to those available in BASIC. There are, as mentioned previously, user defined structures, the most significant of these, in this case, are the RECORD Types. Extensive use has been made of Record Types to allocate memory for all the data used in the programmes. It is possible to build up records that consist of previously defined records, thus a sophisticated structure can be defined to store all the data necessarily associated with a particular application.

The limitation for integer numbers in Turbo Pascal is -32 768 to 32 767 because integers are stored in two bytes. The storage of real number representations in Turbo Pascal is done using 6 bytes of memory which provides a range of real numbers from 1 E-38 to 1 E+38 with a mantissa of 11 significant digits. Real arithmetic under Turbo Pascal does not have the poor accuracy due to rounding errors common in earlier microcomputers.

A general global record structure is used to store input screen text and input field parameters applicable to the screen. The detail of the record is given in Appendix B. The input screen text is created using a text editor and stored in separate text files on disc. These files are read into memory at the start of the programme as part of the initialising procedures. This method of input screen generation means that any alterations to the input screens can be done without changes to the programme code. However if the number of input fields changes then the programme code has to be modified accordingly. Such modification is greatly simplified because it is only necessary to add or delete assignments made to field identifiers in the code. The positioning of the input field on the screen is done by the 'field parameters' in the input screen text files.

The photometric data associated with each luminaire as supplied by the manufacturers is stored in a single nested record along with additional data related to the electrical power consumption and the cost of the luminaires. Similarly the data associated with all the loads connected to a power distribution board is stored in a more complex nested record. These records are stored in sequential order in files on disc storage. PASCAL incorporates a means of referencing any field in a nested record, thus simplifying the manipulation of these large data structures. Self-explanatory identifiers have been chosen for all variables so that the source code is self-documenting.

2.3 GENERAL CURSOR CONTROL AND DATA ENTRY

Through out all the programmes the control of the cursor remains simple. The arrow keys on the keyboard are used to move the cursor around the input screens. Data is only accepted or modified by the terminating action of the carriage return key. This action is similar to the popular spreadsheet programmes that are commercially available.

Under data input conditions the action of the carriage return key is to accept input, check it for validity and store the data in the appropriate record field. The cursor advances to the next input field if the data previously input was valid. If the data is not valid the cursor is not advanced to the next data field, but waits for correct data to be input. An error message is displayed on the bottom line indicating invalid data entry and the limits within which the data for the particular field must lie so that the operator is guided as to what he did wrong and how he can make the necessary corrections.

All input screens use a number of procedures to check the validity of the input data. There are four procedures [3] used to check the validity of Reals, Integers, Character and Text type inputs respectively. The limits for each input field are programmed into the code since such limits are not likely to change.

The general procedures used for cursor control and data entry are given in pseudo-code in Appendix B.

2.4 MASS STORAGE DEVICE

The theoretical limit to the number of records that can be stored on disc in a single file is 65 535. In practice the size of the record and the size of the disc storage medium are the limiting factors to the number of records that can be stored. Disc storage is sequential. The only disadvantage of sequential storage is the access time when the files grow large. To overcome this a look up table could be kept in memory that links the record name to its number in sequential storage. The additional programming required for the lookup table maintenance would not be excessive and could be a simple solution if access times become a problem. It is not expected that any luminaire manufacturer will produce a product range that would require excessively large files. Similarly the general building project is unlikely to require an excessively large file for the storage of the different room dimensions and lighting designs, or for the storage of loads connected to the distribution boards.

The disc storage device is not restricted to a Floppy Disc drive or to a Winchester Disc drive. The amount of data to be stored and the speed of programme execution will determine which type of device is used. The programme execution speed will be dependent on the type of storage device because there is a data access time difference between the two types of disc drives.

2.5 ILLUMINATION PROGRAMME CONCEPTS

A common lighting design method used by practising consulting engineers involved with building lighting design is the Lumen Method [4]. The method is simple to use and all reputable luminaire manufacturers supply documentation with the photometric data required for the lumen method calculations.

As the fundamental aim of the software is to save time it was considered necessary for the photometric data and room dimensions to be stored on a disc storage medium interfaced by computer software. The software envisaged would provide a means of entering and editing photometric data and room dimensions on the storage medium as well as retrieving the data for implementation in lumen method calculations. The actual lumen method calculations would also be incorporated in the software. In addition to the pure photometric data further data pertaining to the luminaire, such as cost and power requirements are merely an extension of the luminaire library structure. These latter figures are used to provide benchmarks for the lighting designer to evaluate the layout. The important aspect of such a luminaire library system is that it would not be restricted to any one manufacturer as is the case with many of the lighting design software packages that run on microcomputers.

The initial input of luminaire photometrics would be time consuming but this would be recovered when repeated lighting designs are performed. It is only necessary to refer to a luminaire by its manufacturer's name and its catalogue number. No further input is required by the software to access the photometric data for use in the lumen method calculations. The programme is therefore structured so alternative layouts can be calculated simply by changing the type of luminaire used (Figure 2.1). In order to change the luminaire the manufacturer and catalogue number are altered and the calculations are performed with the new photometric data retrieved from disc storage. Similarly it is possible to use the same luminaire for a number of different room dimensions, when only the room dimensions need be altered.

Finally a paper record can be made of each of the alternative designs calculated for either presentation to the client or for project records. Only the finally accepted layout is stored on the mass storage medium.

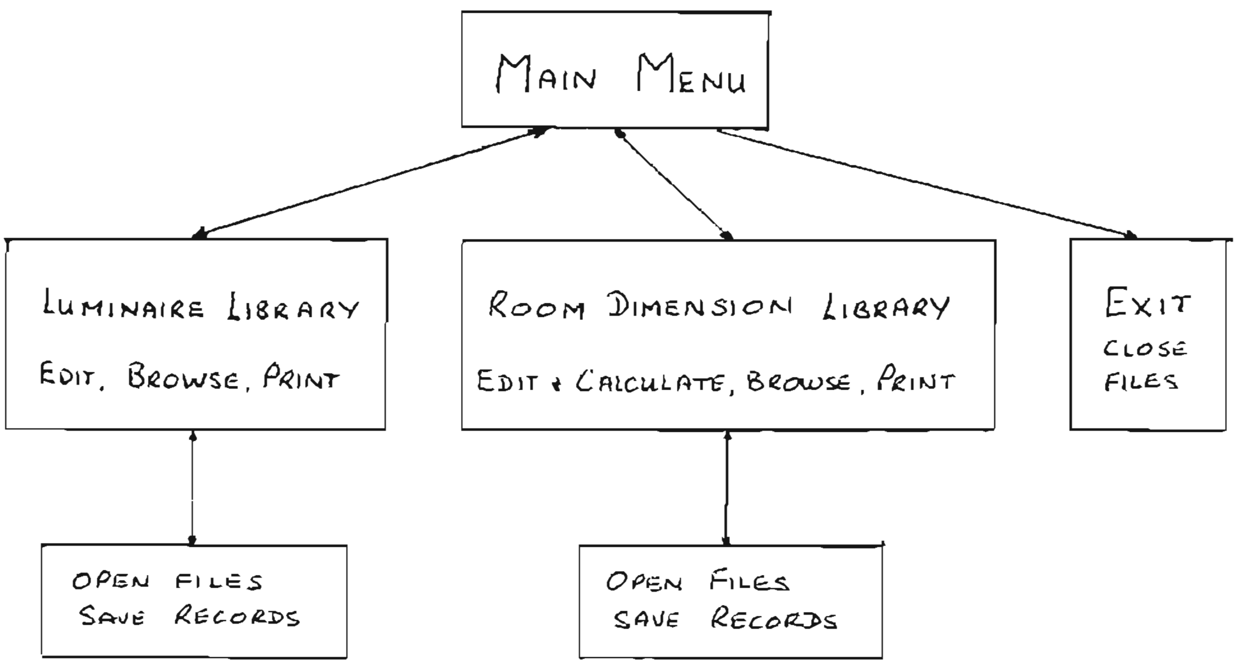

FIGURE 2-1 Flow diagram of the illumination procedures

2.5 CABLE SIZING PROGRAMME CONCEPTS

The aim of saving time can be further extended to the sizing of cables used to connect sub-distribution boards to distribution boards and distribution boards to points of supply. The calculations involved are not complex but become time consuming when there are many cables sizes to be calculated.

In typical low voltage radial distribution networks found in commercial and industrial buildings there is usually one point of supply from the supply authority. This may be in the form of a low voltage connection or medium voltage (11kV) supply for which, in the latter case, the consumer is responsible for the transformer. In either case the size of the load has to be determined before a supply of electricity can be negotiated. The loads in such installations may consist of a range of luminaires, single and three phase socket outlet points, air conditioning heaters and motors for chillers and other small inductive loads such as computer equipment, typewriter machines (or word processors), etc. These loads can all be classified into one of four major categories:

* Lighting,
* Socket outlets,
* Other miscellaneous loads,
* Sub-distribution boards.

Under the heading of other miscellaneous loads would fall air conditioning loads and loads with fixed connections that are not normally connected to socket outlet points. By such grouping of loads it is possible to make an orderly collection of the load data for storage and later manipulation by a software programme. Each of the categories have different data that is required for the correct summation of load currents and subsequent sizing of cables where cables are required, such as power factor and starting currents.

Having acquired all the data necessary for the summation of the load currents, the cable sizes could be calculated according to voltage drop and fault level criteria. All that is required of the programme is an algorithm to determine the radial connections between distribution boards and sub-distribution boards. The calculations could then be performed to determine the cable sizes and the fault levels at various points around the network.

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CHAPTER THREE

LUMEN METHOD - LIGHTING DESIGN

3.1 STATE OF THE ART !

There have been great strides made recently in the computerisation of lighting design. Most of this work has been undertaken by the large luminaire manufacturers in Europe and in particular West Germany. The emphasis seems to have been on graphical presentations of illuminance levels achieved from a particular layout. The software developed by these manufacturers has made use of libraries for the storage of luminaire photometric data.

South African manufacturers have imported a variety of software packages which run on numerous different machines. As a natural consequence of the fact that the luminaire manufacturers have been responsible for the majority of lighting design software it is not surprising that the libraries associated with the software contain only luminaires sold by a particular manufacturer. There are some packages which have facilities that allow the lighting designer to alter the contents of the libraries and to insert those luminaires of his choice, irrespective of the manufacturer. The advantage of having a library with different manufacturers' luminaires is the comparison of results of a design using luminaires from different manufacturers.

Many of the illumination design software packages are stand alone programmes that are not interfaced to more general electrical distribution design programmes. The advantage of being able to communicate between illumination programmes and distribution design programmes is that the lighting loads calculated in the illumination programmes can be readily available for load summation in the power distribution design programme.

The LUXOR computer programme developed by Fahmy [1] uses optimisation strategies to calculate optimal lighting systems. The programme requires that input data be preprocessed before illumination distribution is calculated. The data input is unwieldy and no regard has been taken of the fact that the operator is human. The photometric data required for the calculation of illuminance distribution is retrieved from a special catalogue file in which isolux diagrams are pre-stored in the form of numerical maps. The programme output is in graphical and text form.

The aim of the illumination section of this dissertation is to provide a tool for the calculation of lighting layouts and the documentation of lighting loads for use in the cable sizing section. There has been no attempt to provide graphical output as this would have involved many more programming hours than were available. The text output is simple and clearly presented to be useful in determining the most suitable layout from a number of alternatives.

3.2 LUMINAIRE PHOTOMETRICS.

The luminaire photometric data required by the Lumen Method is given in Table 3-1. The room index is calculated from the room length, width and mounting height of the luminaire. The 'lamp-lumen' output is obtained from data supplied by the lamp manufacturers. The lamp light deterioration factor and the maintenance factor required by the lumen method formula vary considerably from installation to installation. These two figures are entered into the programme at the same time that the room dimensions and type of luminaire to be used are entered.

COEFFICIENTS OF UTILIZATION FOR A RATIO OF S/H_m = 1,50

REFLECTION FACTORS			ROOM INDEX									
Floor	Ceiling	Walls	0,60	0,80	1,00	1,25	1,50	2,00	2,50	3,00	4,00	5,00
0,1	0,7	0,5	–	0,45	0,50	0,54	0,58	0,62	0,65	0,68	0,70	0,72
		0,3	–	0,40	0,45	0,50	0,54	0,59	0,62	0,65	0,68	0,70
		0,1	–	0,36	0,41	0,46	0,51	0,56	0,59	0,62	0,66	0,68
	0,5	0,5	–	0,43	0,48	0,53	0,57	0,61	0,64	0,66	0,69	0,70
		0,3	–	0,39	0,44	0,49	0,53	0,58	0,61	0,64	0,67	0,69
		0,1	–	0,36	0,41	0,46	0,50	0,55	0,59	0,62	0,65	0,68
	0,3	0,3	–	0,39	0,44	0,48	0,52	0,57	0,60	0,62	0,65	0,68
		0,1	–	0,36	0,41	0,46	0,49	0,55	0,58	0,61	0,64	0,66
BZ Classification			–	4	4	4	4	4	4	4	4	4

TABLE 3-1. Coefficients of utilisation for the Siemens CCS luminaire range with reflectors.

3.3 LUMINAIRE LIBRARY AND ITS STRUCTURE.

As explained in the preceding section there is a mixture of data types associated with each luminaire. The catalogue number and lamp type are stored as string expressions while the numerical data is stored in integer and real formats depending on whether the number is best represented by an integer or real. All the data pertaining to the luminaire is stored in a user defined RECORD where each separate item of data is contained in a field within the record. The type of each field depends on the data to be stored in it. In Pascal the record structure allows a combination of any type to be associated in one record, as long as the types are standard types or have been previously declared as user defined types. The data structure of the luminaire record is given in Appendix C.

To add a new luminaire to the library the menu option directing the programme to the luminaire library section must be selected. The file name into which the new luminaire is to be stored is entered and the screen for the luminaire data appears. The luminaire data may be typed in. The record is automatically saved after the last field is entered. To edit existing records the facilities contained in the browse procedures allows the operator to do any of the following:

* Find a record by name,
* Find a record by number,
* Go to the first record in the library file,
* Go to the last record, or
* Step to the next of previous records.

Each time one of the above actions have been selected the record in the library is read from disc into memory and displayed on the screen. Once the required record is found the browse routine must be exited and the Modify routine selected. At this point the programme is the same as if the record was a new record.

3.4 PROJECT LIBRARY AND ITS STRUCTURE.

The project library has a data structure that stores all the data relating to the room for which the lighting design is being done. The data is referenced by the room name which is entered by the operator. The record that is used to hold the data pertaining to the rooms and the subsequent final lighting design is simple, containing no complex data types. The structure of the record is given in Appendix D.

The manner in which the records are entered as new or edited existing records is the same as that described for the luminaire library. The only difference between the luminaire library and the room library operation is the calculation of the number of luminaires required to provide the desired average illuminance. This is performed at the end of the input stage. The results of the calculation are added to the record and stored on disc.

