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THE DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR  
ENERGY COST MANAGEMENT, USING AN EXPERT SYSTEM SHELL.

A CASE STUDY IN THE INTEGRATED USE OF SOFTWARE PACKAGES

Report presented by L J ROBERTSON

In fulfilment of the thesis requirements for  
the degree of;

Master of Technology (Computing Technology). 1989

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TABLE OF CONTENTS

- 1 ABSTRACT
  - 2 INTRODUCTION
  - 3 STANDARD PC SOFTWARE PACKAGES AS TOOLS FOR "REAL" PROBLEMS.  
User specifications for useful applications.  
Computer functions; building blocks for useful applications.  
Software tool packages; sets of computer functions.  
Applications requiring integrated use of more than one software tool package; selection of packages and strategy.
  - 4 ENERGY COST MANAGEMENT; AN APPLICATION FOR INTEGRATION OF STANDARD SOFTWARE TOOL FUNCTIONS  
Introduction to Energy Cost Management (ECM).  
ECM using an Lotus Symphony.  
Energy Cost Management using multiple software packages.
  - 5 DATABASE MANAGEMENT SUPPORT FOR ECM.  
DBMS support requirements.  
Data entry module.  
"Intelligent database" functions.
  - 6 DECISION SUPPORT SYSTEM DEVELOPMENT.  
Definition of overall aims.  
Development methods.  
High level ECM decision tool.  
MD control by load pattern adjustment.  
MD control by operation rescheduling.  
Prototype development problems and solutions.  
Testing and evaluation of final version.
  - 7 CONCLUSIONS.  
The value of integrated use of PC Software packages.  
Evaluation of the decision support and database support systems for ECM.
  - 8 REFERENCES AND ACKNOWLEDGEMENTS.
- APPENDIX A CURRENT ECM SPREADSHEET OUTPUTS  
APPENDIX B DATA USED IN DECISION SUPPORT SYSTEM  
APPENDIX C DECISION SUPPORT SYSTEM OPERATION  
APPENDIX D KNOWLEDGE BASE RULES & SOURCE CODE  
APPENDIX E VP EXPERT TIPS, TRICKS AND TRAPS  
APPENDIX F DATA DICTIONARY (PROPOSED DBMS)  
APPENDIX G DATA ENTRY MODULE SOURCE CODE  
APPENDIX H SPECIFICATION FOR FURTHER WORK  
APPENDIX I RESULTS OF KNOWLEDGE ACQUISITION EXERCISE;  
APPENDIX J SUPERSEDED KNOWLEDGE BASES

## 1 ABSTRACT

### 1.1 Key phrases:

Energy cost management;

Expert system;

Decision support system;

Integrated use of software products.

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### 1.2 Abstract

The theory of minimizing total energy usage is well known (if not well documented), and the techniques are widely practiced. Because of the way in which energy is sold, the total cost incurred may be affected even more strongly by the time-distribution of the energy usage, than by the total quantity used. A major subject of ECM is the MANAGEMENT of this time-distribution of energy usage, with the objective of minimizing of total energy costs to the user.

A software package (named ECMES, Energy Cost Management Expert System) has been developed using the Lotus Symphony integrated spreadsheet software package. The ECMES application consists (currently) of three modules offering analyses of several aspects of electrical energy cost management (plus three corresponding modules for gas costs, which are not considered further). The Symphony ECM application modules have been developed over the last few years, largely on a spare time basis, by Professor W Monteith of Massey University's Production Technology Department.

The analysis of Energy Cost Management on a PC is one which requires functions supplied by several standard software packages, particularly spreadsheet, graphics, database and expert system. The relatively recent availability of moderately priced and user-friendly expert system development packages has brought an additional set of powerful tools within the reach of the application developer. A Decision Support System (using an Expert System shell) has been developed, which is well integrated with the spreadsheet data, and with a database, to expand the functions of the original spreadsheet ECM analysis tool.

Theoretical work on the data requirements and the production rules has opened up possibilities for future work.

## 2 INTRODUCTION

The theory of minimizing total energy usage is well known (if not well documented), and the techniques are widely practiced. Because of the way in which energy is sold, the total cost incurred may be affected even more strongly by the time-distribution of the energy usage, than by the total quantity used. A major subject of ECM is the MANAGEMENT of this time-distribution of energy usage, with the objective of minimizing of total energy costs to the user.

A software package (named ECMES, Energy Cost Management Expert System) has been developed using the Lotus Symphony integrated spreadsheet product. The ECMES application consists (currently) of three modules offering analyses of several aspects of electrical energy cost management (plus three corresponding modules for gas costs, which are not considered further). The Symphony ECM application modules have been developed over the last few years, largely on a spare time basis, by Professor W Monteith of Massey University's Production Technology Department. It is a software package whose "time has come", appearing in a time when energy cost management is becoming recognised as of great commercial significance, and its study is developing into a recognised field. The Lotus Symphony software package used to develop the ECMES package offers a very powerful tool for data analysis of this type, combining "traditional" spreadsheet, file management, and word processing functions as well as a powerful macro "language", and good screen handling facilities.

The Symphony based ECM application was conceived from the beginning as one which would carry out many of the functions undertaken by an expert, and hence could be classed (in the most general sense of the phrase) as an "expert system". During 1988, however, it was recognised that there were opportunities for extending the usefulness of the package by integrating the spreadsheet package with a "conventional" expert system application.

Although the facilities offered by Symphony are sufficiently powerful to allow an expert system to be constructed, this was recognised to be an inefficient approach to providing these functions. The investigation of the software requirements, the specification and development of this expert system application, and the method of integration of the packages form the subjects of this thesis.

As is evident from the title, the thesis has two aspects; the general aspect of integrating the functions of several (standard) PC software tools, and the more specific aspect of providing a decision support application for the (Lotus Symphony based) Energy Cost Management package.

The thesis is structured so as to present the more general aspects of software integration first, proceed to an examination of Energy Cost Management (both as a subject, and then as a facility provided by the spreadsheet package), and finally to the development and integration of decision support system.

The decision support system developed is well integrated with both the Symphony-based Energy Cost Management application, and also with a database facility. Functions are provided which extend user understanding of the energy usage within their organisation, and allow detailed and highly interactive exploration of the effects of changing energy use patterns on total energy costs. In the course of the project, experience has been gained in the field of energy cost management generally, the theory and use of expert system shells, and the theory and practice of integrated use of software packages.

The Decision Support System developed is by no means a finished product, and specifications are suggested for future work.



### 3 STANDARD PC SOFTWARE PACKAGES AS TOOLS FOR "REAL" PROBLEMS.

#### CHAPTER SUMMARY

This section sets out to explore briefly the qualities and specifications which will allow a computer application to be of use to a user, the (primitive) software functions required for such applications, and the distribution of these functions among the standard software tool packages. The final part of this section explores the issues involved in developing applications requiring the functions of more than one software tool.

#### CHAPTER CONTENTS

- 3 STANDARD PC SOFTWARE PACKAGES AS TOOLS FOR "REAL" PROBLEMS.
- 3.1 USER SPECIFICATIONS FOR USEFUL APPLICATIONS
  - 3.1.1 Accept the data available.
  - 3.1.2 Perform the task(s) required.
  - 3.1.3 Perform tasks in the way required.
  - 3.1.4 Present the results in the way required.
- 3.2 COMPUTER FUNCTIONS; BUILDING BLOCKS FOR USEFUL APPLICATIONS
  - 3.2.1 Functions required.
    - 3.2.1.1 Data input and verification.
    - 3.2.1.2 Data storage and retrieval.
    - 3.2.1.3 Mathematical manipulation/processing.
    - 3.2.1.4 Program flow control.
    - 3.2.1.5 Presentation of results.
- 3.3 SOFTWARE TOOL PACKAGES; SETS OF COMPUTER FUNCTIONS
  - 3.3.1 General purpose programming languages.
  - 3.3.2 Database management systems (DBMS).
  - 3.3.3 Expert System.
  - 3.3.4 Spreadsheet.
  - 3.3.5 Word Processing.
- 3.4 APPLICATIONS REQUIRING INTEGRATED USE OF MORE THAN ONE SOFTWARE TOOL PACKAGE; SELECTION OF PACKAGES AND STRATEGY.
  - 3.4.1 Prospects for integration.
    - 3.4.1.1 Spreadsheet/Database.
    - 3.4.1.2 Spreadsheet with Expert System.
    - 3.4.1.3 Expert System (application) with Database.
    - 3.4.1.4 Word processing with Spreadsheet, and database.
  - 3.4.2 Methods of approaching integration.
    - 3.4.2.1 Select and use an integrated software product.
    - 3.4.2.2 Programming languages (3GL's).
    - 3.4.2.3 Use individual standard software packages.
  - 3.4.3 Integration of operation.
    - 3.4.3.1 "Automenu" (or equivalent).

- 3.4.3.2 Use of Microsoft "Windows", "Desqview", or "Software Carousel".
  - 3.4.3.3 Use of one of the application packages to control use of others.
  - 3.4.3.4 Use of a multitasking Operating system.
  - 3.4.4 Integration of data.
  - 3.4.5 Evaluation and selection of packages and approach method.
    - 3.4.5.1 Integration approach.
    - 3.4.5.2 Evaluation of packages.
    - 3.4.5.3 Assignment of functions.
- 

### 3.1 USER SPECIFICATIONS FOR USEFUL APPLICATIONS

#### 3.1.1 Accept the data available.

The application should not demand data until it is actually required. It should contain only an appropriate level of data validation, and should provide ample opportunity for reentry. Good facilities for review of data should be available.

#### 3.1.2 Perform the task(s) required.

The application developer needs to give much attention to the definition of the real TASK (in human terms, as opposed to computer terms) to be undertaken, making the very careful distinction between those required by the operator, and those required by the application. Note; from a marketing perspective, it is essential the a user be able to readily appreciate the task which the package offers. Software functions/capabilities must then be selected and integrated to offer the greatest facility to the PERSON undertaking the task. Very few real tasks can be completely accomplished by a computer - PEOPLE need to start and finish them, the computer is almost always a just a tool. As with any tool, it is quite possible for poor software to make the accomplishment of a task more onerous, or slower, rather than easier and quicker.

#### 3.1.3 Perform tasks in the way required.

Operations not directly and necessarily part of the user' real TASK form a distraction, and need to be eliminated if possible. More common forms of distraction include the need to refer to a large software manual (applications should be self-documenting), unclear commands and menu choices, and lack of flexibility available in sequencing of activities.

#### 3.1.4 Present the results in the way required.

It is undoubtedly easier to assimilate such information as trends and patterns from graphically presented data than from text; unfortunately, the facilities for inputting graphical information are neither as cheap, nor readily available as the means

for presenting graphical data. Text presentation is still necessary for cases where individual data items need to be input/output. Apart from the issue of graphics versus text, the ease with which a user can assimilate the data presented depends heavily on the quantity of data which is presented at any one time, and how it is presented (as well as how attention-focussing devices such as colour, blinking text etc are used). Good screen layout is essential.

## 3.2 COMPUTER FUNCTIONS; BUILDING BLOCKS FOR USEFUL APPLICATIONS

### 3.2.1 Functions required

#### 3.2.1.1 Data input and verification

Note; The most general interpretation of "data input (method)" is intended (ie, the inclusion of input obtained from keyboard, mouse, communications package, remote data acquisition devices, etc), as is the most general interpretation of "data" (ie keyboard characters as well ikon and menu item selections).

Data input functions required by true software applications vary greatly, but several classifications are important;

The importance of correctness:

Banking or medical data at one extreme, and "speculative" data such as is commonly used in spreadsheet applications, at the other extreme.

The volume of data:

Database applications, in contrast to expert system applications.

The domain and presentation of data:

Expert system input frequently require only selection from among a limited number of (menu) choices whereas the input of large quantities of real numbers or text may be necessary for a database application.

The mode of data entry

Batch or interactive.

The degree to which the software constrains and structures the sequence and format of data entry;

Spreadsheets and word processing packages impose very loose requirements on the sequence etc of data entry; database systems generally require the most severe constraints on the format of data entry, while Expert systems tend to impose restrictions particularly on the sequencing of data entry events.

#### 3.2.1.2 Data storage and retrieval

All but the most simple applications require to store and retrieve data; the questions to be answered relate to the quantity, the required speed of retrieval, and the formatting of the data.

#### 3.2.1.3 Mathematical manipulation/processing

Mathematical manipulation, in this context refers to any (batch) operation which takes numerical data as its input, and produces numerical output without any further intervention by the operator. This definition therefore includes such operations as fourier analysis, matrix operations, solution of differential equations, finding of roots, curve fitting etc, as well as the more simple "calculator" functions.

#### 3.2.1.4 Program flow control (decision making, menu selection etc)

The modern tendency is to allow program flow to be controlled by the use of pull-down menus, mouse and icons systems etc. Good guidelines for the selection and design of menu items etc exist: Each menu should have (in the same position) the means for returning to the previous menu and to the main menu, the menu choices should be unambiguous, and the default item (or the initial cursor position) should be chosen with care.

#### 3.2.1.5 Presentation of results

Key aspects are the use of some technique to focus attention on the critical items (either by the use of colour, "windows" or careful screen design), and simultaneously present sufficient related "peripheral" or "background" data. Graphical presentation of data is undoubtedly effective, however two factors need to be taken into account;

firstly, if the application is interactive, at some stage data will have to be read from the graph, which is often not easy, and secondly, modified data will have to be reentered, and graphical input equipment such as digitising tablets are neither readily, widely, nor cheaply available.

The presentation of non-graphical data is therefore important, and a combination of graphical and numeric data is probably the ideal.

### 3.3 SOFTWARE TOOL PACKAGES; SETS OF COMPUTER FUNCTIONS: (An examination of theory of operation of software packages).

One of the key points to note from the following is the extent of overlap between the functions offered by the various common PC software tools. The extent of overlap is illustrated in Figure 1.