3.5 THE LUMEN METHOD : AN Algorithm for lighting design.

As mentioned previously the lumen method of calculating a lighting layout is popular amongst the consulting engineers. It emphasised that the lumen method calculates total lamp flux required in a room to yield the average illuminance level. The number of luminaires required can be found by dividing the lamp flux required by the lamp flux emitted by one luminaire. Further assumptions made when using the lumen method are : the room is a rectangular parallelepiped and the luminaires are installed in a regular uniform pattern to provide a uniform distribution of light on the working plane.

For practical purposes the coefficient of utilisation tables have been limited to one value of reflectances for the ceilings, walls and floor. Practical experience has shown the an engineer will favour one set of values for the reflectances and may choose either the worst case reflectances (10% for floors, 30% for ceilings and 10% for walls) or the middle case reflectances (10% for floors, 50% for ceilings and 30% for walls) (see Table 3-1). The coefficient of utilisation data in the library of luminaires may be entered at the preference of the engineer. The additional memory required is in the order of 400 bytes. It was initially intended that the record sizes be kept small.

A more rigorous development of the lighting design section of this dissertation could in itself be the subject of a separate dissertation. The aim of this dissertation is to develop a tool which would assist the consulting engineer in his overall building design work.

The algorithm used for the lighting design encompasses the room dimension input, the luminaire selection and retrieval from disc, the room index calculation, the calculation of the number of luminaires required for the desired average illuminance, a display of the results and finally the acceptance of the design for storage on disc. The flow chart in Figure 3-1 shows the sequence of the programme execution.

3.6 PROGRAMME INPUTS AND OUTPUTS.

The external text files of the input screens (Appendix E) contain the text that appears on the screen at run time, as well as a list of the input field parameters applicable for each input screen. In some cases the text part of the input screen has been included in the programme code. The reason for this is that the first development on this software began in March 1984, and subsequently programming methods have improved. One such improvement has been the method of screen handling which now makes use of external text files.

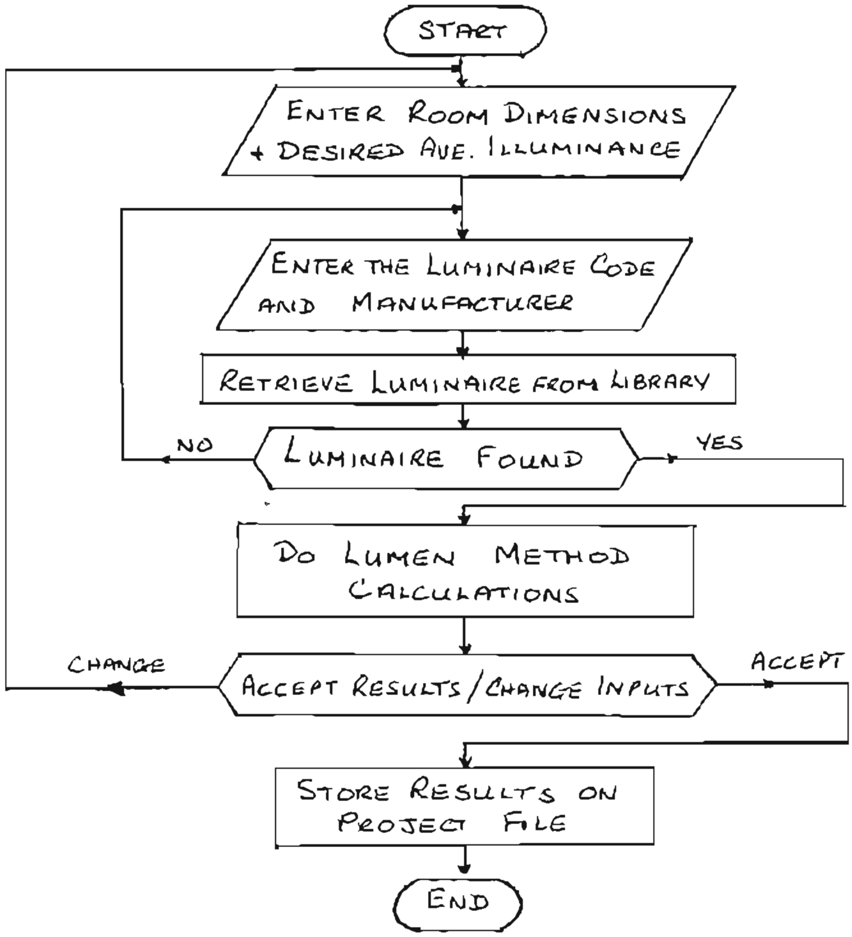

FIGURE 3-1 Programme flow for the lighting design and luminaire library sections

The run time screens show that the input field messages are displayed on the bottom three lines of the screen. These input messages fall under three headings:

* CMD: for inputs that will direct the programme execution,
* MSG: for messages that explain what input is required,
* INP: for input commands.

The 'left elbow arrow' character on line 22 of each input screen is the prompt that indicates the contents of the current input field. The current contents may be altered by typing in new values or the input field may be left unchanged simply by pressing the carriage return key (the elbow arrow key).

The input and output data is shown in Appendix E. Two examples of lighting calculations are given. It is interesting to note that the larger the room the more efficient the lighting layout becomes. This is evident if the power consumed per square meter of floor space and the corrected illuminance figures are examined. The corrected illuminance is the expected average illuminance after 100 hours of lamp life, corrected for the integer number of luminaire that are calculated by the lumen method formulae.

The paper print out option available prints out the contents of the luminaire library one record at a time. Similarly the room dimension and lighting design record may be printed out one record at a time. The purpose of this facility is to provide paper based documentation for inclusion in project records. It is not always convenient to use the computer to retrieve a record for discussion purposes and even if a computer was available the magnetic storage media is useless on a site where environmental conditions are not ideal.

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CHAPTER FOUR

CABLE SIZING FOR LOW VOLTAGE RADIAL NETWORKS

4.1 STATE OF THE ART !

The design of a low voltage distribution network must take into account the following factors: maximum load, diversity of loads, short circuit level, cable sizes, voltage regulation, type of protective device, discrimination of protective devices and cost of the installation [1].

When planning a network the typical sequence of events might be to first draw up a schematic diagram of the network from the point of supply right down to the last load on the network, labelling the distribution boards (DB's) and individual loads. The maximum current for each individual load must be taken into account when summation of the load currents drawn from the DB's is performed. Future growth and diversity between loads connected to each DB must also be considered. Once the total load for the network is known the size of the transformer may be selected or the size of the connection from the supply authority may be negotiated. In either case the short circuit level at the point of connection to the network is required to determine prospective fault levels at each DB in the network.

The sizes of the cables connecting the DB's together are calculated according to the maximum sustained current to be draw such that the cable temperature remains within its thermal rating. In the event that starting currents are higher than normal running currents the cables supplying such loads are sized according to the voltage regulation drop when starting current is drawn. The second criteria that the cables must satisfy is that the cable impedance must be low enough to ensure that the voltage at the load at last point of the network does not fall below 95 percent of the nominal phase to neutral voltage at the point of supply [2]. Two final checks on the cable sizes must be made to ensure that the short circuit rating is not exceeded and that the amount of copper installed in the network is the most economical.

The software packages mentioned in Chapter One cover what is described above to a lesser or greater degree of sophistication. Each has it's merits and disadvantages, in the areas of either the human interfacing aspects or in the cost of the package. The results of the survey carried out (Appendix A) reveals that 26 of the 36 respondents use some form of software to assist with electrical installation designs, therefore it is apparent that the computer offers some advantages to the designer.

However, the contact that the author has had with practising electrical consulting engineers in a number of different practices around South Africa lead to the opinion being held that there is a general lack of efficient software that determines cable sizes. There have for example been some practices that have used commercially available spreadsheet programmes set up to select low voltage cable sizes, and some practices have developed 'in house' programmes specially developed for cable sizing. Such efforts, though a means of improving design accuracy invariably do not make efficient use of the capabilities of the computer. If well developed, the specialised programme will concentrated on the tasks it has been designed to perform in an efficient and concise manner with a friendly and easily understood human interface.

It is apparent that there are a number of power system analysis packages available that analyse a network once the cable parameters are known. It is intended that the programme developed for this dissertation will rectify the situation of a lack of cable sizing programmes available in South Africa.

4.2 THE SABS CODE OF PRACTICE Ø142

'The fundamental principles that form the basis of this code of practice are primarily intended to ensure the safety of persons, livestock and property against hazards that may arise from any reasonable use of an electrical installation. Two major hazards inherent in the use of electrical installation are shock currents and excessive temperatures that may cause burns, fires, and other injurious effects.' [2]

Personnel must be protected against contact with live parts of the electrical installation by means of proper insulation, barriers or enclosures. In the event of a fault between live parts and enclosures, the enclosures must be connected to earth by a low impedance path according to the SABS Code of Practice. The design process must ensure that electrical components, particularly cables, are adequately rated so as not to be overloaded and reach dangerous temperatures when in normal use.

The design requirements affecting the safety of personnel are covered in detail in the SABS Code of Practice. The thermal ratings of cables and the voltage drop calculations used in this dissertation adhere to the requirements of the Code of Practice.

4.3 CLASSIFICATION OF LOADS AND THE QUESTION OF DIVERSITY

The types of load most commonly found in industrial and commercial buildings may be broadly classified as lighting, socket outlet points, air conditioning plant and distribution board feeders. These loads are discussed in more detail below.

The question of the appropriate diversity factor has to be carefully considered. There are a number of statistical figures quoted for diversity factors applicable to various installations. However, the amount of spare capacity available on a DB feeder cable may be a result of the actual diversity being different to the statistical diversity expected, or the amount of future growth allowed for being excessive. Just as it is important that the diversity of loads is not under estimated, because the most economical installation is required, it is also important that the diversity is not over estimated because the electrical installation must be safe. Statistical diversity figures vary widely from building to building, from one geographical region to another and from season to season.

It is proposed here that there is one safe and reliable way of determining what the diversity of loads is in any electrical installation: By considering each DB in turn the following rule should be applied to determine the actual current that must be supplied to the DB to satisfy the load demands. Any load that may draw current from the supply simultaneously with other loads must be added to the total cumulative current demanded by the local DB and by the network. The highest value of total cumulative current demanded by each DB at any time of the day or at time of the year must be the current on which the minimum cable installation should be based. The maximum total cumulative current demanded by the network will in turn determine the size of the supply feeding the network.

For example, there is invariably no diversity applicable to lighting loads in an office block because all the lights in the offices are switched on for the duration of the working day. In addition the probability of any air conditioning plant operating to cool the building down on the hottest days is high, which will add to the total demand (the increase in ambient temperature also affects the current rating of protective equipment and cables alike). Therefore the current associated with the maximum KVA demand of an installation is the current required by all the loads drawing power simultaneously. This figure is usually lower than the total connected load of the installation, which implies that there some diversity of loads.

The statistical figures quoted in the SABS Code of Practice for diversity factors applicable to elevators are not a reliable method for determining the load applicable for elevators. For example, for 3 elevators or more a factor of 60 percent is recommended for estimating the total load [2]. Assuming that 3 elevators each draw 50 amps, SABS considers the estimated load to be 3 X 50 X .6 which equals 90 amps. During peak traffic hours in the morning, lunch time and evenings the three elevators are likely to be operating continuously and simultaneously drawing the full load amounting to 150 amps (starting current ignored for the purpose of discussion). The cable supplying power to the elevator DB sized on thermal rating for 90 amps load would be a 25 square mm cable and if sized for 150 amps would be a 50 square mm cable (two sizes larger). If the 25 sq mm cable were installed it would operate 50 percent overloaded for about an hour three times a day unless the protective device disconnects supply, a situation that can not be accepted. The inevitable temperature rise in the cable could be dangerous and a potential fire hazard. Voltage drop has not been considered here, although it is appreciated that the cable size may be larger due to the limitation of the cable impedance. The cable impedance reduces the voltage at the motor terminals so it is lower than at the supply end of the cable. This means unless the starting current is used to calculate the voltage drop at the motor terminals the voltage at the motor may be too low for the motor to even start. The implication of the above discussion is that the amount of current drawn from the supply must be accurately estimated if overloading, undervoltage or disruption of the supply is to be avoided.

The point being made here is statistical methods of applying diversity factors in cable sizing can be misleading. A reliable method is to take each DB and determine which loads will operate simultaneously and use the current drawn by these loads to determine the size of the cable. Spare capacity for future growth can be considered in addition to the requirement of the 'simultaneously operating loads'.

This consideration of loads operating simultaneously must be born in mind when using the programme to size a cable network. The data entered under the various input screens must pertain to those loads which are operated simultaneously. There is no other way which the programme can determine the diversity of the loads. A full total connected load design can be done by adding those loads which were omitted in the first network design. A comparison of the two designs will yield the diversity factors.

4.3.1 Light circuits supplied by 2.5 mm sq wiring

The generally accepted standard size of wiring used for lighting circuits is 2.5 square mm. There are of course exceptions where the lighting load on a circuit is small, in which case the size of wiring installed is reduced to 1.5

quare mm. The rating of the protective device used on a 2.5 sq mm circuit is 20 amps and on a 1.5 sq mm circuit is 15 amps.

It is not always clear at the detailed design stage what the actual routing of the wireway will be and how many conductors will be carried in each wireway. These details are often left to the contractor to finalise in accordance with the SABS Code of Practice. Therefore for the relatively small increase in cost between 1.5 sq mm and 2.5 sq mm wiring the 2.5 sq mm wiring offers spare capacity on most lighting circuits for derating effects due to the grouping of wiring in wireways.

The derating effects that arise due to the grouping of wiring in wireways should never be ignored. It is hoped that the formal lists of circuits generated by this programme will highlight areas of congestion at DBs.

The input screens for the lighting circuits are given in Appendix F. The two screens associated with the lighting circuits are the cross reference screen and the lighting circuit input screen. The cross reference screen is used as a time saving device where the luminaire identification numbers used on the drawings is linked to specific luminaires in the lighting catalogues stored in the luminaire library. The programme ensures that the luminaires exist in the library files on disc before the programme control moves on to the next input. This checking procedure eliminates some obvious errors linked to the luminaires later in the programme when luminaire power requirements are retrieved. The the lighting circuit input screen uses the luminaire code entered in the cross reference table to identify the luminaires used in the various circuits. Under the headings circuit identification, luminaires per circuit, total circuit length and number of phases for the circuit, the relevant information is stored in memory. The data structure used to store all the DB circuit details is given in Appendix G

The summation part of the programme retrieves the power requirements of each luminaire from the luminaire library and uses the information to determine the power demand for each circuit. It is possible that one circuit may have different luminaires, therefore the programme checks for previously defined circuit identifications and adds any additional power requirements to that circuit. The number of phases supplying each circuit is used to balance the loads over all three phases. There is however no check that the number of phases entered is consistent for the circuit with different luminaires (this is one area for future improvement).

4.3.2 Power outlets on 4 mm sq wiring

A similar discussion detailed in section 4.3.1 for the lighting circuits applies for the size of wiring used as a standard on socket outlet circuits. The wiring size used as a standard for socket outlets is 4 sq mm and the circuit is protected by a 25 amp protective device. In circumstances where the load is expected to be small and the length of the circuit is short 2.5 sq mm wiring is sometimes used. The protective device is then changed to the lower rating of 20 amps.