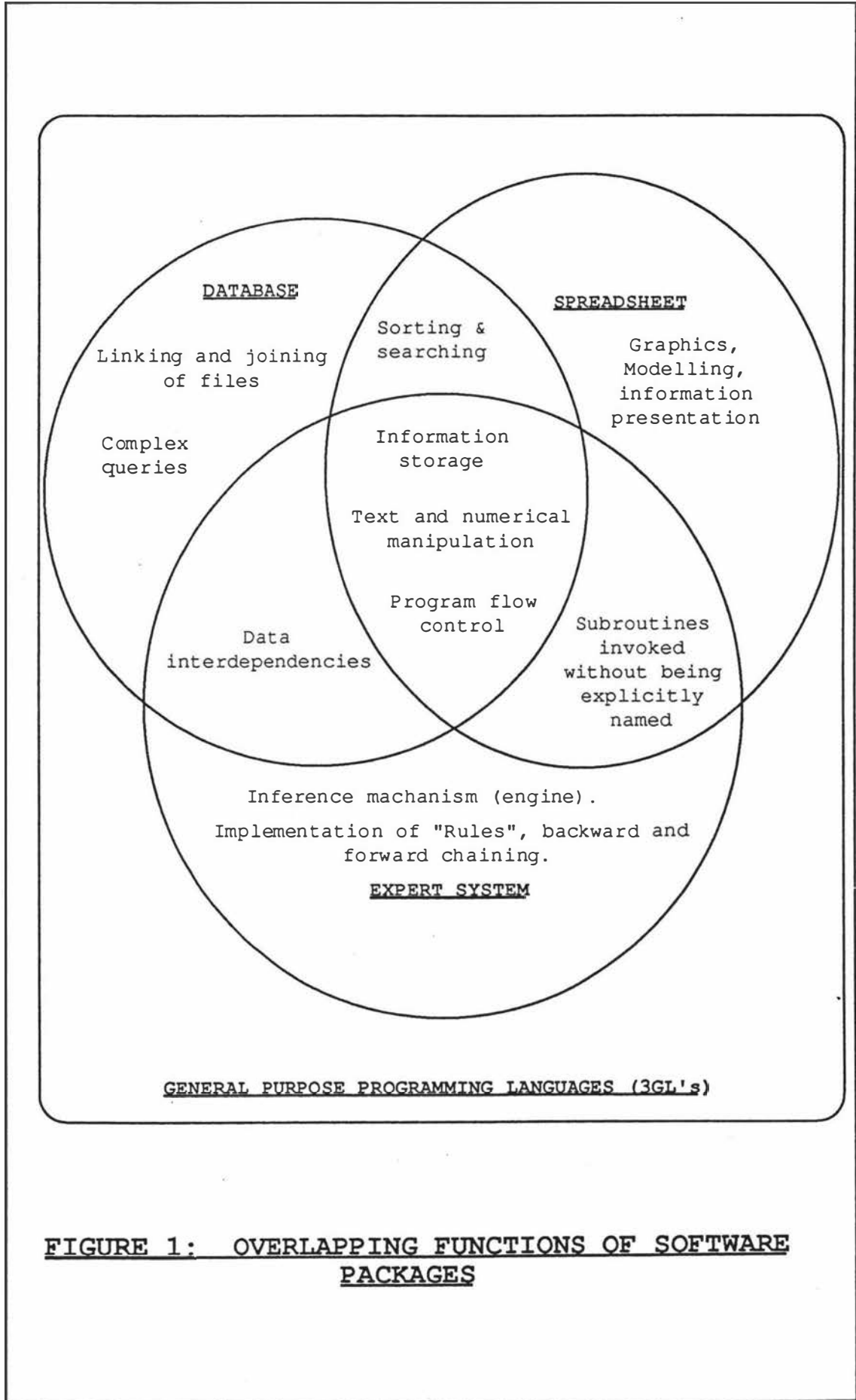
Almost all of the tools with rudimentary programming facilities can emulate the functions of the other tools. For example, it is quite possible to construct an expert system application using a database language such as Ashton Tate's "dBase", though it is almost certainly more difficult than by using an expert system shell. It is likewise possible to create an expert system application using the macro programming languages of the more advanced spreadsheets.

#### 3.3.1 Programming languages (3GL).

The general purpose programming language is undoubtedly the most versatile of the PC software tools, but it is also one of the tools offering the lowest programmer productivity. The majority of software tool packages are originally compiled from such languages.

#### 3.3.2 Database management systems (DBMS),

The essential facility of a file management application is the storage and retrieval of data. To qualify for the title of database management system, an application needs to add to the capabilities of a file manager, facilities for manipulating, associating and linking data from several files at once. Database management systems have been subjected to much theoretical analysis; Most PC based database packages are based on E Codd's relational data model [9]. Although DBMS's are somewhat more specialized than a general purpose programming language, many DBMS packages include excellent high level programming languages designed to allow advantage to be taken of the efficient file access facilities. Ashton Tate's "dBase" DBMS's provide a good examples of these qualities.



**FIGURE 1: OVERLAPPING FUNCTIONS OF SOFTWARE PACKAGES**

### 3.3.3 Expert System

"Expert systems" commonly comprise an "inference engine" which operates on specialized data stored in a "knowledge base". The expert system "inference engine" treats the knowledge base "rules" as a special type of subroutine (procedure) which is "result-addressable" that is, a subroutine which is invoked (called, addressed) when the result it produces is specified. By contrast, in a conventional programming language (such as Pascal), procedures are "name-addressable", that is, they are called when the name of the procedure is specified.

Note this distinction; in PASCAL (for example), a procedure is addressed by referring to its NAME (irrespective of the contents/results of the procedure). For example, should the main program contain the code

```
begin
    CalculateOutput
end;
```

the pascal program will recognise "CalculateOutput" as the name of a procedure or function, and will then find and execute "Procedure CalculateOutput", or "Function CalculateOutput". In the inference engine of a backward chaining expert system, the "procedures" (RULES) are addressed not by their names, but rather by specifying a variable which is found in their results section; For example, when VP Expert encounters the "Find XXX" in the following code, it looks for a rule which has "XXX =" in its conclusion (the section following its "then" statement); that is, a rule which if passed, will produce a value for XXX. In this case such a search locates "Rule 1". "Rule 1" however requires the fulfilment of two conditions (b= 2, and c= 3) in order to "pass", and only the value of "c" is known. VP Expert therefore seeks a further rule containing "b=" in its conclusion, leading to the evaluation of "Rule 2". If "y" is found to be equal to 5, then "Rule 2" "passes", "b" is assigned the value 2, "Rule 1" "passes", and the value "something" is assigned to "XXX".

```
c= 3
Find XXX;

Rule 1
    if    b= 2 AND c= 3
    then  XXX = "something";

Rule 2
    if    yyy = 5
    then  b = 2;
```

There is also a very strong theoretical similarity between the concept of "rules", as used by expert



systems knowledge bases, and the concept of functional dependency (of non-key attributes on key attributes) within a tuple of a (relational) database. This connection has been well recognised by the designers of such expert system shells as VP Expert, which provides a specific command (INDUCE) to create a set of rules directly from a database. Unfortunately, most PC database implementations provide very poor (if any) support for "keys", necessitating careful use of this command.

Detailed information on the theory and operation of expert systems can be found in Levine and Drang [1], and Frenzel [6].

### 3.3.4 Spreadsheet

General programming languages, their slightly more specialized variants, databases, and the even more specialized expert system shells have all been subjected to a great deal of theoretical investigation. The spreadsheet, by contrast, provides a very complex programming environment, but has apparently been subjected to minimal formal investigation. Unlike all of the other software packages which originated on mainframe computers and were ported to PC's, the spreadsheet originated as a PC tool, and is primarily still a PC tool (mainframe versions do, of course, exist). The scarcity of formal investigation also means a scarcity of formal definition of spreadsheet functions; observation shows a common core of functions consisting of;

- A fixed-size array of data elements, designed to be held entirely in memory;

- Means of identifying and manipulating specific sections of this array (cells, ranges, windows, "databases"),

- A set of utility functions (usually available via pull-down menus) allowing the user to manipulate (move, copy, delete etc) either the array as a whole, or sections of it.

- A "programming language" allowing two types of functions;

- a/ The definition of a numerical relationship between one element of the array and any number of others, by simply defining the relationship formula, and attaching this to the "target" element array, and

- b/ The ability to store, and execute automatically, sequences of the utility functions, (as "macros").

- A powerful means of presenting results, both graphically, and by a built-in windowing facility, allowing the user to "browse" the length and width of the array at any time.

The limitations of the spreadsheet are; Firstly, the fact that it is memory based means that the total quantity of data which can be held is limited; the spreadsheet is definitely a fixed size array - maybe large, but definitely fixed. Secondly, while the "macro" languages undoubtedly contain the major functions offered by general purpose programming languages, they are interpreted languages, limiting their speed, and (more importantly), being constructed as a sequence of keystrokes (related to the pull-down menu selections, they are notoriously difficult to debug and maintain.

While the functions available are generally sufficiently powerful to offer the major functions of a programming language, the real strength of the spreadsheet lies in the area of data presentation, rather than data processing; The "browsing" facilities, the availability of windows and graphics functions, and the ability to observe the effect of changing data in one cell on the values of all linked cells, offers a degree of user interaction unparalleled by other software tools.

In the absence (or at least ignorance) of any formal theory of spreadsheet operation and programming, these were investigated very briefly as part of this project. It was found that the essential aspect of spreadsheet operation was that, whereas a general purpose programming language has "name-addressed" subroutines/procedures, and expert systems have "result-addressed" subroutines, the spreadsheet has "universally addressed", or "unconditionally addressed" subroutines. That is, every time a data item is entered to a spreadsheet, ALL subroutines (cell formulae) are (re)evaluated. This principle can be alternatively stated as; subroutines in a programming language are activated whenever their NAME is invoked, expert system rules are activated whenever their RESULTS are invoked, but spreadsheet cell formulae are invoked UNCONDITIONALLY whenever any data is entered.

### 3.3.5 Word Processing,

The word processing application is the most specialized of the applications presented, and the only one which is not a development tool (some WP's do allow macros for various operations to be set up, but these are very limited in scope).

### 3.4 APPLICATIONS REQUIRING INTEGRATED USE OF MORE THAN ONE SOFTWARE TOOL PACKAGE; SELECTION OF PACKAGES AND STRATEGY.

#### 3.4.1 Prospects for integration.

Note 1; this section is intended to examine the prospects from the user's view, rather than the availability of tools/techniques.

Note 2; The possibilities for integration with other packages, and especially graphics and communications packages has not been addressed here; In the case of the communications packages, this is because from a users point of view, they are primarily an alternative means of data entry, and as such should theoretically need be no more than another single command option within an application. In the case of graphics packages, the functions offered are far from standardized, varying between packages which are simplified CAD applications, and such things as graphics toolboxes supplied with 3GL programming languages. The latter could definitely be used to advantage in the case of an application developed using (eg) TurboPascal.

Note 3; most software packages have facilities for "calling" other packages/batch programs, so if the only capability lacking in a proposed package is (for example) a particular mathematical function, the easiest route may be to develop this in a 3GL programming language, and call the resulting .EXE file when required.

##### 3.4.1.1 Spreadsheet/Database

As has been noted in section 3.3.4 above, the strength of the spreadsheet lies in its ability to present data; one of its weaknesses is that, being memory based, and of a fixed size, the quantity of data which can be stored is limited. This weakness suggests the possibility of combining the data storage and retrieval capabilities of a database with the data presentation strengths of the spreadsheet. Spreadsheets generally have few built-in security features (the ability to carry out "what-if" exercises to explore the effect of modifying data is counted as one of the spreadsheet's strengths); however unless very carefully controlled, this facility can result in a user losing all record of what data is historically correct, and what data is the result of hypotheses. In an application where this situation is a possibility, a database could be used to maintain an "authorized version" of the data, available for reloading to the spreadsheet as required.

#### 3.4.1.2 Spreadsheet with Expert System (application)

There is a degree of overlap between the applications for which a spreadsheet would be the obvious choice, and those for which an expert system shell would come to mind; both are used for exploring hypotheses, the spreadsheet being more suitable for cases where the rules are simpler, and the quantity of data is larger, whereas expert systems are preferred where the quantity of data is smaller, and the rules are more complex. Cases where part of an application leans toward the expert system territory, and other parts of the application lean towards the spreadsheet, are common. One such application forms the main subject of this thesis.

#### 3.4.1.3 Expert System (application) with Database

The theoretical bases for database design (and particularly relational database design) have been well established, however all too frequently the result of a rigorous modelling and normalizing exercise is a somewhat "fragmented" data structure consisting of a large number of files, requiring a large quantity of data to correctly and fully describe the application. The practical problem which then arises is that of deciding whether the combination of the data capture effort, plus the effort and time required to develop and apply equally an equally rigorous data analysis, is practical at all (and whether it is justified by the value of the application).

Two opportunities for integration of these types of package have been identified. Firstly, the possibility of using an expert system application as an "intelligent interface" to a database exists. Secondly, the similarity between database design theory, and the theory of expert system rules (see section 3.3.3) could be exploited to allow inference of expert system rules directly from database files (and, by returning information to the database, allow the construction of an application which "learns").

#### 3.4.1.4 Word processing with Spreadsheet, and database

The allowable length of string variables, size of database fields, and size of spreadsheet cells (with the exceptions, such as Symphony) set by other packages often place severe limitations on the quantity of text which can be stored, so the ability to integrate a word processor with other packages is very desirable.