The input screen for the socket outlet circuits calls for the following information about each circuit: a description of the type of outlet, the circuit identification, the number of outlets on the circuit, the outlet current that is to be drawn, the circuit length, the load power factor, and the number of phases supplying the load. This data is used on its own for the summation of loads and distribution over the three phases. The input screen is given in Appendix F and the data structure in Appendix G.

4.3.3 Other miscellaneous loads

To accommodate the loads which cannot be supplied by 2.5 sq mm or 4 sq mm wiring a separate input screen is used to collect data about these loads. These typically consist of air conditioning plant, and water pumps. The input screen is the same in appearance as that used for the socket outlet loads, except that the starting factor applicable to each motor load is also required. The input screen is given in Appendix F and the data structure in Appendix G.

4.3.4 Feeders to sub-distribution boards

The distribution board feeders are entered into the programme through the sub-distribution board (SDB) feeder input screen (Appendix F). The destination name of the SBD, its route length and the number of phases it supplies to the destination SDB are required as input. The data structure is given in Appendix G.

4.3.5 Detailed cable specification.

Each of the loads entered in the input screens described in sections 4.3.3 and 4.3.4 require further data to be entered to enable the programme to determine the size of the cable supplying the load. The input screen which calls for the detailed cable specification (Appendix G) is automatically displayed when all the details called for in the first input screens (4.3.3 or 4.3.4) have been entered.

The detailed cable specification screen calls for the following data for each load: the type of protection ('close' or 'course' as described by the Code of Practice), the type of conductor (Copper or Aluminium), the type of cable (multi core armoured or unarmoured, single core unarmoured, or flat unarmoured), the conditions of use (defined, on a rack, in wireways), whether the cables are to be laid adjacent or spaced and finally the ambient temperature. The minimum and maximum conductor sizes are displayed on the right hand side of the screen to let the operator know what the cable size limitations are for each load. The type of protection, the spacing of the cables and he ambient temperature are all used to determine what derating factors must be applied if any. The data structure is given in Appendix G.

The Code of Practice lists a table of rated currents of PVC-insulated cables with copper or aluminium conductors. The data called for above is used to determine which column of which table (copper or aluminium) is to be selected for cable sizing purposes. At this stage the programme only caters for cables with copper conductors, but will in the future cater for aluminium conductors. It is merely a question of adding the table of rated currents for aluminium conductors. This has not been done primarily because the SABS Code of Practice is currently under revision and is expected to be published in January 1987.

4.4 BALANCING THE PHASES

The currents drawn by each load connected to a DB are summated to give the total load current for that DB. The current required by each DB is accumulated starting at the farthest DB from the point of supply. The loads are accumulated for each DB in succession back towards the first DB closest to the point of supply. The programme automatically finds the circuit routes of the various feeders in the radial network (ring networks cannot be designed using this programme).

The circuit route of the network is determined by an iterative procedure rather than a recursive procedure. The only discernable merit in using a recursive procedure is the concise code generated, but the degree of difficulty in debugging and programme maintenance far outweigh the merits of concise code, particularly since the memory available on microcomputers is so cheap and abundant. Each DB record is referenced by its name. Each feeder cable is linked to its source, by the entries made at the DB feeder input stage, and to its destination by the names given in the same input screen under the heading 'Destination DB'.

The first record in any project file must be called 'TRFMR' as this acts as the root record from which all the network feeders emanate. The programme searches the project file for the root record and determines whether there are any feeders (called sons for the purpose of explanation). If sons exist then the first son is retrieved from disc and it in turn is checked for sons. When a record with no sons is found the loads connected to that DB are summated and added to the feeder DB load (the father). The father DB is checked for any other sons. The whole process is repeated until all the feeders have been traversed and the total load current required from the supply is summated at the TRFMR record.

The distribution of the loads over the three phases of the supply, assuming three phase supply is done according to the simple algorithm in Figure 4-1. When the accumulative current of all three phases is zero the programme will take the first phase as being the phase with the least current. Similarly if two phases have the same accumulative current the programme will select the first phase of the two phases with the same value. If the load is to be supplied by a three phase connection then the line current is added to all three phases.

```
IF the feeder is three phase THEN
 BEGIN
  IF the load is single phase THEN
    Add the circuit current to the phase with the
      least current
  ELSE
    Add the line current to all three phases;
 END
ELSE
  Add all the circuit currents to the phase whose total
    network cumulative value is the smallest;
```

FIGURE 4-1 Algorithm for distributing loads between three phases of the supply.

4.5 SIZING OF CABLES ACCORDING TO THERMAL RATING

The details entered for each cable under the Detailed Cable Specification input screen are used to determine which column in the table of thermal current ratings [2] is to used to determine the size of the cable. These current ratings are stored in a two dimensional array of real numbers in memory at run time. The appropriate column is searched to determine what size of cable would supply the current safely. The programme then checks the voltage drop at the load end of the cable to ensure that it is within limits. If, as is usually the case with long cable runs, the voltage regulation drop at the load end is excessive then the next larger size cable is first checked that it is suitable for the installation conditions and then tested for compliance with the voltage regulation drop limits. The size of the cable is incremented until the voltage regulation drop falls to with the limits set.

If, however, the cable size becomes unsuitable for the installation conditions the operator is asked if parallel cable installations are acceptable. If the answer is in the affirmative the impedance of the circuit is reduced. The smallest parallel cable installation is selected within the limits of the installation conditions and voltage regulation drop. The value of the parallel cable impedance depends upon the number of cables installed in parallel. If a parallel installation cannot be considered then the installation conditions of the cable must be altered or the load split into smaller loads supplied by separate cables. The split in such a case is likely to be based on the physical conditions on the site or in the building.

The above explanation of the load summation and cable selection according to the cable thermal rating and the voltage regulation drop is fairly simple. The implementation of these algorithms in Pascal code has generated some 18 pages of source code. This is due to the different types of loads and their classification in this dissertation and to the design methodology built into the programme, as well as the complicated presentation of the SABS thermal current rating of the cables according to the installation conditions.

4.6 THE VOLTAGE DROP CONSTRAINT

The maximum permissible voltage drop from point of supply to the furthest load on the network is 5 percent of the nominal phase to neutral voltage at the point of supply. The point of supply refers to the low voltage terminals of the 11 kV/ 400 V transformer supplying the network.

The determination of voltage drop at any point in the network is not a simple matter. There are at any one time two unknown factors: the voltage drop at the point in the circuit and size of the conductor at that point. If one of these values is known the other can be calculated. However to obtain the most economical installation an iterative process of calculating the cable size and checking the voltage drop is required. The speed of convergence of such a solution obviously depends on the algorithm implemented. For the sake of simplicity and to get a working programme the voltage drop over the whole network is divided equally amongst all the levels of SDBs in the network. This is a simplistic method of determining the cable sizes, which does not necessarily lead to the most economical installation. There are a number of alternative methods that can be implemented for determining the most economical installation, one such method is discussed in Chapter 6

4.7 THE MINIMUM COPPER VOLUME CONSTRAINT

The programme does not attempt to design the cable installation to produce a minimum copper volume installation. There is a facility built into the programme that allows the operator to change the percentage voltage regulation drop for any cable in the network. The installed copper volume figure is displayed on the screen so that the operator is guided to the least copper volume. An alternative optimisation routine is discussed in Chapter 6.

The volume of copper installed in a network is closely related to the costs of the cable installation. The actual cost of the cable installation must be the sum of the cable costs and the capitalised costs of the energy losses in the network [3].

Walkden [3] suggests that where current ratings are exceeded before the limit of voltage regulation is reached, the design is fairly straight forward. If a network is designed with the voltage regulation as the only limiting condition it is a simple matter to modify the design if current ratings are exceeded at any point, even if such modification alters the voltage regulation which may induce changes elsewhere. However if the network is designed on the basis of the thermal current ratings of the cables it is much more difficult to determine any changes if the limit of voltage regulation is exceeded.

Walkden continues to describe a process by which the minimum conductor volume installation can be reached by designing the network under the voltage regulation constraint and then making adjustments for those areas where the thermal rating of the cables have been exceeded.

After eighteen months of part time programme development the restrictions of the method used in this dissertation to determine cable sizes for a radial network have become vividly apparent. Chapter 6 outlines procedures that can be followed to adjust the design methodology incorporated in this programme to arrive at a process which will determine the minimum conductor volume for any given radial network. Once that is achieved the resulting software product would in fact be a cable installation optimising programme and will be of greater benefit to the practising electrical consulting engineer.

4.8 FAULT CURRENT CALCULATIONS.

The calculation of fault currents uses the per unit method which has proved to be reliable and applicable to any system voltage, although the system voltage must be restricted to 400/380 volts in this programme. The formulae used can be obtained from any good text on the topic [6].

The method of fault level calculations is not repeated here save that the algorithm used to determine the cable route impedance is given Figure 4-2.

```
REPEAT
  Read a DB record from the file;
  Find the source DB record and retrieve it;
  Add the feeder impedance to the accumulative total;
  Let the source DB become the load DB;
UNTIL the root DB has been found;
```

FIGURE 4-2 An algorithm for determining the cable route impedance from transformer to load. The routine is repeated for each DB record on file.

4.9 PROGRAMME GENERATED REPORTS

The cable design programme output consists of a table of DBs with destination feeder cable sizes, length of the cable route, the voltage regulation drop at the load end of each cable in both volts and percentage of nominal phase to neutral voltage, the current to be supplied to the load and the symmetrical three phase prospective fault level at the load.

There is a facility to have the table printed out on a line printer for permanent project records.

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CHAPTER FIVE

TESTS AND VALIDATION.

5.1 GENERAL DATA INPUT.

Throughout the development of the software for this dissertation the programme routines were tested as they were completed. The most rigorous tests were applied to the input stages. All conceivable inputs were tested to ensure that incorrectly pressed keys were not accepted as input. For example if a numeric input is expected the computer issues a 'beep' tone if any alpha character is pressed. Similarly the 'beep' tone is issued if an invalid character is pressed in response to an input that expects either 'Y' or 'N'. There are, however, limits too which such testing can be taken; such as when text input is required: any printable character can be accepted.

The limits placed on the numerical input fields were tested to ensure that the programme does not accept any inputs outside of these limits. Each numerical input field is given an upper an lower limit. The advantage of trapping erroneous input at the entry stage are obvious. Any well design software should be able to trap unexpected input and take the necessary action, such as warning that inputs are out of limits or that files don't exist, etc. This programme disables the system error trapping mechanism and incorporates its own error trapping routine. Thus if, for example, the operator removes a disc from a drive the programme detects a system fault and issues a warning that a disc is missing. Such error trapping prevents the programme halting and displaying cryptic system generated error numbers and messages.

5.2 LIGHTING DESIGN PROGRAMME.

The results of the lumen method calculations are presented in terms of the number of luminaires required for the required average illuminance. Since the number of luminaires must be an integer, the results are rounded down to the nearest integer. The corrected illuminance therefore is lower than might be expected. In order to achieve a corrected illuminance that is closer to the desired average illuminance, the required illuminance entered at the input stage should be increased by about 10 percent.

The results of two calculations for different room sizes are presented in Appendix E (Figure E-6 and E-7). The luminaire data used for the calculation is also given in Appendix E, (Figure E-5). The coefficient of utilisation is applicable for room index values between Ø.8 and 5.Ø, any room index values outside this range are defaulted to these limits. The operator must take the value of the room index into account when evaluating the results, as an incorrect interpretation may result if the room index is outside the limits of the programme.

5.3 CABLE DESIGN PROGRAMME.

The cable design programme was subjected to similar tests during the coding phase to ensure that each procedure produced what was expected of it. The input screens were rigorously tested for correct input limits and cursor control.

The addition of load currents were displayed on the screen during the testing phase to ensure the correct balancing of loads over the three phases was obtained. During such testing the fault discussed in section 4.3.1 was detected, but due to a shortage of time the necessary error trapping code could not be written. This of course could lead to erroneous results if the operator enters incorrect figures. The problem is not difficult to rectify and shall be done some time in the future.

The cable sizing part of the programme was tested as a whole using load conditions from a project that the author was involved in while employed in a consulting engineering firm. The project was a Music Conservatory in Windhoek. There were eight DBs connected in a radial network, all of which had lighting, socket outlet and air conditioning loads. The data entry took approximately three hours and was done directly from layouts super imposed on the architects drawings. The actual summation of loads, cable route finding, determination of cable sizes and fault level calculations took less than two minutes.

There were however some problems with the cable sizes as determined by the programme. As described earlier the voltage drop was split evenly over the various levels of DBs in the network. The result was that some cables were larger than necessary. In practice the percentage voltage drop between DB levels is not evenly distributed, but rather selected by the engineer to give the best compromise of cable sizes and voltage regulation. This deficiency in the programme has been discussed and methods for its rectification are suggested in Chapter 6. Otherwise in all cases the cable sizes were correctly selected within the given voltage regulation drop limits.

Some examples of input data and results obtained from the cable sizing and fault level calculations are given in Appendix G.

CHAPTER SIX

FURTHER WORK

6.1 ILLUMINATION PROGRAMME

The value of corrected illuminance is always a bit lower than may be expected. An iterative routine could be included to find the value of the corrected illuminance that is as close to the desired average illuminance as possible. The routine would be a simple loop that incremented the number of luminaires in the layout until the corrected average illuminance was as close to the desired value as possible.

The coefficient of utilisation figures are only included for one value of wall, floor and ceiling reflectances respectively for the range of room indexes between 0.8 and 5.0. The additional values of reflectances may provide the software with more flexibility in terms of the library contents appealing to a broader spectrum of lighting designers. The single row of coefficients is not considered a major restriction on the programme since at any time during the construction stage of a building the wall, floor and ceiling finishes may be changed to suit materials available or client's/architect's change of taste. It may then be impractical for the lighting layout to be altered to provide the correct average illuminance according to the new reflectances of the walls, floor or ceiling.

If a warning message is displayed on the screen when the room index is out of limits would alert the operator to this fact so that he could either divide the room into smaller areas or make the necessary adjustment to the final layout.

The graphical presentation of the results would be an important contribution this software could make to the understanding and interpretation of any lighting layout. Further point by point calculations may be incorporated to do street lighting, sports field lighting and specific flood lighting applications where the lumen method can not be applied. The luminaire library structure may then have to be expanded to cater for a numerical representation of the isolux diagrams associated with exterior luminaires. The modification would not be mean a major programme change because Turbo PASCAL allows records to have variant structures which share the same memory space, depending on a 'tag field' which identifies the structure associated with the data in memory.

6.2 CABLE SIZING PROGRAMME

There are a number of features which could be added to the programme to make the software a complete desk top tool for the electrical consulting engineer. These features are based on the latest commercially available software and include such tools as a 'pop up' scientific calculator, calendar and appointments book, telephone directory and dialler to mention a few. These features may be considered gimmicks but have become standard features in most new software packages available. When used regularly they do save time provided the computer is switched on and at arms reach on the desk top !

On a more technical aspect of the programme it has been pointed out that the determination of cable sizes can be done using either the thermal current ratings of the cables as the limiting criteria, (and then checking for compliance with the voltage regulation drop permitted), or using the voltage drop regulation as the limiting factor to determine the size of the cables, (and then checking for compliance with the thermal rating of the cables). Walkden [3] claims that the later method implies an easier process which is given below:

(a) An estimate is obtained of the distribution voltage regulation in a minimum volume design for the network, when voltage regulation is the only limiting condition.

(b) Working from this estimate, a design is produced taking in to account both conditions of voltage regulation and thermal current rating of the cables.

(c) Incremental changes are made to the design to bring it to the condition for minimum conductor volume.

In his paper Walkden has elaborated on the above three stages of his process and gives an explanation of the formulas involved. There are certain aspects of the paper that need further investigation before they can be implemented on the computer. The transition from the initial assumption that all conductors are continuously tapered to the final practical design using standard cable sizes is one such aspect.

The changes to the existing programme structure that would be required to implement Walkden's design process are not severe. The modular structure of the programme allows the replacement of the cable sizing module with the new cable optimising module. The input facilities and fault level calculation modules would remain unaffected by these changes. The modularity of Turbo PASCAL is a feature which was highlighted in the introduction.

6.3 A CIRCUIT BREAKER DISCRIMINATION PROGRAMME

Work is currently being carried out at an undergraduate level under the author's supervision on a programme to plot the time-current characteristics of low voltage moulded case circuit breakers (MCCB) on a computer screen. The purpose is to determine at a glance whether circuit breakers in a radial distribution system will provide proper discrimination in the event of an overload or short circuit fault.

Some work has been carried out by Siemens in West Germany in the area of moulded case circuit breaker discrimination, but as far as can be ascertained from published literature no work in this area has been directed at the use of a computer to store MCCB current time characteristics which could then be retrieved at will and plotted on a graph. If a number of MCCBs on one leg of a radial network could be plotted on the same scale on the same graph an immediate picture can be obtained about the selectivity between MCCBs.

6.4 A BILL OF QUANTITIES

There are a number of customised programmes written specifically for individual firms in South Africa which take the tedium out of the preparation of a bill of quantities. These programmes are stand alone and are not interfaced to engineering design programmes.

There are CAD packages on the market which have a section that interfaces with the drawings to produce a bill of quantities from the dimensions and materials detailed on the drawings.

Having developed the optimising cable installation programme, the illumination design programme and the circuit breaker discrimination programme, the logical step would be to incorporate a bill of quantities programme that could access the project files already created to draw up a bill of quantities for the electrical installation. This programme would necessarily have a word processing routine to allow for text input applicable to each individual project.

Further, a library of standard clauses could be generated and maintained for use in any project documentation.

CHAPTER SEVEN

CONCLUSION

At the recent 1986 SACAD Conference in Johannesburg a point that was raised about CAD/CAE software was that "the application is the priority around which CAD should be designed and not vice-versa." [1]. Computer Aided Design is a data orientated exercise and the data library rather than the drawings should therefore be regarded as the heart of the software. To achieve the best results with CAD; data, drawings, and design facilities should all be integrated.

Although this dissertation is not a CAD drawing programme but a design tool, the point raised at the Conference applicable to this programme. The software has in fact been designed around the database or library as it has been referred to in this dissertation. The author recognised at the start of the project that engineering design deals with large amounts of data and if a software programme is to assist in the design process then it must have a good communication with a data library. This requirement has been the heart of the software subsequently developed and has proved to be successful method of implementation.

Another very important aspect of software is the ease with which it can be operated. Computer software that guides the operator through each phase of the programme achieves the all important "user friendliness" that is necessary for the software to be of any benefit. The programme developed for this dissertation prompts the operator at every input stage and guides him on any errors or unexpected inputs that may have been generated.

The aim of the software developed for this dissertation was not only to reduce the time that the electrical consulting engineer spends on detailed design but also to improve the quality of the design. The ordered process of design data entry, the communication between data libraries and the automatic cable route detection built into the programme helps to achieve these aims. The accuracy of the design however still remains dependant on the accuracy of the input data. The savings in time obtained when usung this programme have not been well quantified. A trial period in practical use may prove or disprove the theory that this programme will benefit the engineer in practice.

The future work that can still be conducted in this area may lead to a product that will provide the design engineer with all the computer aids that he might need to produce accurate designs and good quality documentation in the most efficient manner.

1. "CAD/CAM Feature", Computech, Vol 2, No 9, September 1986.

APPENDIX A

A SURVEY OF ELECTRICAL CONSULTING ENGINEERING PRACTICES

The questionnaire in Table A-1 was sent to all the Consulting Engineering Practices which dealt with industrial and commercial building reticulation projects. A total of 64 questionnaires were sent out and 36 were returned. To keep the costs as low as possible without jeopardising the validity of the survey the questionnaires were only sent to the head offices of each of the practices as it was thought that the information required would not differ widely from office to office in one firm. It was thought that company policy would dictate how and when clients were invoiced for work completed on the project and thus it would not be necessary to test the opinion of the regional offices of the bigger firms.

The results of the survey are shown in Table A-2 and the results for the individual stages of the project are shown in Graphs A-1 to A-3.

PERCENT	DIVISION OF PROJECT TIME			DIVISION OF PROJECT INCOME		
	Concept	Design	Constr.	Concept	Design	Constr.
0				2		
5	5			3		
10	15			5		
15	5			3		
20	6	1	1	25		2
25	1	2				
30	4	6	6			
35		5	1			3
40		6	6		23	29
45		6	2			2
50		4	17		5	
55		2			1	
60		4	2		7	
65			1			
70						

TABLE A-2 Distribution of respondents over the three stages of a building project for the time spent on each stage and income received for each stage.

It should be noted that the time spent on each phase of the project is not directly proportional to the cost incurred in doing the work. For instance the cost of site supervision varies more directly with the distance of the site from the office. Further the smaller projects (less than R100 000,00) require almost as much work as larger projects in terms of time spent on the concept and detail design stages. The

1. In the three categories of a commercial or industrial project listed below, what amount of time as a percentage of the total time of the project would you normally spend on each stage? What amount of fee income as a percentage of the total project fee income is generally received at the completion of each stage?

1.1 Project concept stage: including preliminary estimates, preliminary design and drawings?

AMOUNT OF TIME ____ %   AMOUNT OF INCOME ____ %

1.2 Detail design stage: including preparation of tender documents and drawings, adjudication of tenders and awarding of the contract?

AMOUNT OF TIME ____ %   AMOUNT OF INCOME ____ %

1.3 Construction stage: including site meetings, construction problems, design changes without extra payment and general contract administration (payment certificates etc.)?

AMOUNT OF TIME ____ %   AMOUNT OF INCOME ____ %

2. Do you think that the efficiency of you business could be or has been improved by using CAD systems in cooperation with architects? YES/NO

3. Do you use any other software to assist you in the detail design of an electrical installation, such as lighting, cable sizing and bill of quantity programs either written in house or commercially developed packages? YES/NO

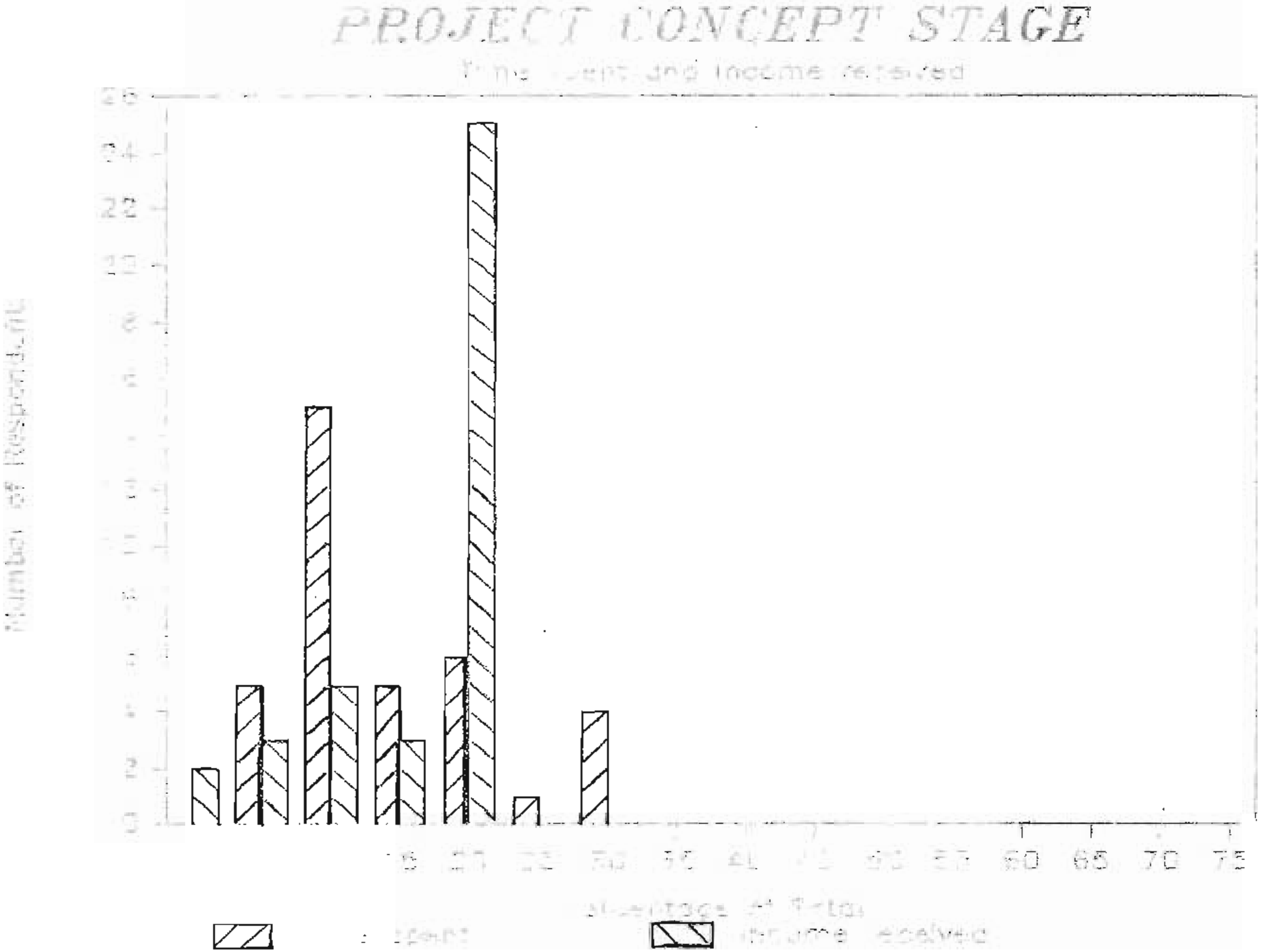
TABLE A-1 Questionnaire sent to electrical consulting engineering firms in South Africa.

survey was conducted to obtain a feel from the industry as to how the time expenditure was distributed over period of a project and how fee income related to this time expenditure.

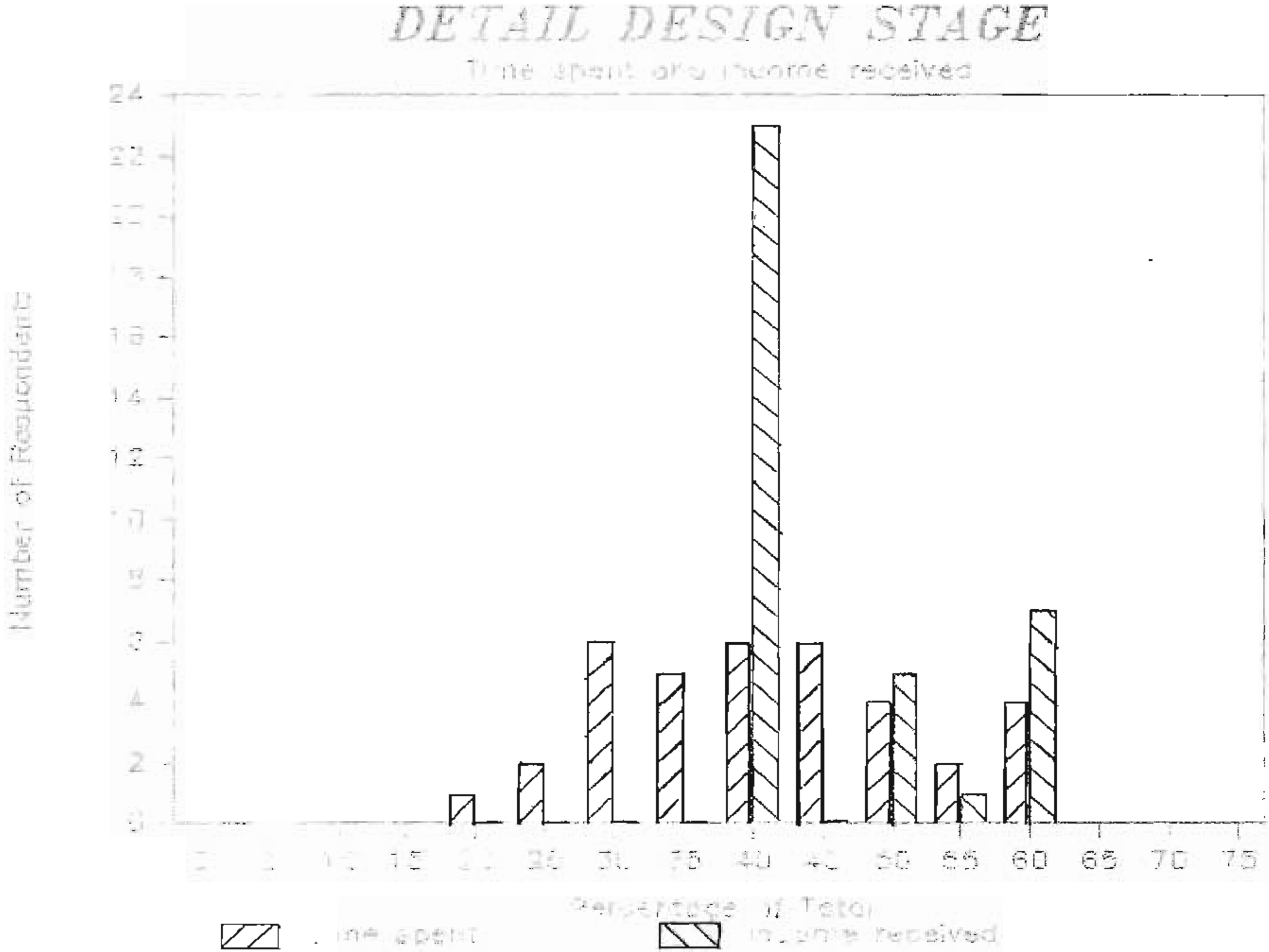
An analysis of the replies to question three of the questionnaire with respect to the amount of time spent on the detailed design stage compared with the amount of fee income received for the work done are summarised in Table A-3. There is sufficient evidence to indicate that the use of computers in the office has reduced the amount of time that is generally spent on the detail design stage compared with the percentage of the project fee income received for the detail design.