### 3.4.2 Methods of approaching integration

#### 3.4.2.1 Select and use an integrated software product

Integrated software products, such as Lotus Symphony, IBM's Goldengate (which has the added feature of communication facilities to some mainframe applications), and the budget priced PFS "First

Choice", attempt to provide several functions in one fully integrated package; typically these functions include the normal spreadsheet functions, plus a fairly good file management system, and a limited word processing facility. Communication facilities are also frequently included. The main advantage of such packages is that the integration (both of data and operation) is already done. The disadvantages lie in the spreadsheet origins of the packages; the "database" facilities are memory resident, limiting their capacity, and the "programming language" is spreadsheet macros which, while powerful, are difficult to maintain. A further problem is that although these packages are "integrated", the features concerned are built-in; if the features required for the proposed integrated application are all available, there is no problem; if they are not, then the developer is little better off than with single-function packages.

A description of the facilities offered by Lotus Symphony can be found in "The Symphony Reference Book" [3]; information on macro development and use can be found in "the Lotus Magazine" [7], and more technical detail regarding file formats etc can be found in "Lotus File Formats" [8].

#### 3.4.2.2 Programming language (3GL's) "toolboxes".

Some of the more popular programming languages (3GL's) have an extensive library of application modules available; a good example is Borland's Turbo Pascal, which is sold with the source code of a simple spreadsheet included in the purchase price, and for which "numerical methods", "database", and "graphics" toolboxes (with source code) are readily available. For a programmer familiar with TurboPascal, assembling and linking such modules to provide an application which offers some of the facilities of a database and a sophisticated spreadsheet would be quite possible, and would provide a "tidy" package for marketing purposes (ie, with few DOS files, no licencing problems, and installation procedures already supplied).

#### 3.4.2.3 Use individual standard software packages.

The final option is to make use of several standard software packages, and to use each according to its particular strengths (as opposed to capabilities).

Note; an important variant of this option is to use a set of individual packages (typically from the one supplier), which are specifically designed to work together. An example of this approach can be found in the VP Info, VP Planner, and VP Expert packages, all supplied by "Paperback software". These packages allow (for example) the operation of the VP Planner spreadsheet from within a VP Expert application.

### 3.4.3 Integration of operation

#### 3.4.3.1 "Automenu" (or equivalent): See Figure 2A.

The "Automenu" package allows the construction of a customised menu system, from which application packages can be selected and run with a minimum of keystrokes. The "Automenu" package is available either commercially or as public domain software.

"Flashup" is similar in operation to "Automenu", but possibly even faster and simpler.

#### 3.4.3.2 Use of Microsoft "Windows", "Desqview", or "Software Carousel" (all about \$200 - \$300); See Figure 2B.

These products allow a number of applications to be displayed simultaneously within different "windows"; only one product is actually "active" at any one time, but the switching between products is simple, and the ability to retain the results of activity on one application, while operating on another is very valuable. Several of these products support (varying degrees of) data exchange between the applications being displayed.

#### 3.4.3.3 Use of one of the application packages to control use of others (via internal menu system, and DOS calls; See Figure 2C.

The limitation of this method is that the chosen application remains in loaded in memory; if the chosen package is large, little memory space remains into which further packages can be loaded).

#### 3.4.3.4 Use of a true multitasking Operating System. Possible choices (for a PC) include XENIX (or other proprietary UNIX implementation), OS/2 or Concurrent CP/M 386.

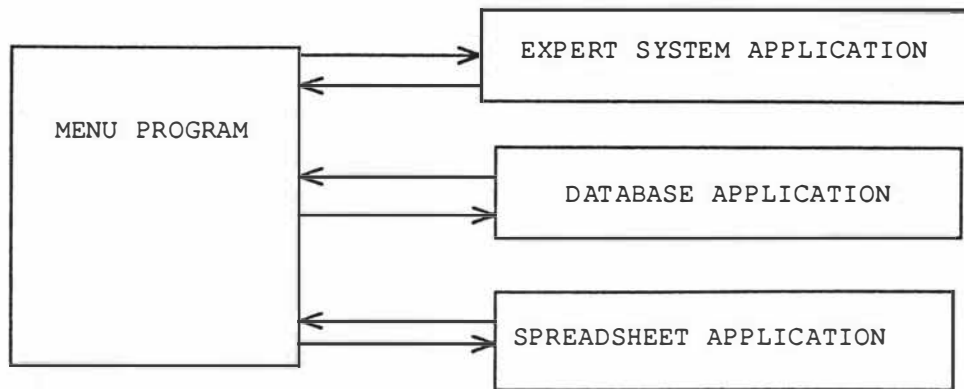


FIGURE 2A: Use of "AUTOMENU", or equivalent.

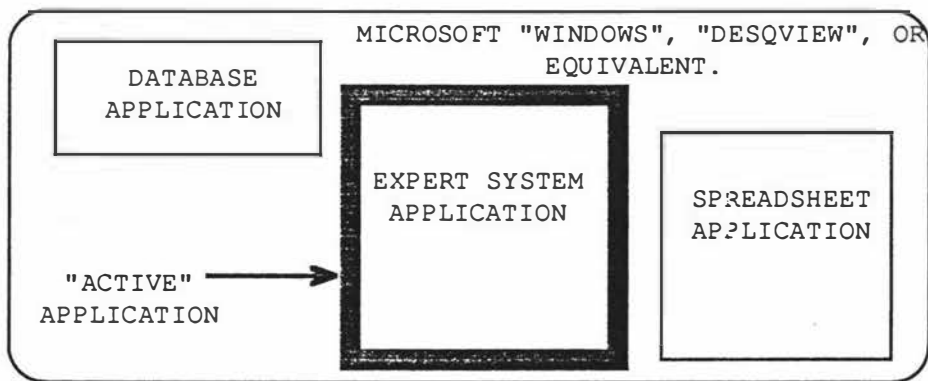


FIGURE 2B: Use of "Active windows".

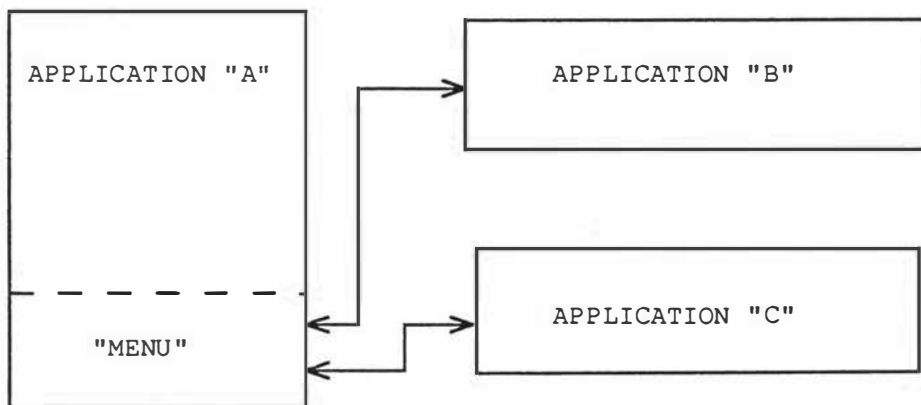


FIGURE 2C: "Menu" as part of one application.

**FIGURE 2: INTEGRATION OF OPERATION**

#### 3.4.4 Integration of data

Products such as VP Expert have extensive facilities for direct import of data used by other products. Products such as Symphony, dBase etc have somewhat more limited such facilities. See Figure 3A. It is suspected that in the case of VP Expert, the ability to import (eg) spreadsheet data is restricted by available memory space, though this has not been confirmed. Other options include the use of intermediate data files, in a format which can be written to/read from by all software packages involved; ASCII and DIF files being the most common (though dBase files are also used by many applications). This is illustrated in Figure 3B.



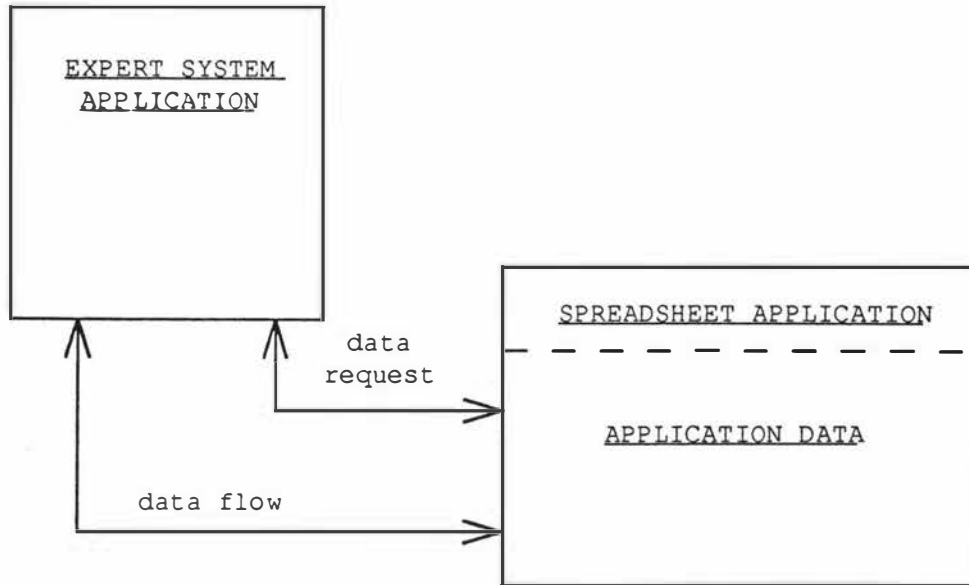


FIGURE 3 A: Data held within one application, accessed directly by other applications

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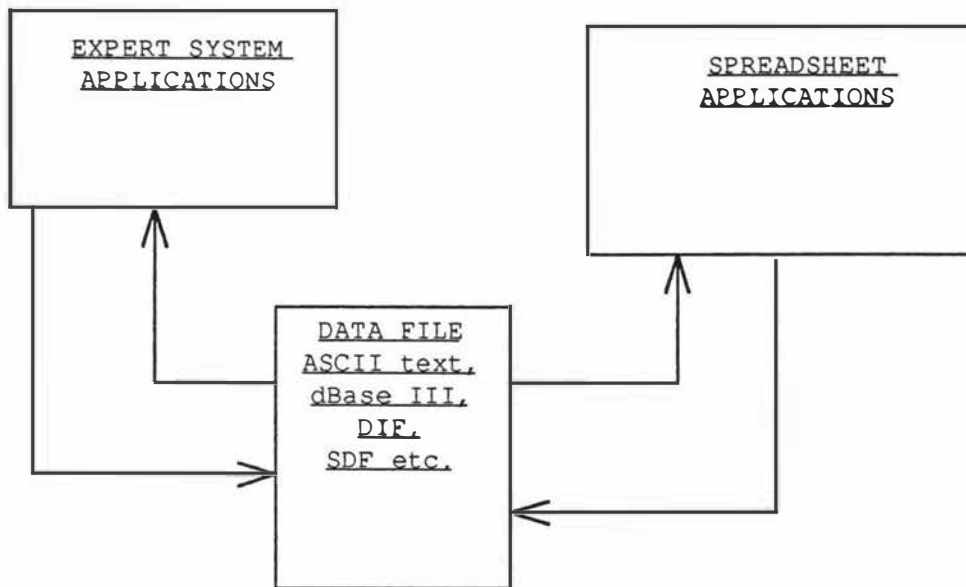


FIGURE 3 B: Data held in separate data file(s).

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**FIGURE 3 INTEGRATION OF DATA**

### 3.4.5 Evaluation and selection of packages and approach method.

#### 3.4.5.1 Integration approach

The selection of the method of approach (from the options presented in section 3.4.2 above) is primarily on the basis of overall cost, however it is essential to appreciate that overall cost includes development cost. Development costs commonly outweigh the capital cost of packages involved. Other factors include those associated with marketing (for example, is it essential to market the application as a single file), available development time, and capability (does data volume preclude the use of a spreadsheet?). An additional practical consideration is the prior commitment to a particular software package. If, for example, a section of the application has already been developed using a spreadsheet, then the use of individual packages will tend to be favoured as the approach to integration.

#### 3.4.5.2 Evaluation of packages.

##### Overall cost;

Overall costs include single licence package costs, and the amortisation of developers' version costs, and development costs.

##### "integrability";

Some packages have extensive facilities which make integration easy (for example, VP Expert has particularly simple functions for using database, spreadsheet and text files, as well as for calling other packages), other packages have few such facilities.

##### Availability of developer's versions;

If all/any of the standard software products used in the application do not have a developers' version, (with a licence allowing distribution of runtime modules), then several problems arise; firstly, a single-licence copy of the offending software package will need to be sold with each "integrated application", and secondly, copy security becomes difficult to control. In practice the most serious problem of this type occurs with spreadsheets, which do not commonly have developers' versions available. The author is aware of only one spreadsheet compiler, "@liberty", and the capabilities of this product are unknown.

##### Hardware requirements;

One factor which needs to be considered very carefully is that commercial software will be attractive to users operating a wide variety of hardware (with differing memory capacity, disk configuration and capacity, and processor type and capability) and peripherals. Although the cost of hardware continues to decrease in relation to capability and more sophisticated peripherals become readily available, an application which requires very

specific or sophisticated capability will nevertheless be at some disadvantage in the marketplace.

#### 3.4.5.3 Assignment of functions.

Assuming that the decision has been taken to develop an application by integrating the capabilities of several software packages, it is necessary to decide how to divide the functions between the various packages. The question is by no means simple, since there may be a very high degree of overlap of CAPABILITY between the packages. Possible criteria for assignment of functions include;

Keystrokes;

Which package can accomplish the task with the minimum number of keystrokes (an important consideration for the user).

Speed;

Which package can execute the function fastest.

Ease of development;

In which package can the function most easily be developed (taking account of available programmer skills etc). Note that a statement to the effect that "it is easier to implement application "A" using language/software package "B", rather than language/software package "C" is only of value if the proposed programmer has equal levels of skill in the use of "B" and "C", and in practice this is seldom so. It would therefore be more useful to state that "a lower level of programmer expertise is required to implement application "A" in language "B" than in language "C"". In practice, it is suggested that this is the criteria most likely to be useful.