Answer to Q3	Percentage of respondents with % Time spent on design > % project income received
No	20%
Yes	7%
Answer to Q3	Percentage of respondents with % Time spent on design <= % project income received
No	7%
Yes	66%

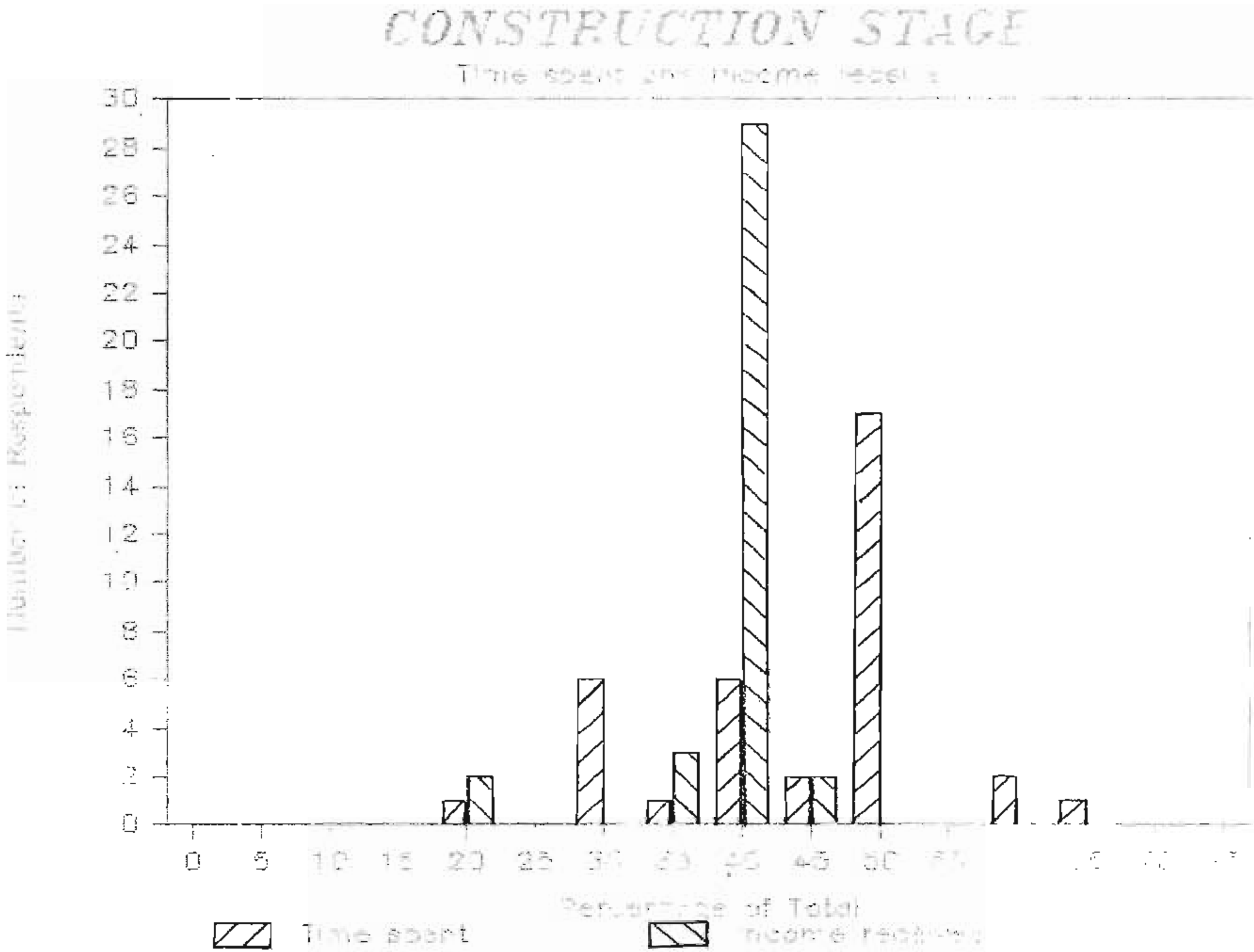
Table A-3 Analysis of Question Three with respect to Detail Design Stage



GRAPH A - 1 Bar chart showing the number of respondents on the verticle axis and on the horizontal the percentage of the total project time spent on concepts and the percentage of total income received for the conceptual stage.



GRAPH A - 2 Bar chart showing the number of respondents on the verticle axis and on the horizontal the percentage of the total project time spent on detail design and the percentage of total income received for the detail design stage.



GRAPH A - 3 Bar chart showing the number of respondents on the verticle axis and on the horizontal the percentage of the total project time spent on Construction supervision and the percentage of total income received for the Construction stage.

APPENDIX B

GENERAL CURSOR CONTROL AND DATA ENTRY PROCEDURES.

The standard data entry programme flow follows the pseudo-code in Figure B-1. The heart of the data entry is contained in the general procedures called from within the Modify Data procedure.

```
BEGIN
  Display current field values on the screen;
  Modify the field values;
  Redisplay modified field values;
END;
```

FIGURE B-1. Generalised data entry programme flow.

The Modify Data sequence is given in Figure B-2. This sequence of instructions is common to all the modify data procedures used in this dissertation. It is only the default values, field messages and structure of the input fields that vary from one screen to the next.

```
BEGIN      { Input field data }
  Display the field default values;
  Display the field prompt messages;
      Get field entries from keyboard using
        'Valid Functions';
  Redisplay the field value;
END;


BEGIN      { Modify data }
  Display the messages at the bottom of the screen;
  REPEAT
    Input field data;
    Adjust the cursor direction indicators;
  UNTIL data entry is complete.
END;
```

FIGURE B-2. Pseudo-code for Modify Data and Input Field programme sequences.

```
BEGIN
  REPEAT
    Read a character from the keyboard;
    If input is a control character then process it
    Else accept the valid character;
  UNTIL the field entry is complete;
  Clear the field window;
END;
```

FIGURE B-3. Pseudo-code for Get Field Input Procedure

The 'Valid Functions' used to enter the field data all use the 'Get Field Input' procedure which is shown in Figure B-3. The two procedures called from Get Field Input, Process Control Character and Accept Valid Character are explained below.

Control characters are processed in the procedure Process Control Character. This procedure has a case statement which checks whether the control character entered is any one of the valid control characters, backspace, carriage return, quit, up, down, left, right or clear. All other control characters will cause an audible tone to be sounded. The Accept Valid Character builds up an input string of the characters entered at the keyboard. The characters are first screened for validity before being added to the input string. For instance, the valid characters allowed in an integer number are '0' to '9' and '-', real numbers may have the same characters as well as '.' for the decimal point. Similarly the valid characters accepted by Valid String and Valid Character may be restricted by passing a set of characters which contains all the valid characters.

It is the input string built up in Get Field Input that is used by the Valid Functions in Figure B-4 and Figure B-5 to determine whether the input should be finally accepted by

```
BEGIN
  Set function to field default value;
  Get field input from keyboard;
  Set function to new input;
END;
```

FIGURE B-4. Pseudo-code for Function Valid Character and Function Valid String.

```
BEGIN
  Convert field default to numeric;
  Set function to default numeric;
  Get field input from keyboard;
  IF control character is Carriage Return AND input
       string > Ø THEN
   BEGIN
    Convert new input string to numeric;
    IF numeric is within limits THEN
      set function to numeric
    ELSE
     BEGIN
      Display error message: entry out of limits;
      Force field re-entry;
     END;
   END;
END;
```

FIGURE B-5. Pseudo-code for Function Valid Real and Function Valid Integer.

the programme. If the input string is not a valid string, character, integer or real then an error message is displayed giving the limits of a valid entry. Re-entry of the field is then forced. The only way to move out of a field is to enter the correct information or to use one of the cursor control keys, in the latter case any characters entered in the field will be lost (the exception here is if the control character is the carriage return key, which updates the field in memory before moving on to the next field).

The MS-DOS operating system has a rigid format for file names. The file name must start with a letter and can only be up to eight characters long. The 'Dot' extension associated with a file name can only be up to three characters long. A typical file name would be 'SIEMENS.CAT'. The extension is used for identifying the same type of files, such as the room dimension files which are grouped under the '.DAT' extension, the luminaire library files which are grouped under the '.CAT' extension. These extensions are concatenated, under programme control, with the file name entered by the operator. Thus to avoid ambiguity and run time errors the procedure Get File Spec, Figure B-6, is used to screen the file name entered from the keyboard. Get File Spec checks that the file name entered at the keyboard has the correct 'syntax'. The procedure then opens the file if it exists and prepares it for processing, or if the file does not exist a new file is created and prepared for processing.

```
Procedure Select a File;

  Procedure Get File Spec;
    REPEAT
      Display file input prompts;
      Get the Field Input; {i.e. the file name}
      Check that the file name is valid;
      IF file name valid concatenate the extension;
    UNTIL File name is OK or Escape key pressed;

BEGIN { Select A File }
  Get The File Specifier;
  IF the file name is valid THEN Open the File;
  IF the file does not exist THEN Make a new File;
END;
```

FIGURE B-6. Pseudo-code for the procedure Get File Specifier.

APPENDIX C

LUMINAIRE LIBRARY.

The luminaire record structure contains more detail than is necessary for the lumen method calculations. The additional data has been incorporated for use in future graphical presentation of results. The future provision of a graphical output showing the illuminance distribution will be in the interests of better human communication. The graphical output could not be included in this dissertation due to the extensive programming required.

The luminaire record structure detailed in Table C-1 is given in Pascal statement format as used in the programme code. The record occupies 284 bytes of memory. The coefficient of utilisation is stored in a 9 element array of real numbers as the coefficients are positive numbers less than one. The 9 elements of the array correspond to the room index values quoted in the photometric data. Similarly the average, lateral and longitudinal intensity figures are not integer numbers and therefore have to be stored as reals. These values are also contained in 9 element arrays corresponding to polar diagram angles from 0, 5 to 75 degrees in steps of 10 degrees.

```
TYPE
     FittingRec = RECORD
                    Luminaire          :  String[15];
                    Lamp               :  String[15];
                    LampPower          :  Real
                    SHmRatio           :  Real;
                    StartAmps          :  Real;
                    RunAmps            :  Real;
                    CoefUtilise        :  ARRAY[1..9] of Real;
                    AveIntensity       :  ARRAY[1..9] of Real;
                    LongtIntensity     :  ARRAY[1..9] of Real;
                    LatrlIntensity     :  ARRAY[1..9] of Real;
                    Cost               :  Real;
                    Lumens             :  Real;
                    NoLamps            :  Integer;
                  END;
```

TABLE C-1 The Luminaire Data Structure.

The data items StartAmps and RunAmps are corrected line currents obtained from the ballast manufacturer's documentation. Both running and starting currents are provided for the occasions when these two figures differ.

The starting current is used for calculating voltage drops for the larger lamps. The starting current figure will become useful in the future development of this package for determining the maximum number of luminaires that can be safely connected on one circuit, or alternatively giving the rating of the protective device and the size of conductor supplying the luminaire circuit.

The LampPower figure is the rated power in the lamp installed in the luminaire and is used for calculating the amount of lighting power installed in a room expressed in Watts per square meter. This figure is often used as a guide to the economy of the lighting design as it is closely related to the energy consumed. The Cost figure is the cost of the luminaire and is used to calculate the total capital cost of the luminaires in the design. This figure when used in conjunction with the watts consumed per meter of floor space provides a useful guide to the level of lighting achieved with respect to the project budget.

APPENDIX D

ROOM DIMENSION AND LIGHTING DESIGN LIBRARY.

The record structure of the room dimension library file is tabulated in Table D-1. The record occupies 128 bytes of memory.

```
TYPE
     RoomRecord = RECORD
                     RoomId            :  String[15];
                     Width             :  Real;
                     Length            :  Real;
                     WorkPlane         :  Real;
                     InstalHeight      :  Real;
                     Maintenance       :  Real;
                     ReqIllum          :  Real;
                     RoomLuminaire     :  String[15];
                     Catalog           :  String[10];
                     RoomLamp          :  String[15];
                     RoomIndex         :  Real;
                     NoLumiaires       :  Real;
                     MaxSpacing        :  Real;
                     InitLuminance     :  Real;
                     Load              :  Real;
                     CaptCost          :  Real;
                     Accept            :  Boolean;
                  END;
```

TABLE D-1 The Room Dimension Data Structure.

Each record is identified by the RoomId field, which is a 15 character string. The RoomId must be unique in any one file to avoid inconsistent results. The sequential search through the library will retrieve the first occurrence of the RoomId if there are duplicate Ids. The WorkPlane and InstalHeight fields refer to the height of the working plane and the height at which the luminaire is installed respectively. These heights are measured from final floor level. The mounting height referred to in the lumen method formula is the difference between the installation height and the working plane. These heights have been included to avoid misinterpretation of the meaning of 'mounting height' as applied to the formula.

The field Maintenance is the maintenance factor applicable to the dust conditions in the room. The ReqIllum field is the average illuminance required on the working plane. RoomLuminaire, Catalog and RoomLamp refer to the luminaire, manufacturer's catalogue file (on disc) and the lamp type. These fields are used to retrieve the luminaire photometrics from the luminaire library on disc file.

The number of luminaires, the maximum center to center spacing for uniform light distribution, the initial illuminance, the connected load of the lighting design and the capital cost of the luminaires are stored in the remaining fields of the record. The Accept field is used by the programme to keep track of those layouts that have been finally accepted and stored on disc.

APPENDIX E

LIGHTING PROGRAMME INPUT AND OUTPUT SCREENS.

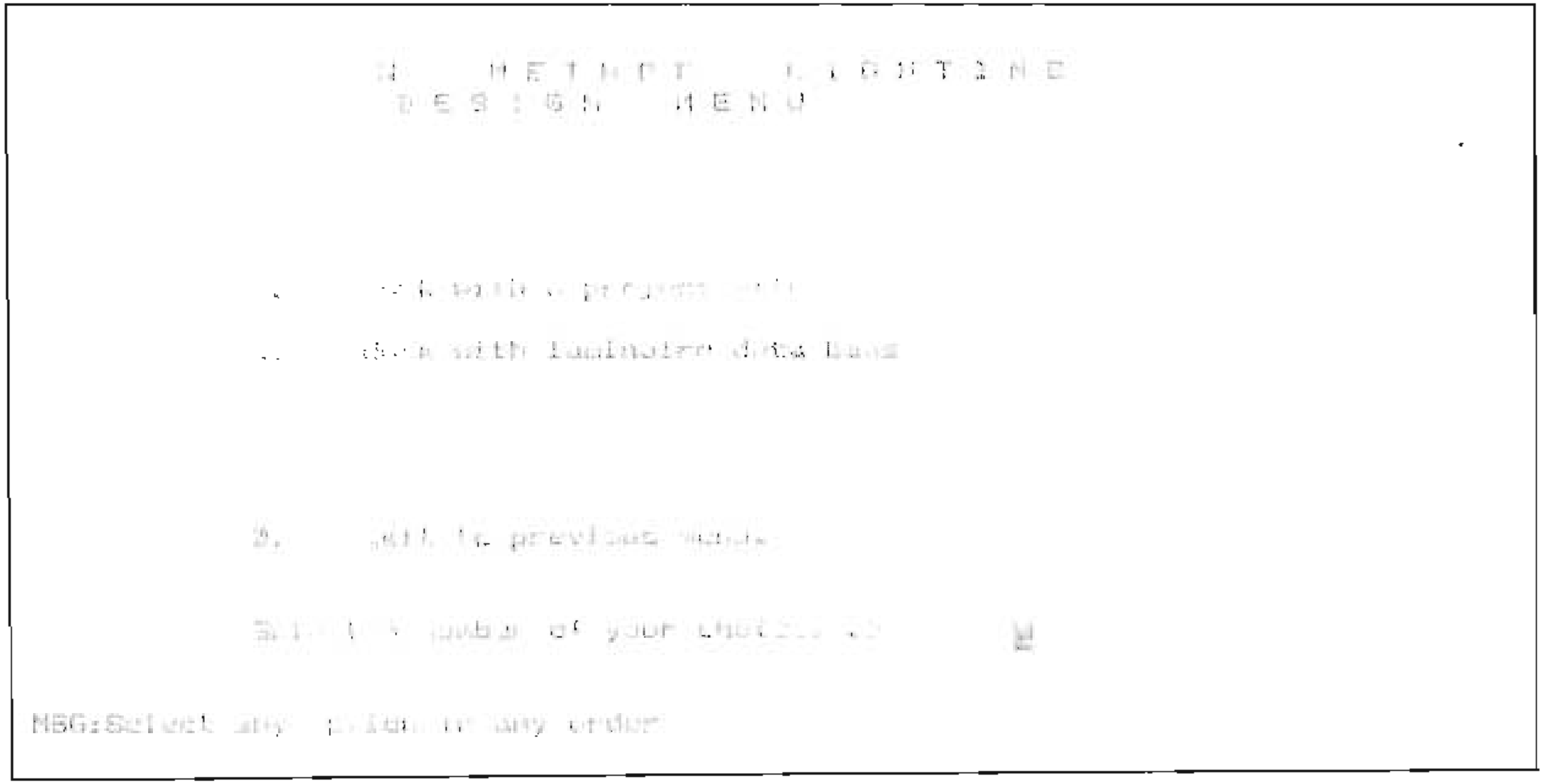


FIGURE E-1 The lighting design menu at the stage before a number has been selected.

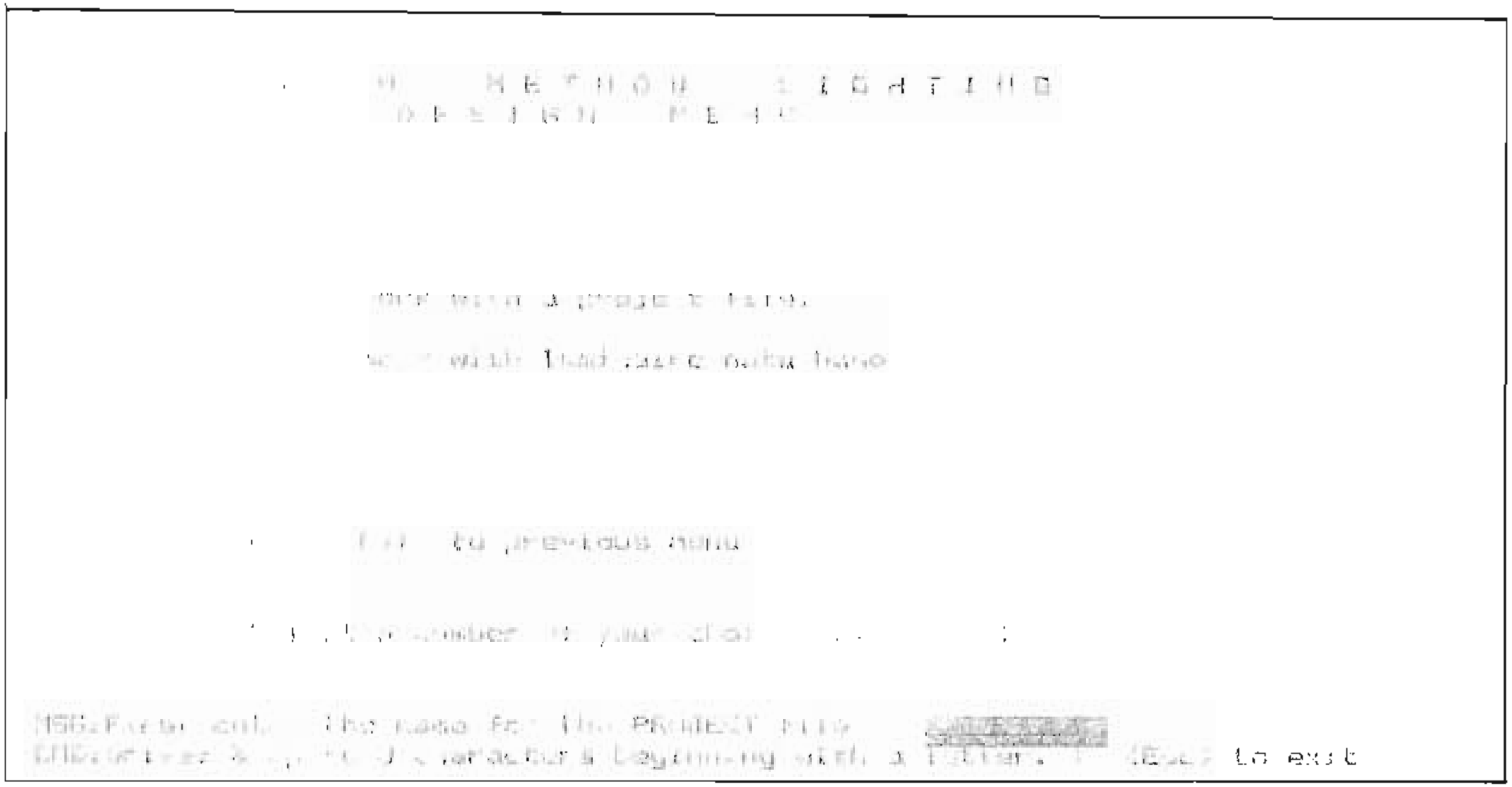


FIGURE E-2 The lighting design menu after the option one had been selected. The programme requests the name of the project file in which the room dimensions are stored.

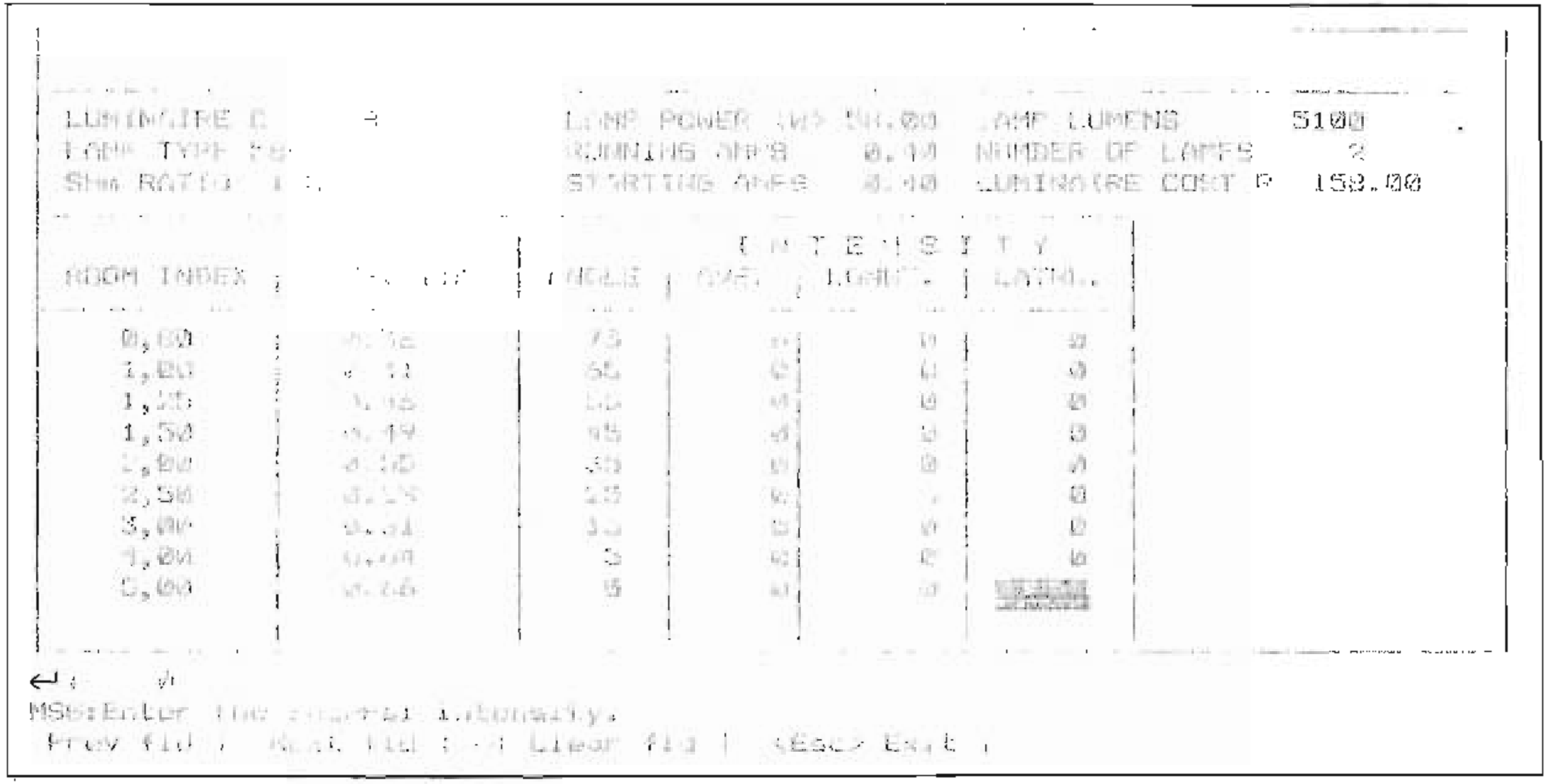


FIGURE E-3 An example of a luminaire record being entered into the library. The cursor is on the last field. When the carriage return key is pressed the programme will automatically store the record on disc.

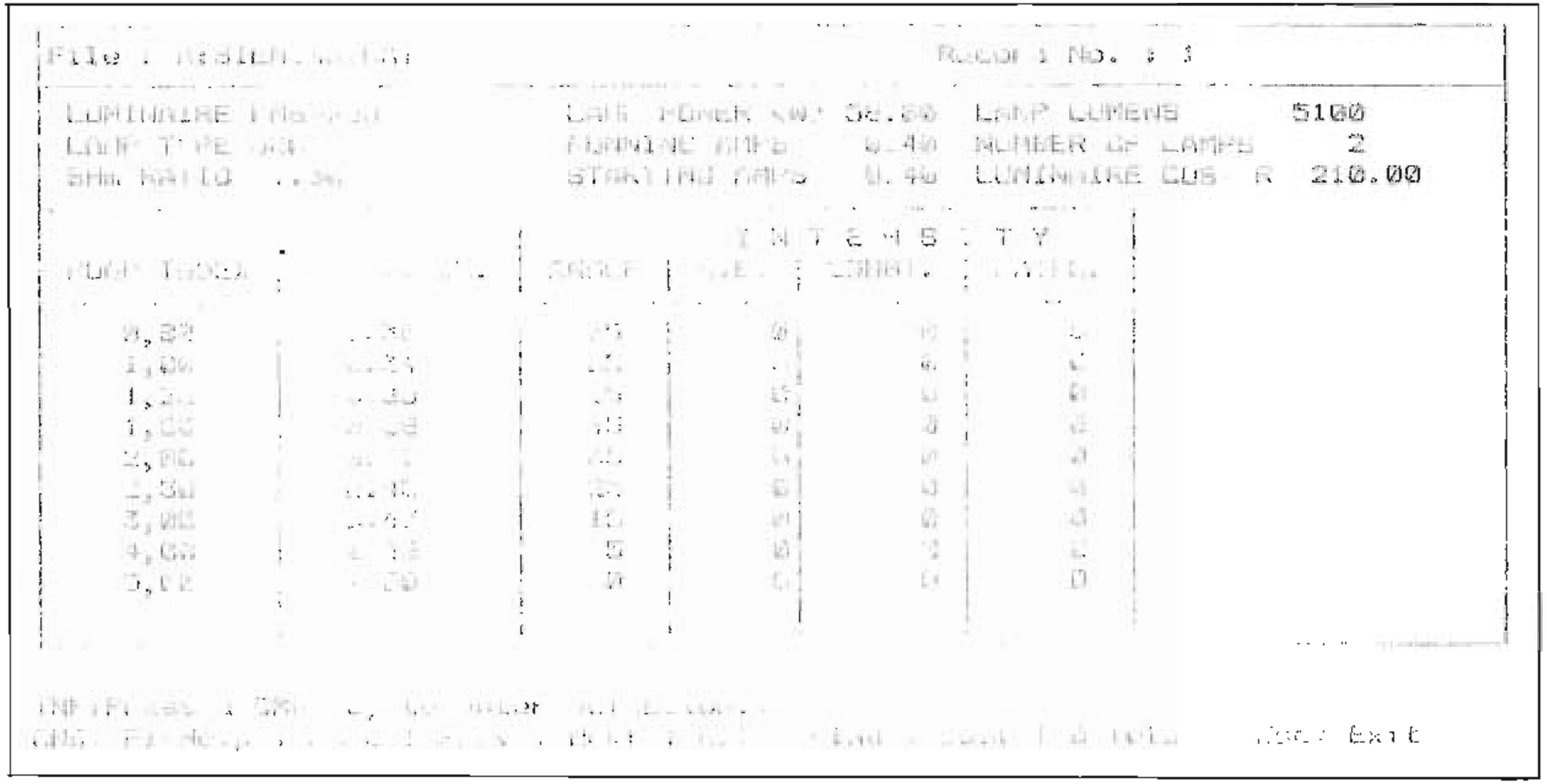


FIGURE E-4 An example of a luminaire record in the BROWSE mode. The CMD line shows what options are avilable in this mode.