Logical groupings of functions;

No matter how good the integration of operation is, it is unlikely to be acceptable to call one package from within a loop executing within another package, simply to use the first package's superior mathematical functions.

The final criterion has been found to be the most commonly applicable.

## 4 ENERGY COST MANAGEMENT; AN APPLICATION FOR INTEGRATION OF STANDARD SOFTWARE TOOL FUNCTIONS

### CHAPTER SUMMARY

The following section begins with a brief description of the subject of Energy Cost Management, the use of a spreadsheet application developed by Prof Monteith of Massey University to assist with the analysis and management of energy costs. The final section compares the computer functions required for ECM with the functions available from standard software packages, and selects additional software packages.

### CHAPTER CONTENTS

#### 4 ENERGY COST MANAGEMENT; AN APPLICATION FOR INTEGRATION OF STANDARD SOFTWARE TOOL FUNCTIONS

- 4.1 INTRODUCTION TO ECM
    - 4.1.1 The concept of energy cost management
    - 4.1.2 Energy costing basics
    - 4.1.3 Principles of ECM
      - 4.1.3.1 The analysis of historical usage patterns
      - 4.1.3.2 Prediction of future energy usage
      - 4.1.3.3 Analysis of cost reduction measures
  - 4.2 ENERGY COST MANAGEMENT USING LOTUS SYMPHONY
    - 4.2.1 Application modules
    - 4.2.2 Application functions
    - 4.2.3 Inputs and Outputs
  - 4.3 ENERGY COST MANAGEMENT USING MULTIPLE SOFTWARE PACKAGES
    - 4.3.1 A comparison of ECM tasks and software package functions
    - 4.3.2 Selection of integration approach (integration of operation, data)
    - 4.3.3 Selection and evaluation of software packages (general).
      - 4.3.3.1 Selection of packages to extend the Lotus Symphony ECM application.
      - 4.3.3.2 Selection and evaluation of packages, assuming no prior commitment to Lotus Symphony.
    - 4.3.4 Assignment of functions to packages.
-

## 4.1 INTRODUCTION TO ECM

### 4.1.1 The concept of energy cost management

Minimizing the cost of energy can be approached from two directions; reducing the total energy usage, and MANAGING this energy usage in such a way as to minimize total costs.

The theory of minimizing total energy usage is well known and documented (much of this theory is very closely linked with classical thermodynamics and heat transfer theory), and the techniques are widely practiced.

The reader is referred to the "Fuel Efficiency Booklets" [11], for information on this subject.

Because of the way in which electrical energy is sold, the total cost incurred by the consumer is influenced even more strongly by the time-distribution of the energy usage, than by the total quantity of energy used. The subject of ECM is the MANAGEMENT of this time-distribution of energy usage, and the end result is the minimizing of total (long term, as well as short term) energy costs to the user.

Rising energy costs have acquired a long history, and it is therefore surprising that the management of energy costs has only recently come to attract a similar degree of effort to that which has been expended on the reduction of energy usage.

The importance of energy cost management stems from two principles; Firstly, energy charges, and in particular electrical energy charges, vary greatly and hence total energy costs to an organisation can be very significantly affected by the planning (management) of energy usage (see "An Expert System Approach to Industrial Energy Use Management [12]); Secondly, energy costs are a major cost element in many operations, often exceeding the overall profit margin. The management of energy costs has therefore the potential of immediately increasing total profit margins by a large factor, at the expense of minimal outlay.

### 4.1.2 Energy costing basics

Energy supply authorities commonly calculate total electrical energy costs by summing the results of two types of charge rates; a unit charge rate (tariff) calculated in \$/kWh, summed continuously over the charging period (intended to cover the cost of energy used), and a Maximum Demand charge rate, calculated on the basis of \$/kVA based on the peak kVA drawn over any 30 minute period during the charging period.

Electricity supply authorities commonly have a number of tariff structures, one of which is selected at the time the connection contract is agreed.

#### 4.1.3 Principles of ECM

There are three essential aspects of energy cost management;

- a/ The analysis of (past) energy usage patterns,
- b/ The identification of the present situation, leading to the prediction of future usage patterns, and
- c/ The analysis of possible means of reducing overall energy costs.

These are illustrated in Figure 4, and will now be examined in turn.

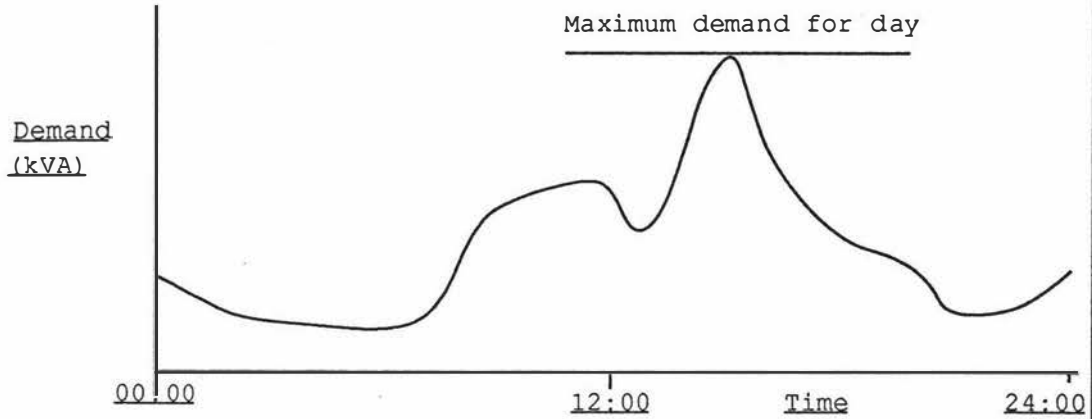


Figure 4A: Accurate appreciation of current position.

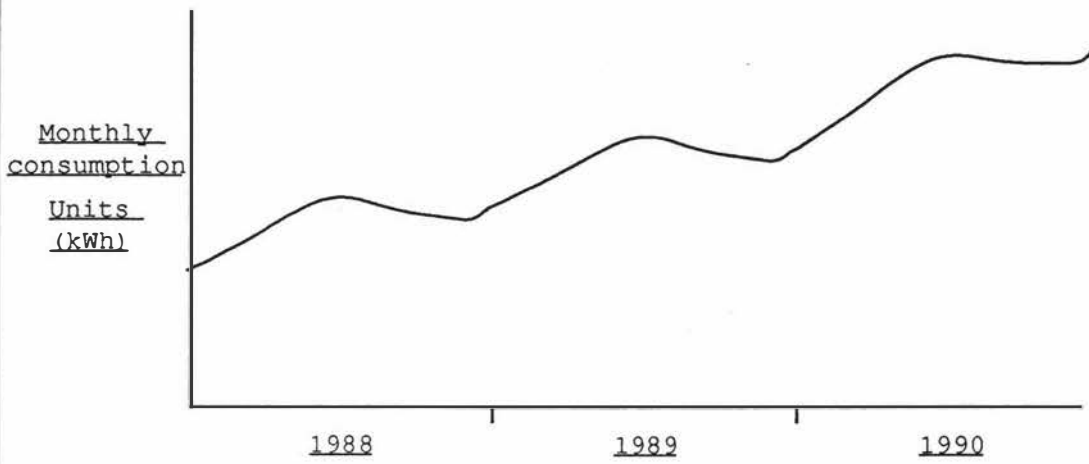


Figure 4B: Prediction of future demand

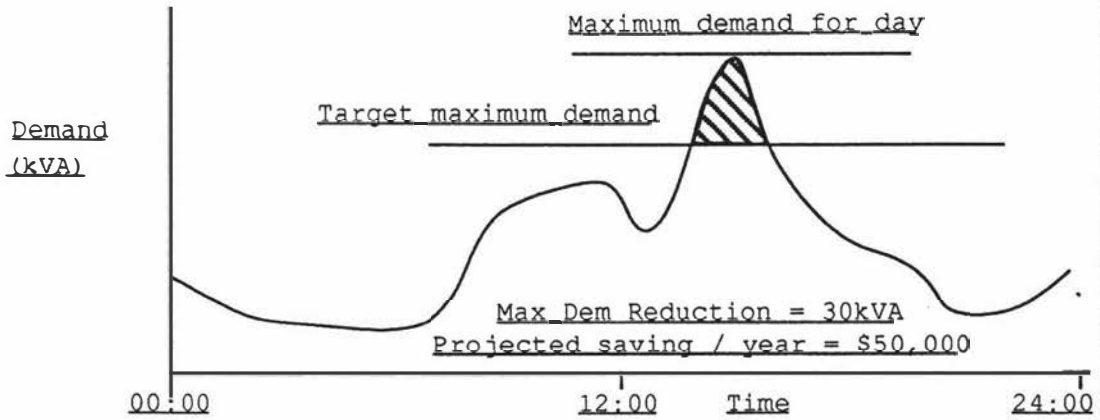


Figure 4C: Analysis of cost reduction proposals

**FIGURE 4: PRINCIPLES OF ENERGY COST MANAGEMENT**

#### 4.1.3.1 The analysis of historical usage patterns

The pattern of energy usage of a large organisation is an extremely complex one; the operation of every single component of the overall pattern has its own set of constraints, many of which interact with those of other components. By careful analysis of the overall pattern, useful large scale effects can be identified, and then used to advantage. The analysis will be concerned with: the strength of the cyclic components of usage, hourly, diurnal, weekly, monthly, and seasonal (yearly); the occurrence and height of peak demands, the "background" load (corresponding to equipment on 24 hour operation), and the patterns of demand as they are correlated with work and business patterns.

#### 4.1.3.2 Prediction of future energy usage

The most immediate use for the understanding of the pattern of energy usage so gained, is for the accurate prediction of future energy costs. This prediction is necessary both in order to prepare accurate cash flow plans, and also to allow informed economic decision making regarding energy cost saving measures.

#### 4.1.3.3 Analysis of cost reduction measures

Methods of reducing energy cost include;

##### a/ Energy saving

The simplest method of reducing energy costs is simply to reduce the nett energy usage, eg by the installation of insulation to reduce heating and cooling costs, turning off idling equipment etc. The benefits of such measures are well known and appreciated.

##### b/ MD Control

It is quite common to find that the largest single cost incurred by an electricity user is that due to the Maximum Demand charge levied by the distribution authority. As such, maximum demand is a prime candidate for cost controlling measures. One approach to MD control is to install a simple Maximum Demand load shedding controller, designed to turn off selected loads should the total demand exceed some pre-programmed level; the drawback associated with such devices is that they are (at least until recently) capable of only limited intelligence in the selection of which devices to switch off, and have no means of accounting for the relative importance of the process consuming the power. A more constructive approach, and one which is likely to allow much greater levels of MD reduction to find management favour, is that of carefully rescheduling the various loads throughout the day/month, in such a way as to minimize the MD. Such rescheduling needs to begin with an examination of the current daily load patterns, and a detailed knowledge of the interdependencies of equipment, labour, and raw materials etc within the organisation.



Two alternative means of rescheduling consumption to reduce Maximum Demand are illustrated in Figures 5 and 6.

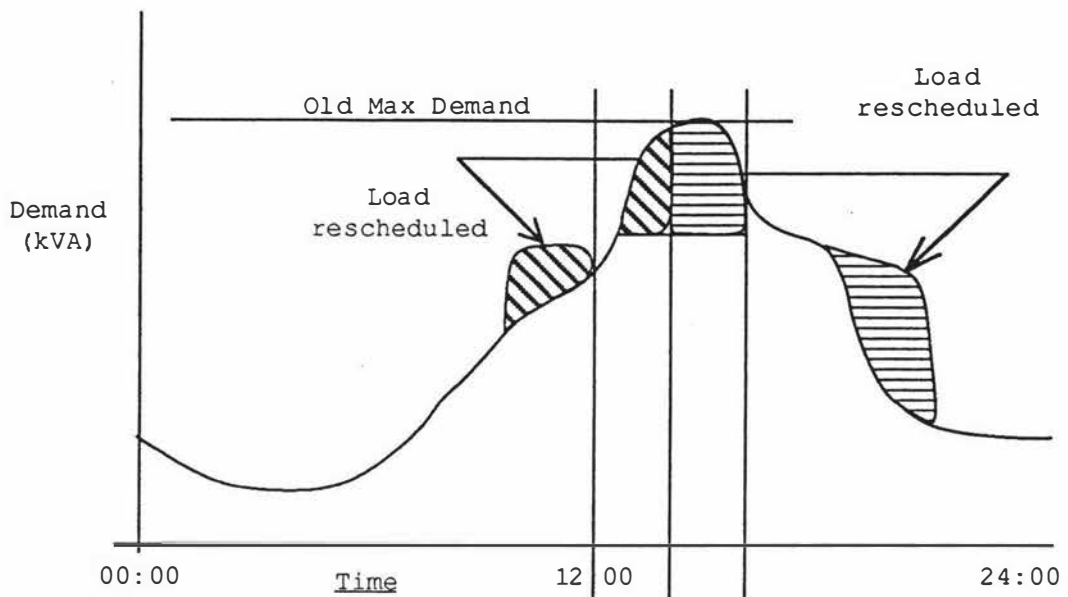


Figure 6 B: Daily load pattern prior to load rescheduling

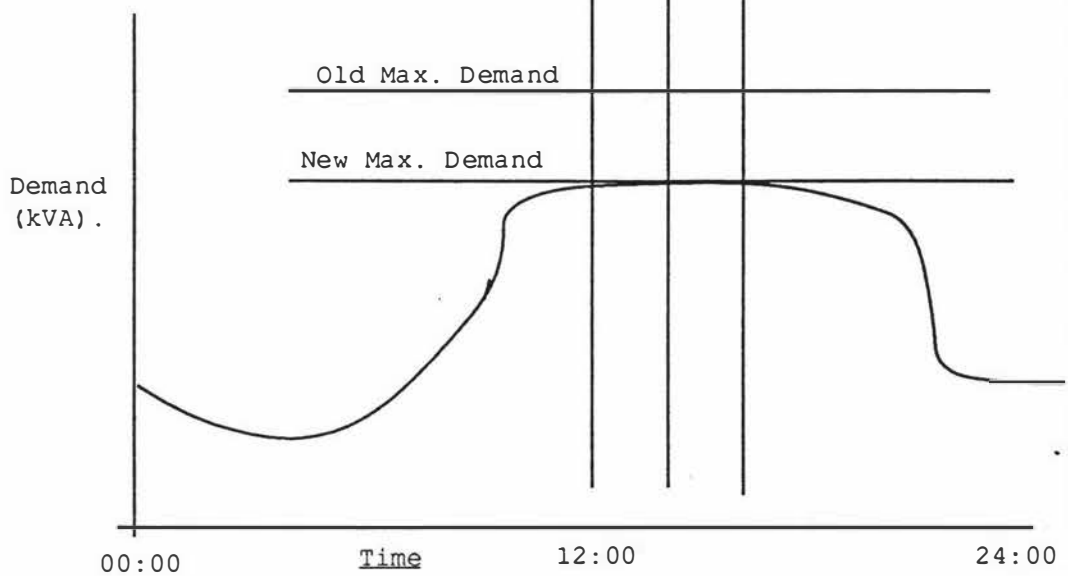


Figure 6 B: Daily load pattern prior to load rescheduling

**FIGURE 5: LOAD RESCHEDULING TO REDUCE MAXIMUM DEMAND**

Max Dem (kVA)