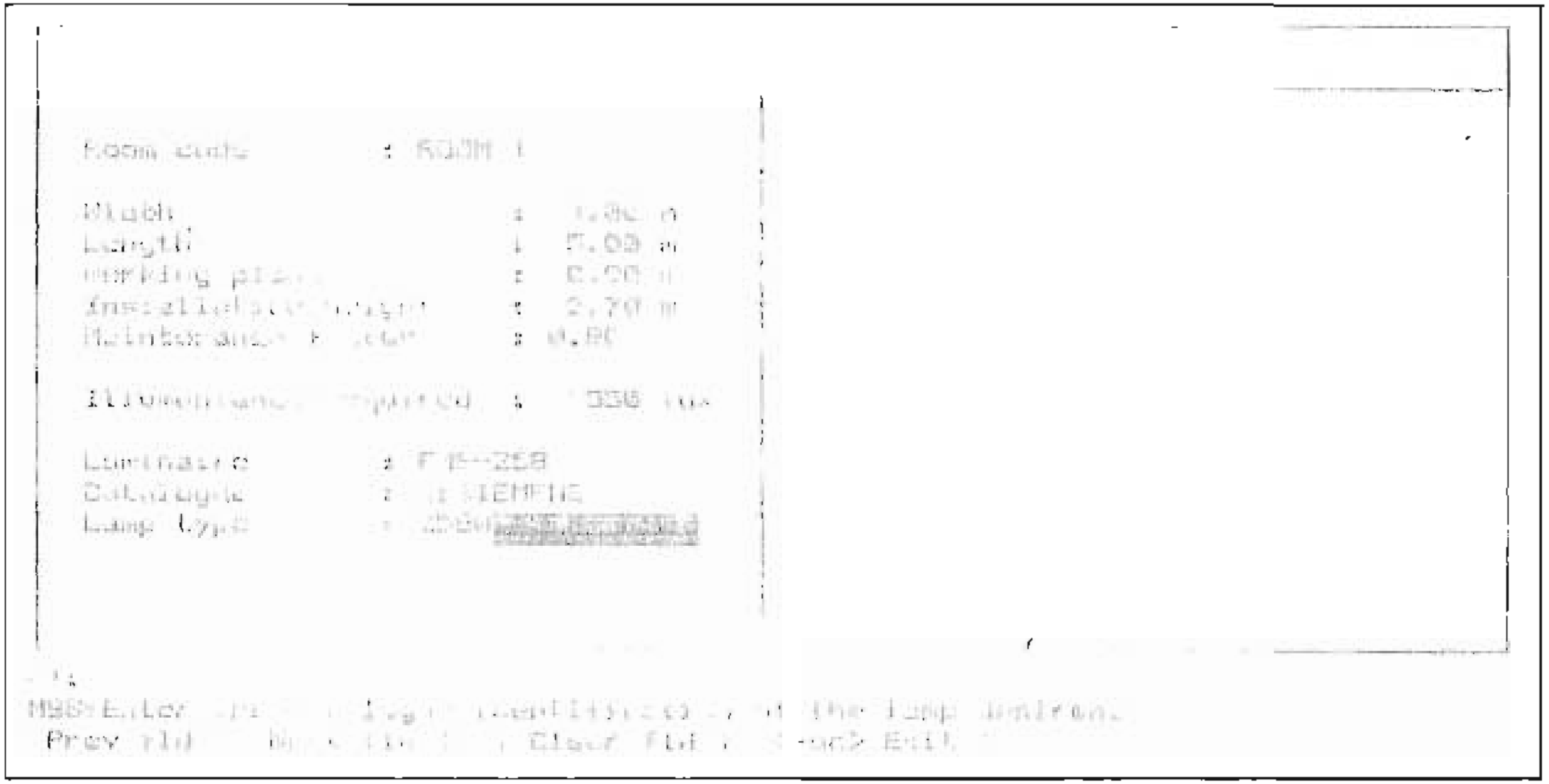


FIGURE E-5 The room dimension and luminaire specification input screen at a stage when all the necessary data has been entered. A carriage return key will cause the programme to calculate the number of luminaires required for the illuminance of 550 lux. The results of this calculation are shown in Figure E-6.

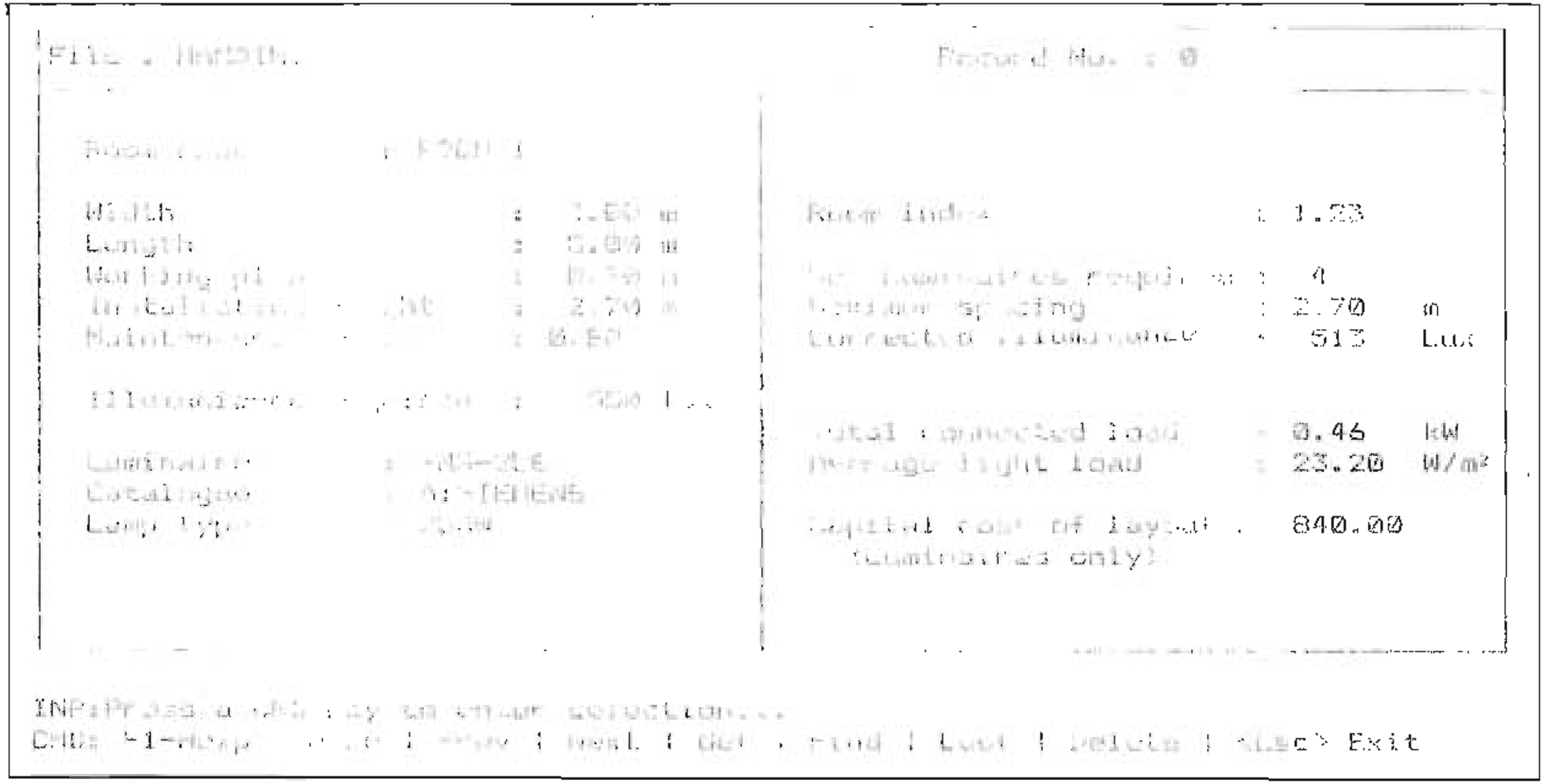


FIGURE E-6 The results of the calculations performed on the data entered in Figure E-5. This screen is in fact an example of the room dimensional records displayed in the BROWSE mode.

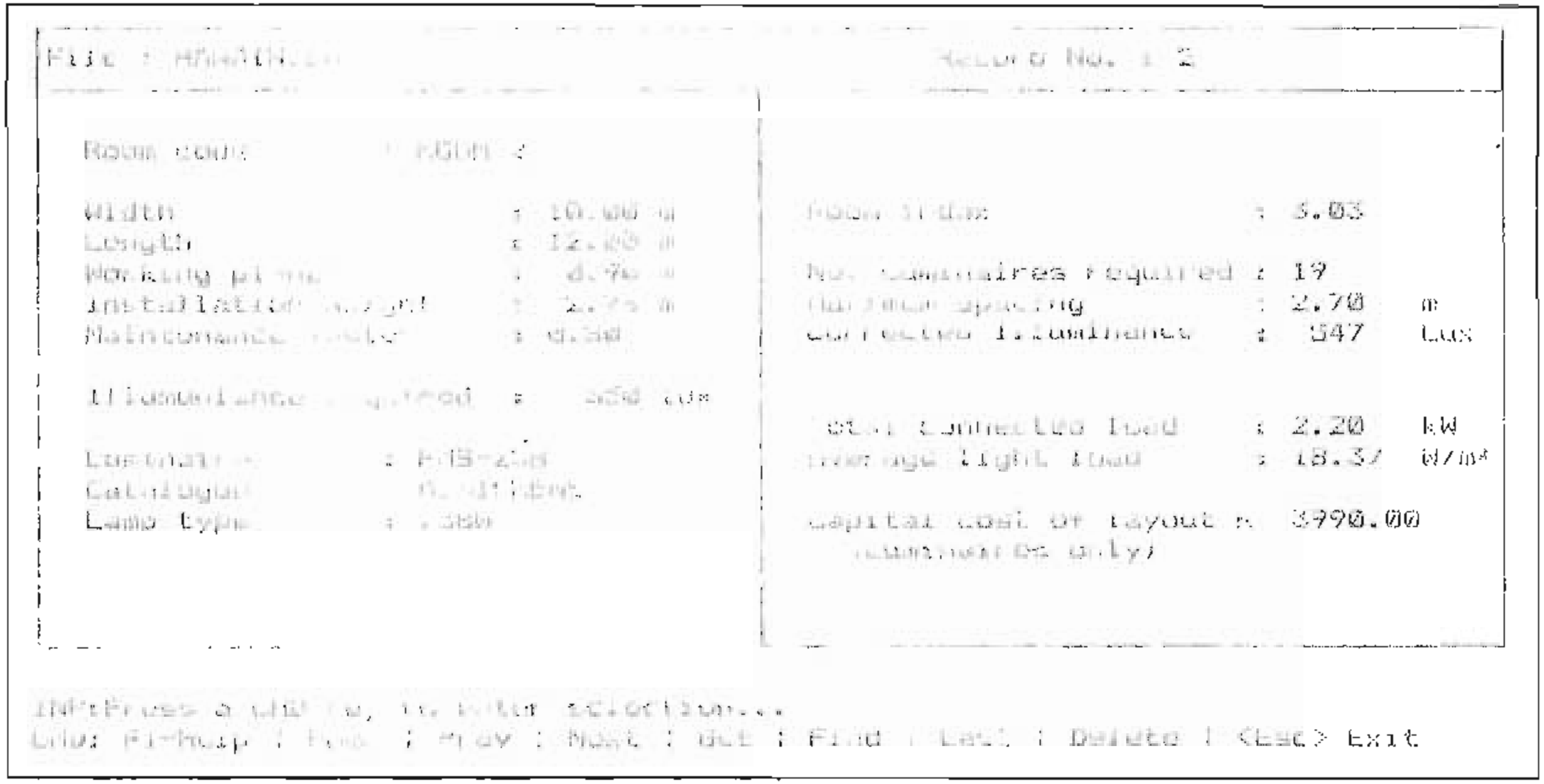


FIGURE E-7 The results of a lighting layout for a room of a larger size. The average light load per square meter has been reduced and the corrected illumination level is closer to the desired value.

```
[illegible]
[illegible] MENU

1. [illegible] a project file.
2. [illegible] with [illegible] data base.

0. [illegible] to previous menu.

Select [illegible] number of your choice...

21,00
20,48,001,N,A,You [illegible] select an option in any order.
```

FIGURE E-8 The text file containing the screen text and field parameters used to create the screen in Figure E-1. The numbers on the bottom line of the screen are the Y, X, Field length, Type of field (Numeric) and Type of field exit (Automatic). The field input prompt is the remaining text on the bottom line.

```
Room code         :

Width                        :          m
Length                       :          m
Working plane                :          m
Installation height          :          m
Maintenance factor           :

Illumuniance required        :          lux

Luminaire         :
Catalogue
Lamp type
```

```
10,02
22,05,015,T,M,Enter the identification of the room. Up to 15 characters.
29,07,005,N,M,Enter the width of the room in meters.
29,08,005,N,M,Enter the length of the room in meters.
29,09,005,N,M,Enter the height of the working surface above FFL in meters.
29,10,005,N,M,Enter the height of the luminaire above FFL in meters.
29,11,003,N,M,Enter the maintenance factor for the room ( 0 - 1 ).
29,13,005,N,M,Enter the illuminance level required in the room ( Lux ).
22,15,015,T,M,Enter the catalogue identification of the luminaire desired.
22,16,010,T,M,Enter the name of the catalogue file ( in B: drive ).
22,17,015,T,M,Enter the catalogue identification of the lamp desired.
```

FIGURE E-9 Another example of a text file used to create, in this case, the input screen shown in Figures E-5, E-6 and E-7.

APPENDIX F

CABLE SIZING PROGRAMME INPUT SCREENS.

The input screens shown in this appendix are those that are used for entering the data associated with each DB, e.g. lighting, socket and other circuit details. The Cross reference input screen is used by the programme to retrieve the poer requirements of previously stored luminaires.

The loads entered in the screens in this appendix are fictitious loads used for demonstration purposes. The result of the cable sizing performed on this data is given in the end of the appendix.

PROJECT [illegible] FIRE DRAWING CODE CROSS REFERENCE

Drawing code for luminaire	Manufacturer's catalogue file name	Luminaire catalogue number
[illegible]	SIEMENS	CCG-258
[illegible]	[illegible]	PMS-258

DB: TRFMR SUB-DISTRIBUTION BOARD FEEDERS RECORD No. 1

Destination Sub-DB name	Cable route length (Meters)	Single or three phase feeder
MDB	10.Ø	3

↵ :

MSG:Enter the destination distribution board identification.

Up ¦ Down ¦ Left ¦ Right ¦ ─¦ Clear fld ¦ <Esc> Exit & Save ¦

DB: TRFMRDETAILED CABLE SPECIFICATION (Installation conditions RECORD No. 1

Load end	Protection	Copper/ Aluminium	Cable type	Conditions of use	Group-spacing	Ambient Temp.° C	Conductor Size Min mm²	Max
MDB	Close	Copper	A/Multi	Defined	Spaced	30	2.5	300.0

↵ :Close

MSG:The over-current protection can be c(O)urse or c(L)ose.

Up ¦ Down ¦ Left ¦ Right ¦ ←¦ Clear fld ¦ <Esc> Exit & Save ¦

DB: NBB [illegible] standard wiring. RECORD No. 2

Type of Luminaire	[illegible] Location	Luminaires per circuit	Total circuit length <m>	Number of phases
1			20.0	3

MSG: Enter the [illegible] code used on drawings.

Up | Down | [illegible] Right | [illegible] Clear fld | <Esc> Exit & Save

DB: [illegible] [illegible] POINTS [illegible] standard wiring. RECORD No. 2

Type of outlet	[illegible]	No. Outlets per cct.	Outlet current	Circuit length	Load PF (CosØ)	Phases per outlet
850	[illegible]	2	0.5	[illegible]	Ø.8	1

[illegible] outlet point.

Up [illegible] Down [illegible] Right [illegible] Clear [illegible]

DB: MDB LOADS [illegible] CONFORMING TO 2.5 & [illegible] mm² standard wiring. RECORD No. 2

Type of load	Circuit No.	No. Loads per Ckt.	Load current	Starting factor	Cable length	Load PF (CosØ)	Phases per load
PUMP	[illegible]	1	[illegible]	[illegible]	[illegible]	0.8	3

< ! :
MSG: Enter the [illegible] for the type of load.
Up [illegible] Down [illegible] : Right [illegible] Clear fld [illegible] <Esc> Exit & Save [illegible]

DB: HDB DE[illegible] CABLE SPECIFICATION (Installation conditions) RECORD No. 2

Load End	Protec[illegible]	Copper/ Aluminium	Cable Type	Conditions of use	Group spacing	Ambient Temp. °C	Conductor Size Min mm²	Max
[illegible]	C [illegible]	[illegible]	[illegible]	[illegible]	spaced	30	[illegible].5	300.0

MSG: Overwr[illegible] ing HDB record 2 (Y/N) [illegible]
[illegible] ambient temperature in degrees C.
Up [illegible] Right [illegible] Exit & Save

DB: MED   SUB-DISTRIBUTION BOARD FEEDERS   RECORD No. 2

Destination name	Cable route length (meters)	Single or three phase feeder
A1	[illegible]	3
B1	[illegible]	3
[illegible]		

MSG: Enter [illegible] distribution [illegible] identification.

Up | Down [illegible] Right | | Clear [illegible] | <Esc> Exit & Save |

DB: MDB DETAILED CABLE SPECIFICATION (Installation conditions) RECORD No. 2

Load end	Protect. [illegible]	Copper/ Aluminium	Cable type	Conditions of use	Group spacing	Ambient temp. °C	Conductor Size mm² Min	Max
A1	[illegible]	Copper	[illegible]	[illegible]	Spaced	30	2.5	300.0
[illegible]	[illegible]	Copper	[illegible]	Defined	Spaced	30	2.5	300.0

MSG:Override [illegible] MDB record 2 (Y/N) ?

MSG:[illegible] [illegible]'s ambient temperature in degrees C.

Up [illegible] Down [illegible] Right [illegible] Clear [illegible] Esc: Exit & Save

DB: A1 LIGHT FITTINGS 2.5 mm² standard wiring. RECORD No. 3

Type of Luminaire	Circuit identification	Luminaires per circuit	Total circuit length (m)	Number of phases
1	L1	[illegible]	20.0	1
2	L2	12	25.0	1
1	L3	6	15.0	1
1	L4	8	18.0	1

MSG:Enter the luminaire code used on drawings.
Up | Down | Left | Right | | Clear fld | <Esc> Exit & Save |

[illegible] [illegible] [illegible] [illegible] POINTS [illegible] standard wiring. RECORD No. 3

Type of outlet	[illegible]	No. outlets per cct.	Outlet current	Circuit length	Load PF(CosØ)	Phases per outlet
[illegible]	[illegible]	3	[illegible]	[illegible]	0.8	1
[illegible]	[illegible]	[illegible]	[illegible]	23.6	[illegible]	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1

[illegible] the type of outlet point.

Up [illegible] Down [illegible] Right [illegible] Clear [illegible] Esc [illegible] & Save .

DB: A1 SUB-DISTRIBUTION BOARD FEEDERS RECORD No. 3

Destination sub-DB (name)	Cable route length (meters)	Single or three phase feeder
A2	24.0	3
A3	48.6	3

MSG: Enter the sub-distribution board identification.

Up | Down | Left | Right | -| Clear fld | <Esc> Exit & Save |

DB: n1 GENERAL CABLE SPECIFICATION (Installation Conditions) RECORD No. 3

Load ref	Protection	Copper/ Aluminium	Cable type	Conditions of use	Group-Spacing	Ambient Temp. °C	Conductor Size mm² Min	Max
n2	[illegible]	Copper	[illegible]	Defined	Spaced	30	2.5	300.0
n3	[illegible]	Copper	[illegible]	Defined	Spaced	30	2.5	300.0

MSG: Saving, Al

MSG: File [illegible]

Up [illegible] Down [illegible] Clear [illegible] Exit [illegible] Save

DB: 02   LIGHT FITTINGS   2.5 mm² standard wiring.   RECORD No. 4

Type of Luminaire	Circuit identification	Luminaires per circuit	Total circuit length (m)	Number of phases
1	L1		12.0	1

MSG:Enter the [illegible] code used on Drawings.

Up | Down [illegible] Right | ^Y Clear fld | Esc> Exit & Save

DB: [illegible] ... USER POINTS 1 and standard wiring. RECORD No. 4

Type of outlet	[illegible]	No.Outlets per c.t.	Outlet current	Circuit length	Load PF(Cosø)	Phases per outlet
S30	[illegible]	2	0.5	10.0	0.8	1

MSS:Enter the ... type ... outlet point.
Up ↑ Down ... Esc Exit & Save

DB: AC LOADS NOT CONFORMING TO 2.5 , 4 mm² standard wiring. RECORD No. 4

Type of load	Cir [illegible] id [illegible]	No.Loads per cct.	Load current	Starting factor	Cable length	Load PF(CosØ)	Phases per load
PUMP	P1	1	105.0	8.0	10.0	0.8	3
PUMP	P2	1	35.0	6.0	12.0	0.8	3

MSG:Enter [illegible] the type of load.
Up ↑ Down ↓ Left ← Right → Clear Fld , <Esc> Exit & Save

JOB: A2 REF: [illegible] CABLE SPECIFICATION (Installation conditions) RECORD No. 4

Load end	Protect. Cla.	Copper/ Aluminium	Cable Type	Conditions of Use	Group-Spacing	Ambient Temp. °C	Conductor Size Min mm²	Max
PUMP	Class	Copper	A/Multi	Rack	Spaced	30	1.5	300.0
PUMP	Class	Copper	A/Multi	Rack	Spaced	30	1.5	300.0

[illegible]
[illegible]
[illegible]

DB: [illegible] LOADS NOT CONFORMING TO [illegible] 4 mm standard wiring. RECORD No. 5

Type of load	[illegible]	No.Loads [illegible]	Load current	Starting factor	Cable length	Load PF(Cos∅)	Phases per load
PUMP	[illegible]	1	45.0	8.0	5.0	0.8	3

MSG:Enter the code for the type of load.

Up : Down : Left : Right : -- Clear fld : <Esc> Exit & Save :

Db: A3 DETAILED CABLE SPECIFICATION Installation conditions RECORD No. 5

Load end	Protection	Copper/Aluminium	Cable type	Conditions of use	Group-spacing	Ambient temp. °C	Conductor Size Min mm²	Max
PUMP	Fuse	Copper	[illegible]	Defined	Spaced	30	2.5	300.0

MSG: Save [illegible]
MSG: Enter [illegible] 's ambient temperature in degrees C.
Up [illegible] Right [illegible] Clear [illegible] Esc Exit & Save

DB: B1 [illegible] 2.5 mm² standard wiring RECORD No. 6

Type of Luminaire	Circuit identification	Luminaires per circuit	Total circuit length (m)	Number of phases
2	L1	12	35.0	1
2	L2	12	23.0	1
2	L3	7	25.0	1
2	L4	8	24.0	1

MSG: Enter the luminaire code used on drawings.
Up | Down | Left | Right | - Clear fld | <Esc> Exit & Save |

DB: B1 SUB[illegible] GENERAL POINTS [illegible] mm² standard wiring. RECORD No. 6

Type of outlet	[illegible]	No.Outlets per cct.	Outlet current	Circuit length	Load PF(Cosø)	Phases per outlet
SSO	[illegible]	2	[illegible]	32.0	0.8	1
SSL	[illegible]	2	[illegible]	23.0	0.8	1
[illegible]	[illegible]	4	[illegible]	[illegible]	0.8	1
SA[illegible]	[illegible]	1	[illegible]	15.8	0.8	1
[illegible]						

[illegible]

[illegible] the type of outlet [illegible]

Up [illegible] Down [illegible] Clear File [illegible] Exit & Save [illegible]

Project F[illegible] : [illegible]IN.RES, L.V. CABLE INSTALLATION

Cable Source	Route End	Current (A)	Cable to be installed No.	Size (mm²)	Length (m)	Volt Drop Volts	%	Fault Level kA
A1	[illegible]	[illegible]	1	50.0	23.0	1.27	0.6	4.6
MDB	A1	[illegible]	[illegible]	[illegible]0.0	73.[illegible]	2.[illegible]	1.20	5.6
A1	[illegible]	[illegible]	1	1[illegible].0	[illegible]	[illegible].92	[illegible].33	2.2
TRFMR	MDB	[illegible]	[illegible]	150.0	10.0	[illegible]	0.15	9.0
MDB	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible].43	1.0

INF:Press [illegible] to enter selection...
CMD: [illegible] Print results ; <Esc> Exit

APPENDIX G

CABLE SIZING PROGRAMME DATA STRUCTURES.

```
CableSpecType   =   RECORD
                      [illegible]
                      CableMaterial         :   CableMaterialType;
                      CableType             :   CableTypeOptions;
                      Conditions[illegible] :   PossibleConditions;
                      CableGrouping         :   GroupingTypes;
                      [illegible]
                      AmbientTemp           :   Integer;
                      MaxConductorSize,
                      MinConductorSize      :   Real;
                    END;
```

FIGURE G-1 The data structure for the detailed cable specification.

```
[illegible]         RECORD
                      [illegible]
                      [illegible]
                      [illegible]           :   Integer;
                      [illegible]           :   Real;
                      [illegible]           :   Integer;
                    END;
```

FIGURE G-2 The data structure for the light circuits.

```
SocketType      =   RECORD
                      [illegible]
                      [illegible]
                      [illegible]
                      OutletCurrent         :   Real;
                      OutletCctLength       :   Real;
                      [illegible]
                      [illegible]
                    END;
```

FIGURE G-3 The socket outlet circuit data structure.

[illegible]

FIGURE G-4 The data structure for the miscellaneous loads. Note that the detailed cable specification is nested in this record under the identifier: OtherCableSpecs.

[illegible]

FIGURE G-5 The data structure for the DB feeder circuits. As with the miscellaneous loads the detailed cable specification is nested in this record.

[illegible]

FIGURE G-6 All the above data structures are nested in this DB record. The nesting of all these data structures facilitates the storage of all the load data for a single DB in one record. The array of fourteen elements correcponds to the number of rows on each screen free for data entry. This is not a permanent restriction.

```
[illegible]
                    Integer;
                    Integer;
[illegible]
```

FIGURE G-7 The data structure for the cable sizes, voltage regulation drops and fault currents calculated for the network.

```
CrossRefType     =  RECORD
[illegible]
```

FIGURE G-8 The luminaire cross reference data structure.

APPENDIX H

THE MAIN MENU.

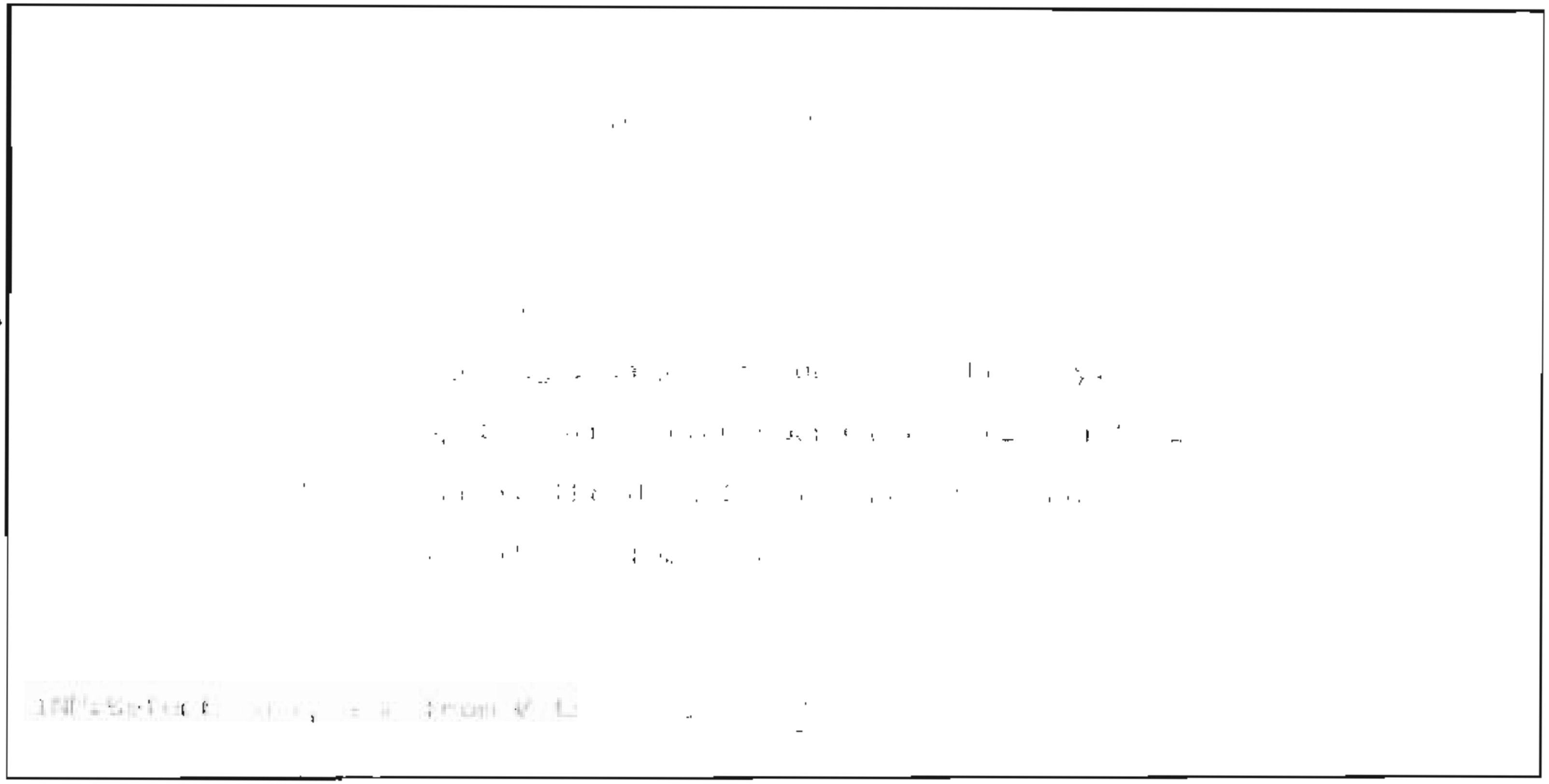


FIGURE H-1 The main menu screen that directs programme control to either of the four options.