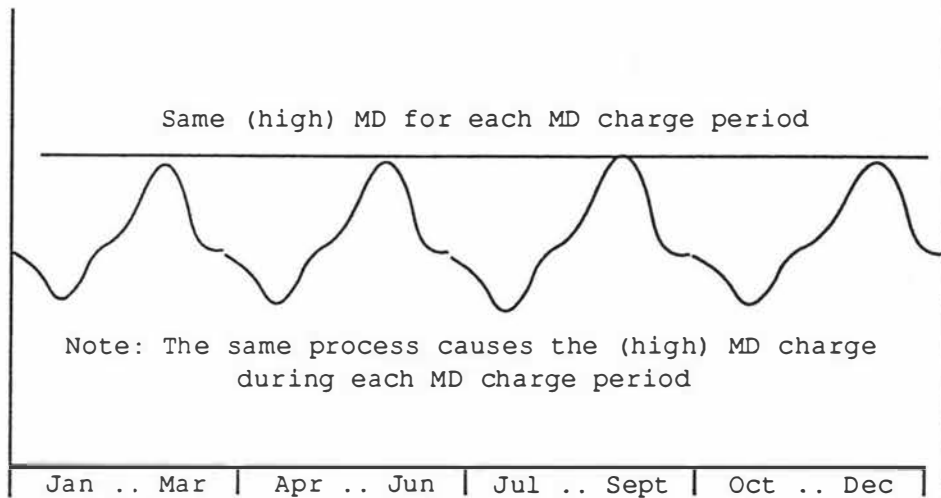


Figure 7A: Load pattern prior to rescheduling

Max Dem (kVA)

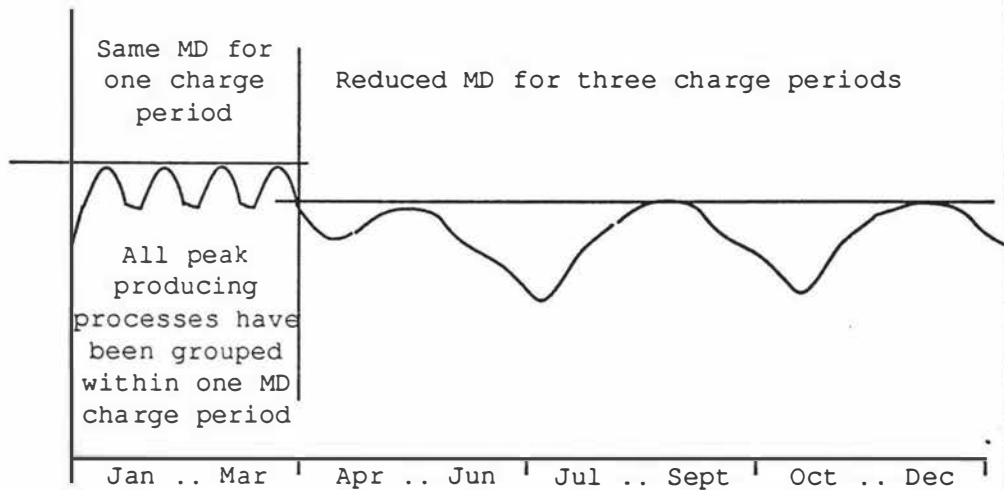


Figure 7B: Load pattern after rescheduling

**FIGURE 6: THE EFFECT OF CONCENTRATING PEAK-PRODUCING PROCESSES INTO ONE MAXIMUM DEMAND CHARGE-PERIOD**

Since the primary purpose of the maximum demand charge is to allow the supply authorities to recover their equipment costs (as opposed to covering the purchase of the bulk power from the generation organisations), and since equipment costs are related to peak voltage and current ratings, maximum demand is measured in kVA, rather than kWh. A poor power factor incurs a heavy penalty in this way, and makes the installation of power factor correction equipment important. The degree of power factor correction needs to be the subject of an economic decision, balancing equipment lifetime and capital cost against annual savings.

c/ Rescheduling of consumption

The second primary component of a typical electricity tariff is the unit cost, (calculated in \$/kWh), and it is common to find that the unit charge rate varies by a factor of 2 from one time of day to the next. Rescheduling all operations to the small hours of the morning may well not be either practical, nor economically desirable (due to such factors as penal labour rates), but the rescheduling of some load to low tariff times is a potential source of large savings.

d/ Selection of alternative tariff structures

As has been mentioned previously, supply authorities commonly have a number of tariff structures, some of which may offer distinct advantages to a user with a particular load pattern. Even if the criteria used by the supply authority for selection of a tariff is clear, changes in the nature or practices of an organisation may offer opportunities for requesting that an alternative tariff be used.

In the case of large consumers, it may be possible to negotiate a one-off tariff; in the case of very large consumers it may even be possible to negotiate directly with generation authorities.

e/ Selection of alternative energy sources.

Where supplies of low cost alternative fuel exist, these may obviously be exploited to reduce overall energy costs; options range from the use of locally available biomass for heating, to the construction of a combined cycle power station to utilise gas available on a "use it or lose it" contractual basis.

## 4.2 EVALUATION OF ECM USING AN INTEGRATED SOFTWARE PACKAGE (Lotus Symphony, Version 2.0)

### 4.2.1 Application modules

The Lotus Symphony application developed by Professor Monteith currently consists of six modules, entitled

- Electricity analysis
- Gas Analysis
- Electricity Inventory
- Gas Inventory
- Electricity Consumption and Production.

### 4.2.2 Application functions

It is not the function of this thesis to provide a detailed description of all of the functions of the Symphony ECM application; this would be overly lengthy and largely superfluous to the main topic.

The features of most relevance to this thesis can be summarised as follows;

Monthly consumption and Maximum Demand data recorded over a three year period is analysed, and is presented graphically in several different ways (with the object of ensuring the best possible comprehension of the patterns by the human (expert) user). A limited range of tariff data is also entered, and used to analyse costs in similar manner to consumption.

An interactive method is provided to allow the user to vary the depth of (hypothetical) load shedding, and be presented with a graphical representation of the corresponding shed periods, the resultant MD level, and the cash saving over the current figure.

All electricity consuming equipment is recorded in an "inventory", together with the responsible Department, and the estimated utilisation factor. This data is then analysed (including pareto analysis and ranking), and presented graphically, with the object of ensuring the comprehension by the user of the pattern of usage on a departmental basis.

Finally, data regarding the rate of production of products may be entered, allowing the energy usage to be correlated with the production data (regression analysis).

A current problem with the symphony ECM package is that the raw data is held in a somewhat fragmented and redundant form within the modules themselves, risking data integrity problems.

#### 4.2.3 Inputs and Outputs

The principle inputs required are mentioned above; the total quantity of data is not excessively large, and could be expected to be readily available to an organisation. The reader is referred to Appendix A for examples of the outputs produced by the Symphony application. The examples documented are chosen for their relevance to the following sections of this thesis.

#### 4.3 ENERGY COST MANAGEMENT USING MULTIPLE SOFTWARE PACKAGES

The purpose of this section is firstly to consider the software functions which can be brought to bear on this application, secondly to consider the software packages (tools) in which these functions can be found, and finally to recommend a selection of software packages to extend and improve the ECM function.

##### 4.3.1 A comparison of ECM tasks and software package functions.

In order to identify the software package functions required, it is necessary to (re)examine both ECM as a subject, and also the aims of this project. The former are listed in section 4.1.3, while the latter are found in section 5.1 of this thesis. The particular software functions thus identified are;

- a/ Means of storing and retrieving the raw data
- b/ Means of presenting the data, following sorting and arithmetic manipulation, so as to allow a human expert recognise important features/trends.
- c/ Means of automatically identifying and drawing attention to these features, patterns or trends.
- d/ Means to allow a user to adjust the pattern of energy usage, and observe the effect upon overall cost.
- e/ Means to verify whether a proposed adjustment is valid or desirable.

##### 4.3.2 Selection of integration approach (integration of operation, data)

###### 4.3.2.1 Integration of operation

One of the main factors affecting the assignment of functions is that the size of the Symphony and VP Expert packages preclude these being held in (PC) memory simultaneously. This dictates that the "integration of operation" (see section 3.4.3 above) needs to be of the type in which the user selects one or other software package to be loaded into memory, and when finished with this package, allows it to be released from memory prior to loading alternative packages.

###### 4.3.2.2 Integration of data

It was initially hoped that "integration of data" could be achieved by having VP Expert access the Symphony spreadsheets directly; unfortunately this proved impossible, due to the size of some of the ECM spreadsheets (and the less important fact that VP Expert requires spreadsheets to use the ".WKS" file

extension). Integration of data was therefore achieved by the use of a small intermediate spreadsheet file which can be read and written to by both VP Expert and Symphony. The final prototype also reads and writes data to two dBase III format data files, (holding inventory data, and records of all electrical load movements proposed).

At a later date it is proposed to arrange for the inventory file to be written to by the Symphony application. This operation will require some care, since although the structure of the data is the same in the dBase and Symphony files, the data definition is slightly different; the Symphony file records details of "every item of equipment which consumes electrical power", while the dBase file records details of "every block of electrical equipment which can be turned on or off as a unit".

#### 4.3.3 Selection and evaluation of software packages.

Considering the above list of functions, and the software packages available, the following observations can be made;

A/ The data storage requirements dictate either a dedicated database, or the database functions of a spreadsheet. A consideration of the data volumes estimated in section 5.3.1.1 will show that the MACHINE-SLOT data volume is far beyond the capacity of a spreadsheet, and the COMPANY-DAY entity is probably approaching the practical limit of record numbers for a spreadsheet such as Lotus Symphony. Provided that the decision is made to not implement these two entities, however, the volumes and record numbers of the remaining entities do not preclude the use of a spreadsheet for storage.

B/ The analysis of the numerical data is not complex, either in terms of mathematical functions, or in terms of data volumes; this function could be undertaken with approximately equal ease by either spreadsheet, database, or programming language packages, and by expert system packages with only slightly more difficulty.

C/ While the data analysis requirements do not narrow the choice of software package, the combination of analysis and result presentation requirements suggest the use of a spreadsheet. Provided that the decision is made not to implement the MACHINE-SLOT, and COMPANY-DAY entities the data storage volume is within the capabilities of the spreadsheet.

D/ The data manipulation aspects present a more complex requirement; proposed load movements may or may not be valid (it would obviously be invalid to propose moving the load of an item of equipment which was not



actually in use), and even if valid, may or may not be of any value in reducing total electricity costs. The desirability of subjecting a proposed load movement to several checks suggests the use of the type of production rules available in an expert system shell. Some of the data against which the validity of a proposed move would need to be checked is currently held in the spreadsheet. Other data required for checking is not currently stored at all, and the volume of this data may preclude the use of a spreadsheet database.

A decision was therefore made to develop a prototype decision support system using an expert system shell, and to investigate in more detail the database functions required.

#### 4.3.3.1 Selection of packages to extend the Lotus Symphony ECM application.

##### Expert System Shell

Having decided to proceed with the development of a prototype Decision Support System for the maximum demand control aspect of the ECM application, it was then necessary to decide on the expert system shell to be used.

Two shells were available; VP Expert, (VPX) and Texas Instruments' Personal Consultant Plus (PC+).

The criteria for evaluation were;

Expert System Shell capability;

Size; it was considered that the DSS would probably require of the order of 30 - 60 rules (or would be able to be broken into modules of this size)

Specific ES functions; The relative value of such facilities as backward chaining, forward chaining, semantic nets, and frames was unclear at the outset;

Interface functions; It was considered of great importance that the shell be able to easily interface with external data files, and very preferably with spreadsheet and database files.

Numeric, text etc functions; Though the functions required were not accurately known at the outset, it was recognised that the ability to handle at least a moderate quantity of numeric data was important.

Speed and availability of special functions; No specific criteria were set, although the criteria that response delays should not exceed a few seconds for acceptability was implicit.

Expert System Shell cost;

Since both shells were available, the costs were (to some extent) academic, although it was recognised that should the resultant software be made available commercially, its pricing would have to reflect the package cost to some extent (as well as the cost of the runtime versions).

#### Expert System Shell runtime versions;

It was seen as important that the shell should have a runtime version available, both for commercial reasons (to limit the cost, and increase the profit margin of any software to be distributed), and for security reasons (protect the source code of the application).

#### Expert System Shell skill acquisition

Since the project is partially an exercise in the acquisition of skills, there was an obvious advantage in selecting the shell which was most likely to be encountered in other organisations.

#### Expert System Shell evaluation and selection.

The shells were evaluated as follows;

Both had developers' versions available; (PC+ already owned by Massey, VP Expert available for some \$900);

Initial costs of packages, PC+ \$7000 (estimated, allowing for academic discounts), VP Expert \$ 250;

PC+ supports forward and backward chaining, and frames, VP Expert supports backward chaining, with some facilities for forward chaining;

VP Expert supports the use of dimensioned variables, which can be used in conjunction with the WHILEKNOWN.. END loop construct for numerical analysis, as well as for spreadsheet and database handling. PC+ does not support dimensioned variables, and although it does support frames, these do not appear to be well suited to the type of numerical functions required of this application.

Both have facilities for access to database and spreadsheet etc files, though VP Expert has particularly simple and direct facilities for these;

Because of its low cost, VP Expert is becoming quite widely used, and is supported by a NZ agent.

Primarily because of its simple facilities for database and spreadsheet access, for its superior numeric handling, and its increasing acceptance as a product, the decision was taken to develop the prototype using VP Expert.

With the low price, friendly development environment, and tolerant syntax offered by VP Expert, the Expert System shell is no longer the sole preserve of Academics, but has become another useful desktop tool. It will be interesting to observe the progress of this product, and its emerging uses.

#### Database

The database functions used by the prototype described in section 6.5.1 are actually all carried out by VP Expert, which can retrieve records from a dBase III file given a set of criteria to be met.

No separate database package was therefore required for the prototype ECMES.

#### 4.3.3.2 Selection and evaluation of packages, assuming no prior commitment to Lotus Symphony.

At the outset of this project, a very firm commitment had already been made to the ECM application developed using Lotus Symphony. This commitment has been a major factor in the selection of further software packages and strategies.

Lotus Symphony is an "integrated" spreadsheet package; that is, it combines powerful versions of the traditional spreadsheet functions with a range of other functions normally found in database, word processing, and communications packages. All of these functions use the worksheet as the primary data storage device. Lotus Symphony retails at approximately \$1600 (\$NZ, Jan 1990), and contains a powerful macro language, as well as a powerful set of functions for use in cell formulae. In order to provide all of the above functions, Symphony is a large package, in terms of memory requirements (and incidentally, in terms of loading time). Furthermore, in order to achieve acceptable performance, Symphony requires the complete spreadsheet currently in use to be held in memory. The nett effect of these two requirements is that, once a Symphony application is loaded, most PC's have very little memory space remaining in which to load further software packages.

Both database and expert system shell packages commonly have developers' versions available, and hence the unit cost of the integrated application need not include the single-licence package costs of the database and expert system shell packages. By contrast, very few spreadsheet packages have compilers available, hence every unit of the integrated application must include the cost of a single-licence version of the spreadsheet package. There is therefore a good commercial reason for minimizing the cost of the spreadsheet package selected.

A large number of spreadsheet packages are available; they include;

Lotus Symphony (integrated package)	\$1300
Lotus 123 Version 3	\$ 945
Excel	\$ 995
Supercalc	\$ 795
VP Planner +	\$ 395
PFS First Choice (integrated package)	\$ 295

At a yet lower price bracket is "Joe's spreadsheet" (\$40), and several public domain spreadsheets such as "ASEASYAS".

#### Spreadsheet evaluation and selection;

The public domain spreadsheets, Joe's spreadsheet, and PFS first choice were considered to be somewhat limited in the functions offered, however VP Planner plus has a powerful set of spreadsheet functions, adequate to handle the tasks required for ECM.

VP Planner offers the additional advantage of being directly accessible from within a VP Expert application; that is, from within a VP Expert application it is possible to call up a VP Planner spreadsheet and carry out normal spreadsheet operations, such as graphical presentation of intermediate results, before returning to the VP Expert application. This capability is seen as a major advantage (and is seen as a major disadvantage in the case of the Symphony/VP Expert combination). For these reasons, had no commitment to Lotus Symphony existed, the recommendation would have been to use the VP Planner plus spreadsheet, in combination with the VP Expert Expert System Shell.

#### 4.3.4 Assignment of functions to packages.

It cannot be over-emphasised that the spreadsheet, database, programming language, and expert system shell are all CAPABLE of carrying out all of the functions required; the only question is, which package carries them out with the greatest convenience, ease and speed, and which package requires the least expertise and effort on the part of the developer. This section will only address the assignment of functions amongst the Lotus symphony, and VP Expert packages. The question of assignment of functions had no prior commitment to Symphony existed, will not be addressed.

Considering the three aims of energy cost management described in section 4.1.3, the first two are primarily associated with the manipulation and presentation of numeric data, and hence are located (as they should be) in the Symphony spreadsheet. The third aim, viz "The analysis of possible means of reducing overall energy costs" can be split into two parts, the identification of aspects of current energy use patterns which are likely to offer opportunity for

energy cost savings, and secondly the analysis of possible means of effecting savings. Identification of aspects of current use patterns from which energy cost savings are likely to be possible can be approached in two ways; by an inspection of the data by a human "expert", and by inspection of the (processed) data by an Expert System. The Symphony application takes the former approach, and the strength of the spreadsheet package is used to present the energy use information graphically in a number of ways which can be expected to draw the attention of a human expert.

The exploration of the use of expert systems to identify aspects of energy use patterns which are likely to offer cost savings forms one of the aims of this project; however no clear idea of the functions required existed at the outset of the project. There was a general expectation that "reasoning", and "rules of thumb" would be required to identify factors of key significance: these functions clearly needed to be assigned to the expert system shell. What was considerably less clear was the degree of numerical processing which would be required to identify the "key points". If the numerical processing requirement was to be extensive, then there would be advantage in assigning it to the spreadsheet; if however the numerical processing required was less than extensive, or if a degree of interaction was required between the numerical processing sections and the "reasoning" sections, then the numerical processing sections would be better left within the expert system shell. VP Expert has quite powerful facilities for handling mathematics, and the extent of the calculation was, on balance, considered to be not extensive. It was therefore decided, at least in the prototype versions, to retain any mathematical processing needed to identify ECM aspects offering high potential savings within the expert system package.

Of the functions associated with analysing possible cost saving methods, those which are most straightforward to assign are the functions which check the validity of proposed rescheduling of electrical loads, and which clearly belong with the Expert System package.

As has been previously mentioned, an important factor affecting the assignment of functions is that the size of the Symphony and VP Expert packages preclude these being held in (PC) memory simultaneously. This also precludes rapid and smooth movement between the packages impossible, which in turn encourages the designer to group all functions required at one time in the same package if at all possible. For this reason it is also necessary to include in the Expert System package the functions associated with

displaying the current status including the nett effect of all the load rescheduling movements carried out.

## 5 DATABASE MANAGEMENT SUPPORT FOR (SYMPHONY BASED) ENERGY COST MANAGEMENT.

### CHAPTER SUMMARY

Energy Cost Management is a field which involves considerable quantities of "raw" data; it is therefore important to examine the requirements for data "management".

### CHAPTER CONTENTS

- 5.1 DBMS SUPPORT REQUIREMENTS
  - 5.1.1 Data management functions required for ECM
  - 5.1.2 Data modelling
  - 5.1.3 Evaluation of methods for providing data management functions
- 5.2 DATA ENTRY MODULE
  - 5.2.1 Requirement
  - 5.2.2 Development.
- 5.3 "INTELLIGENT DATABASE" FUNCTIONS.

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### 5.1 DBMS SUPPORT REQUIREMENTS

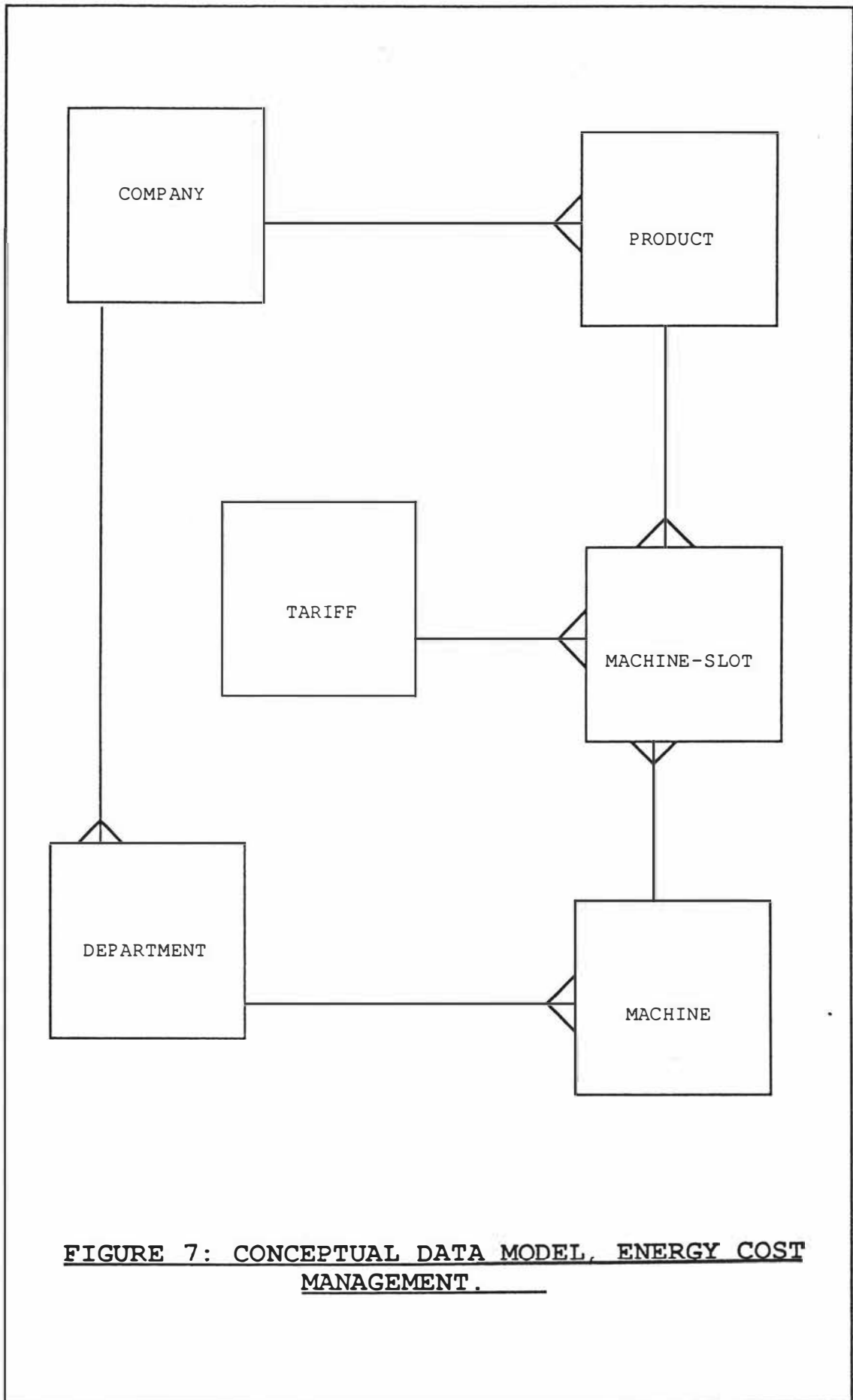
#### 5.1.1 Data management functions required for ECM

The functions required include;

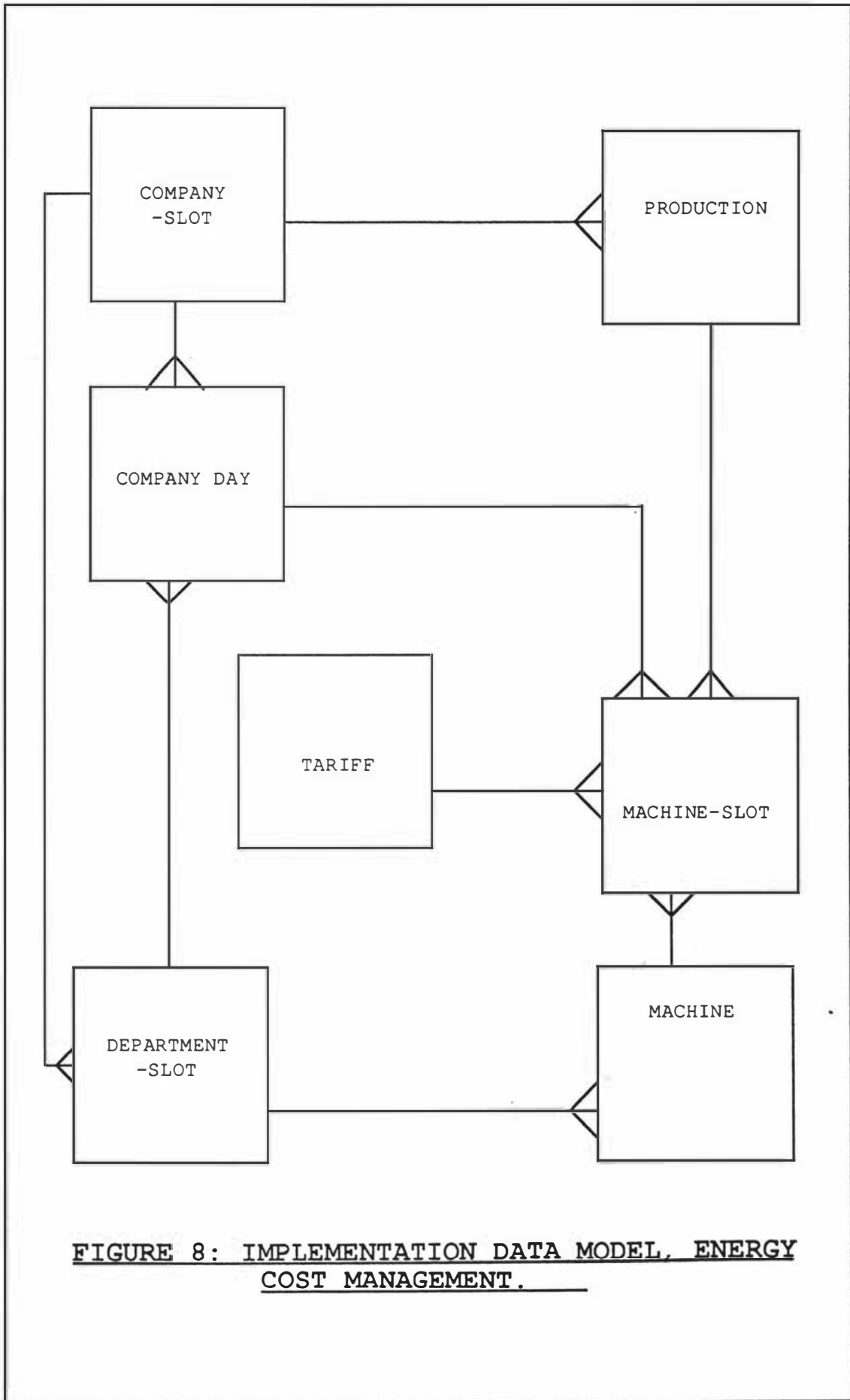
- 1/ The entry and validation of data by the user (scope for the automatic entry of energy consumption figures and equipment usage data exists, but has not been explored within this project).
- 2/ Checks for internal consistency of data.
- 3/ Output of subsets of data (data reporting) both directly to the user, and to the spreadsheet application.
- 4/ Manipulation of data elements during "what if" exercises to determine load patterns which would reduce energy costs.
- 5/ Possible extrapolation/interpolation to supply estimates of missing data.

#### 5.1.2 Data modelling

At the outset of the project, a considerable amount of effort was spent on the development of a fully normalised data model to represent all the data relevant to the ECM application, and the correct relationships between this data. The modelling exercise was based largely on the methods described in Howe [2]. The conceptual data model developed is shown in Figure 7, from which the implementation data model of Figure 8 has been developed. The data dictionary developed for the (Figure 8) data model appears in Appendix F.







**FIGURE 8: IMPLEMENTATION DATA MODEL, ENERGY COST MANAGEMENT.**

As is usual, the development of the data model highlighted valuable information regarding the scope of, and relationships between, the various data entities involved in the ECM application.

A particular gain resulting from the data model development has been the identification of several cases in which functions offered by the Symphony-based ECM system were actually special cases of more general functions; these more general functions may be the subjects of future development. As an example of the latter, the current spreadsheet ECM modules allow the split of unit costs between day and night rates to be examined; an examination of the data model will show that this is only one of several splits which could be of interest, for example, the unit costs split between three 8 hour shifts, the weekend - weekday split, etc.

#### 5.1.3 Evaluation of methods for providing data management functions.

Methods for providing data management functions include the use of a dedicated DBMS, such as Ashton Tate's dBase software, the use of the Symphony file management functions, and the use of an Expert System shell as an "intelligent front end" for a database residing either in separate files, or within the Symphony worksheets.

As has been mentioned in section 4.3.3.1, VP Expert has sufficient facilities for extracting information from database files to meet the needs of the prototype ECMES application, therefore no separate database package was required.

The "intelligent database" functions described in section 5.3 would require a larger volume and higher degree of sophistication in the database transactions involved. For these functions, the database facilities of Symphony, and VP Expert would be inadequate, and the use of a dedicated database management system is recommended. A large selection of suitable packages, including dBase IV, various dBase III clones, paradox, foxbase, and DBXL are available, the final choice would be heavily influenced by the availability of any one of these packages within the development organisation.

## 5.2 DATA ENTRY MODULE

### 5.2.1 Requirement

One of the problems encountered when offering a product developed using Symphony (or indeed, most spreadsheets) commercially is that of protecting the "code" (ie setup information, and macro instructions) from copying and piracy. Several remedies are available, including the use of (a very limited range of) spreadsheet compilers, hardware protection devices, and various "trojans". A further option is simply not to offer the product itself commercially, but rather to offer its use as a service, with the customer providing the raw data.

In the case of the ECM spreadsheet, a heavy program of seminars demonstrating the use of the product, as well as the principles of energy cost management were undertaken, and for these, it was seen as a distinct advantage for attendees to be able to carry out the analyses on data from their own organisations.

For both of the above reasons it was decided to develop a simple data entry module, allowing the raw data for the spreadsheet based ECM system to be entered, edited, displayed and printed etc separately from the spreadsheet, and then imported to the spreadsheet.

### 5.2.2 Development.

The data entry module was developed using dBMAN V, a dBase III work-alike. DBman V was chosen because it was one of the lowest priced dBase-type DBMS's available with a developers' version included in the retail price, and a reasonable windowing facility.

The data entry module is a very simple application, offering the user facilities for inputting and editing consumption and tariff data, and printing out a final version; when the user signals that the data is correct, the data entry module converts all the data input files into a delimited format. The delimited data files can then be imported into a Symphony worksheet using the "File Import Structured" (FIS) instructions.

Appendix G contains the source code of the data entry module, the screen displays, and operating instructions.

### 5.3 "INTELLIGENT DATABASE" FUNCTIONS

The data associated with ECM has two peculiarities; firstly, although the application can theoretically be described completely rigorously, the volume of data required makes this impractical, and secondly, there are complex interrelationships among the data items, few of which can be adequately represented in a simple database. A degree of "intelligence" is therefore required within the database functions.

#### 5.3.1 Requirement for intelligent database functions.

##### 5.3.1.1 Availability of complete data.

As is common, the data modelling exercise showed that many of the Entities were related by a "lowest common denominator" entity. In this case, the "lowest common denominator" entity corresponded to the energy used by a particular item of equipment, during a specific time interval (MACHINE-SLOT). While it is quite feasible technically to implement such a structure, the quantity of information involved would be very large.

Based on estimates of 100 items of equipment for a moderate sized organisation over a three year study period, with maximum demand readings recorded over 30 minute periods, the following table shows that the data structure of Figure 8 would require some 120 Mbytes of storage (taking empirical account of index file etc storage requirements).

#### DATA VOLUME ESTIMATE (FIGURE 8).

ENTITY	RECORD SIZE	RECORD NUMBERS	TOTAL SIZE
Co_Slot	32	36	1152
Production	15	180	2700
Co_Day	43	1095	47085
Dept_slot	30	360	10800
Machine	23	100	2300
Tariff	22	360	7920
Machine_Slot	18	5256000	94.6Mbytes
			TOTAL
			94.6MBytes.

Although careful design could reduce this figure significantly, experience has shown that the "lowest common denominator" entities are frequently the least amenable to volume reduction; the total quantity of data is therefore still going to be very large.

To manipulate this volume of data mathematically to produce an "optimum" load pattern would be a very

large operation mathematically; if the exercise was to have any hope of providing a practical result, a great number of constraints regarding such things as the acceptable sequences, permutations and combinations of equipment usages would have to be identified and accounted for by the software, as would details of time dependent operations (eg seasonal availability of raw materials, or markets) etc etc. No more rigorous analysis of the problem is required to show that such a mathematical treatment is likely to involve a very large effort, and the expenditure of a vast amount of development time. Experience has demonstrated that such a course is all too likely to never result in a useable and marketable.

It is also considered that the quantity of data, and the difficulty of manipulating it in a rigorous fashion (ie, to attempt to perform a mathematically correct optimisation) would be unjustified; there are however real gains possible with a non-rigorous approach. Such a "non-rigorous" approach necessarily implies a degree of intelligence in the application.

#### 5.3.1.2 Complex interrelationships

ECM functions require a database which can store considerable quantities of information regarding energy use. In a practical (as opposed to a theoretically correct) database design, this inevitably results in the existence of record values which are mathematically related to values in other records and entities. An example of such a relationship might be the case where one entity stores monthly consumption figures for a whole organisation, while another stores monthly demands (kVA) and power factors for departments within the organisation. The company figure must equal the sum of (the product of a departmental demand, \* power factor). A further example can be seen in the COMPANY-DAY and the COMPANY-SLOT entities; The sum (over all days of the month) of the sum (over all half hour intervals of each day) of the consumptions in the COMPANY-DAY entity must logically equal the figure in the COMPANY-SLOT entity.

Classic database theory states that the storage of any accumulation totals is dangerous, for the simple reason that any change in the underlying data renders the total incorrect; the theoretically correct approach is rather carry out such accumulations at run time, to ensure up-to-date totals. While obviously correct, such advice is often impractical for both performance and practical reasons; in the above example, the monthly consumption figures are recorded on integrating meters, and are among the most reliable and easily available figures in the whole application.

A problem which is much more general than the ECM application is that of low level data which is

incomplete, either because it is not available, or because the volume and effort of collection are such as not to justify it; in such a case, higher level data cannot be simply accumulated from lower level data. Such cases are common, yet the obvious dependence of the quality of output on quality of input, requires some (if only informal) check of numerical data integrity.

Further problems can occur in cases where low level data and high level data are known accurately, but intermediate data is either absent or inconsistent; an example in the ECM case might occur where good data is available for the MACHINE-SLOT and COMPANY-SLOT entities, but the figures for DEPARTMENT-SLOT do not agree with the other two figures. Another example could arise in a case where monthly consumption, tariff and cost figures are each available, but do not agree.

The problem, then, is to design a practical database, which can cope with the problems of ensuring integrity (and numerical integrity in particular) of data across entities containing related and possibly incomplete data.

The principle of such a database design is firstly to compare statistical and limit parameters of the two entity values, and secondly to offer the user some simple means of adjusting the values to bring them into line (several options will be needed for this). For the case of the second example given above, this would involve comparing the average daily demand (times  $365/12$ ) with the average monthly demand, and (less valuably,) the standard deviation of the 30 minute demand figures with the standard deviation of the monthly figures (statistical parameters); The peak 30 minute demand would then need to be compared to the monthly MD figure (limit parameters). The user would need to be advised of the degree of discrepancy (provided this was above some preset threshold), and offered means of correcting the data.

The options available for correcting the data would need, as a minimum, to include; Re-enter data, adjust data to match statistical parameters, adjust data to match limit parameters, do nothing (but tag the results).

### 5.3.2 Development

Within the limited time available, it was not possible to implement both the decision support functions, and the "intelligent database" functions. It was considered that the decision support functions offered a greater potential usefulness, so development effort was concentrated in that area. The reporting module of the final version of the Maximum demand control decision support system does however implement a very limited version of the integrity checking functions described in section 5.3.1 above, by comparing the statistical parameters of the daily and monthly consumption figures.

## 6 DECISION SUPPORT SYSTEM DEVELOPMENT.

### CHAPTER SUMMARY

Having examined the issues relating to the use of multiple software tools for one application, and also the subject of energy cost management, it is now appropriate to consider the application of additional software tools, and in particular the expert system shell, to this task.

This section describes the stages in defining the aims of the decision support system, the design and development of the prototypes (and the particular problems encountered and solved), and the experience gained from the operation of the prototypes.

### CHAPTER CONTENTS

- 6.1 DEFINITION OF OVERALL AIMS
  - 6.1.1 Identification of savings opportunities.
  - 6.1.2 Analysis of methods of reducing energy costs.
  - 6.1.3 Relationship between decision support system and Symphony ECMES.
  - 6.1.4 Relationship between decision support system, Symphony ECMES, and data structures implicit in the ECM field.
- 6.2 DEVELOPMENT METHODS.
- 6.3 DEVELOPMENT OF THE MODEL 1 SUPPORT TOOL, FOR HIGH LEVEL (ENERGY COST MANAGEMENT) DECISIONS.
  - 6.3.1 Development of model 1 (the first prototype).
    - 6.3.1.1 Knowledge acquisition
    - 6.3.1.2 Selection of ECM aspects to be offered Decision Support.
    - 6.3.1.3 Requirements for decision support application (identified at project definition stage);
  - 6.3.2 Prototype development
    - 6.3.2.1 General
    - 6.3.2.2 Requirements analyses and development of rules
  - 6.3.3 Testing and results, Lessons learned.
- 6.4 DEVELOPMENT OF MODEL 2, AS TOOL FOR MD CONTROL BY LOAD PATTERN ADJUSTMENT.
  - 6.4.1 Requirements analyses and development of rules.
  - 6.4.2 User interface development (principles, problems, solutions)
  - 6.4.3 Testing and results, Lessons learned.
- 6.5 DEVELOPMENT OF MODEL 3, AS TOOL FOR MD CONTROL BY OPERATION RESCHEDULING. FINAL VERSION: MD\_REPOR.KBS, & MD\_REFIN.KBS



- 6.5.1 Requirements analyses and development of rules
  - 6.5.2 User interface development (principles, problems, solutions).
- 6.6 PROTOTYPE DEVELOPMENT PROBLEMS AND SOLUTIONS.
- 6.7 TESTING AND EVALUATION (OF FINAL VERSION).
- 6.7.1 Review of aims.
  - 6.7.2 Operation of final version of decision support system (model 3)
  - 6.7.3 Evaluation of final version against aims.
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6.1 DEFINITION OF OVERALL AIMS

The three aims of energy cost management described in section 4.1.3 are;

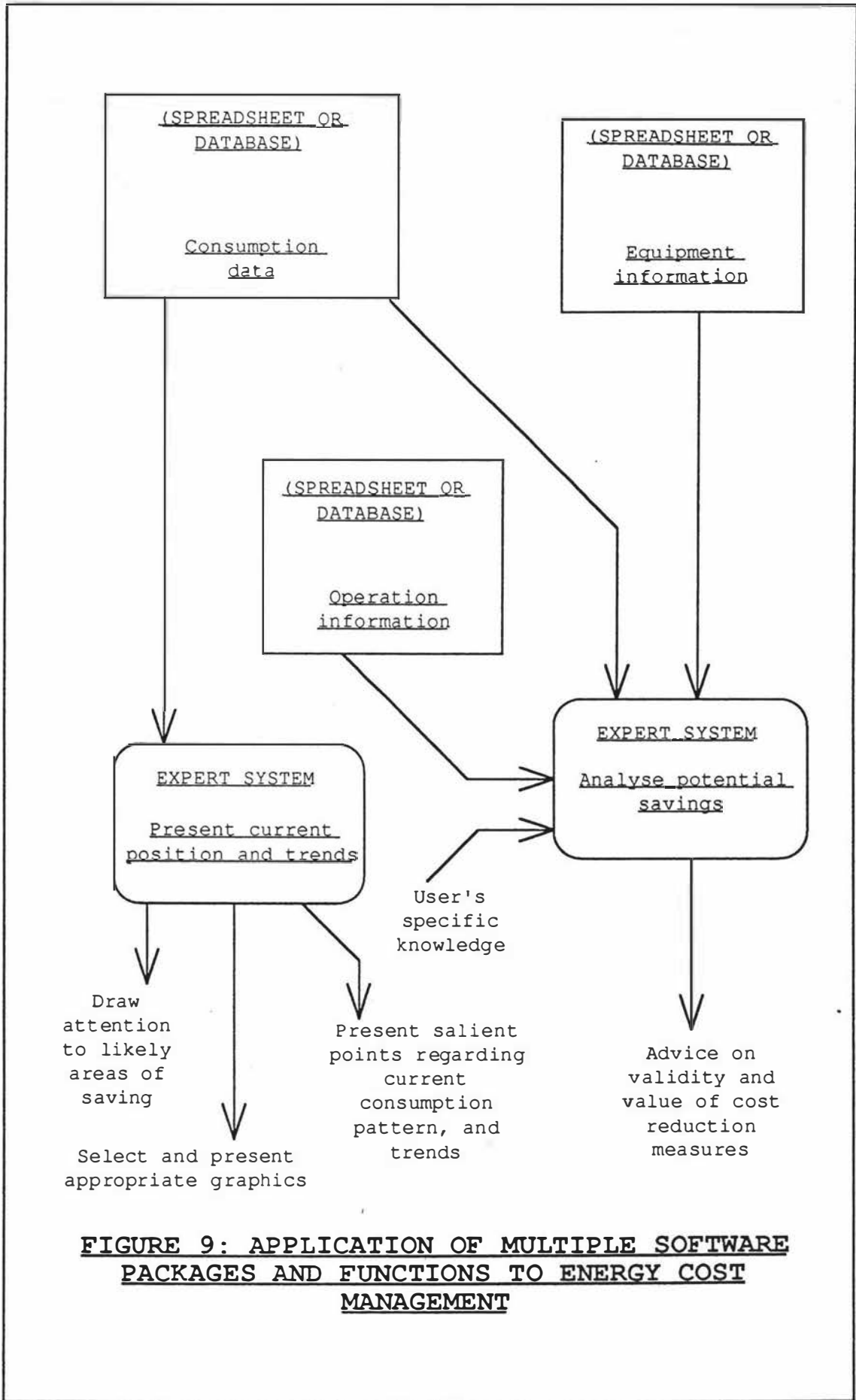
- The analysis of past energy usage patterns,
- The identification of the present situation, leading to the prediction of future usage patterns, and
- The analysis of possible means of reducing overall energy costs.

The first two are primarily associated with the manipulation and presentation of numeric data, and hence are located (as they should be) in the Symphony spreadsheet. The third aim, viz "The analysis of possible means of reducing overall energy costs" can be split into two parts which are firstly the identification of aspects of current energy use patterns which are likely to offer opportunity for energy cost savings, and secondly the analysis of possible means of effecting savings.

At the outset of the prototype development phase, the relationship between the overall aims of the project, the software packages, and the basic information available, was as illustrated in Figure 9.

Note 1; At an early stage in this project, the decision was taken to replace the term "expert system" with "decision support system", both as a title and as a philosophy for the system under development.

Note 2; the following sections are presented in logical, as opposed to strict chronological order.



**FIGURE 9: APPLICATION OF MULTIPLE SOFTWARE PACKAGES AND FUNCTIONS TO ENERGY COST MANAGEMENT**

#### 6.1.1 Identification of savings opportunities.

The identification of aspects of current use patterns from which energy cost savings are likely to be possible can be approached in two ways; by an inspection of the data by a human "expert", and by inspection of the (processed) data by an Expert System. The Symphony application takes the former approach, and presents the energy use information graphically (using one of the strong points of (Symphony) spreadsheets) in a number of ways which can be expected to draw the attention of a human expert. One of the aims of this project has been to explore the use of expert systems to identify aspects of energy use patterns which are likely to offer cost savings. Throughout the prototype development stages, it was hoped to achieve this aim by using a relatively simple statistical analysis (ratios of peaks to means) of key sets of figures (Maximum demands, unit consumptions, and load factors) to identify aspects offering high savings. A further goal of identifying significant overall, and cyclic trends was identified, but was not explored in depth (see Appendix H for further details).

#### 6.1.2 Analysis of methods of reducing energy costs.

Having identified aspects of the current pattern of energy consumption which are offer cost saving potential, the analysis of actually savings was envisaged to involve the user in utilizing his/her knowledge of the details of the particular plant to propose changes to the load usage pattern, and the Expert System application to advise firstly whether the proposed change is feasible/desirable, and secondly what (cost) effect the change will have.

#### 6.1.3 Relationship between decision support system and Symphony ECMES.

The relationship between the decision support system and the remainder of the application was initially envisaged to be as shown in Figure 10; ie the decision support system was intended to obtain data from the spreadsheet application (either directly or via intermediate (summary) data files output by the spreadsheet), would process this data, and return the results (primarily consisting of summary conclusions) to the spreadsheet for presentation to the user.

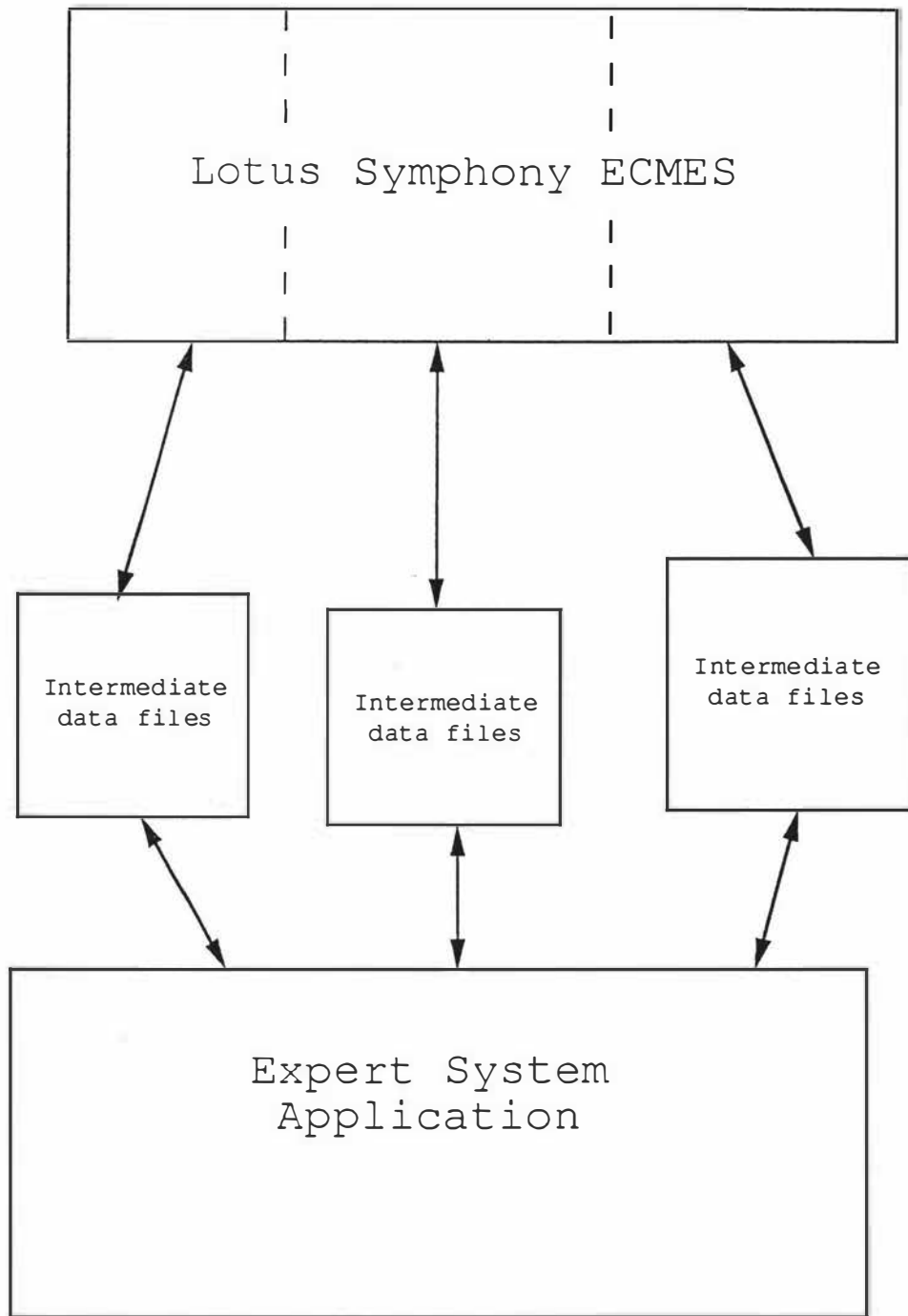


FIGURE 10: SYSTEM INTEGRATION, VERSION 1

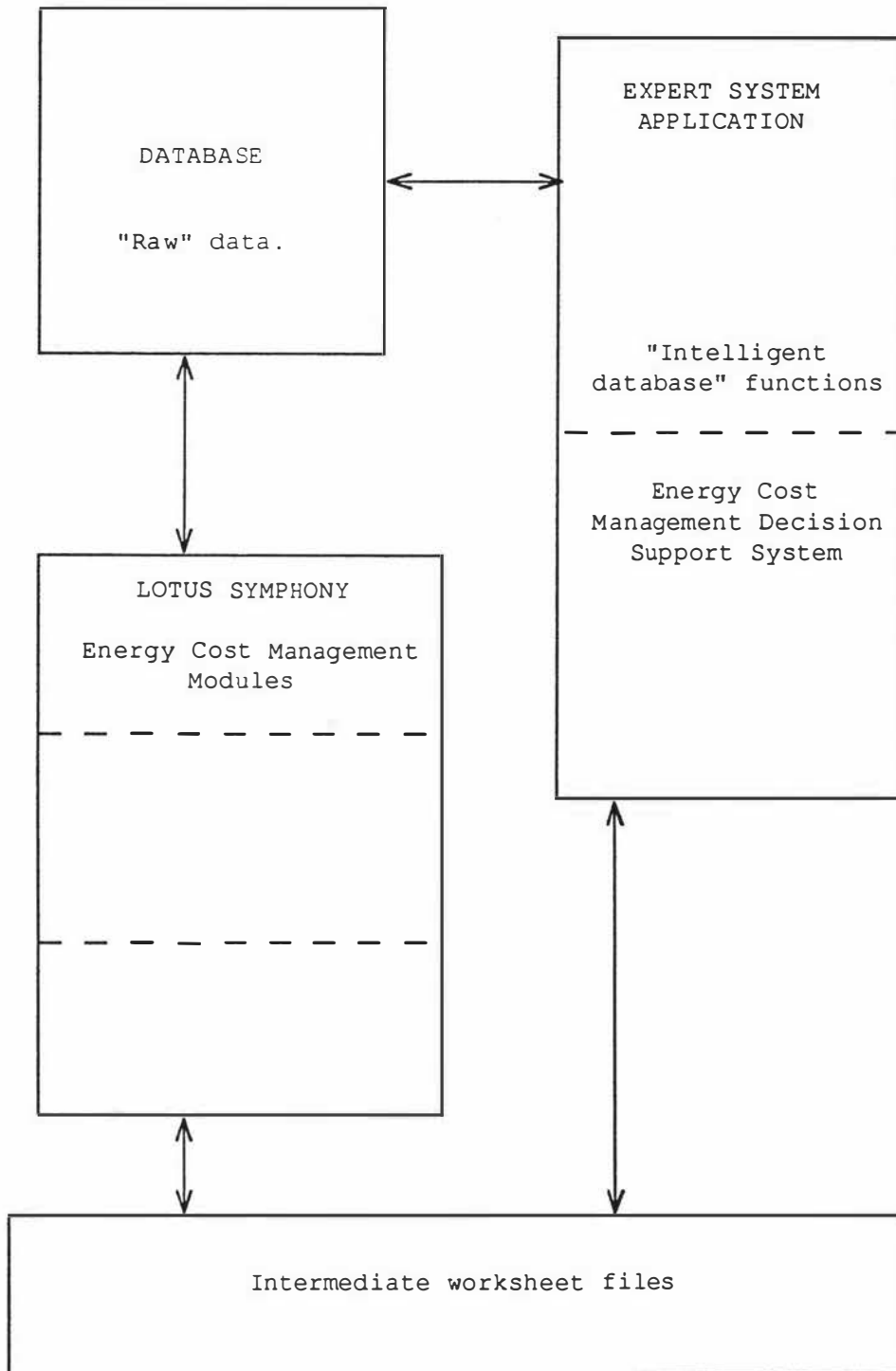
#### 6.1.4 Relationship between decision support system, Symphony ECMES, and data structures implicit in the ECM field.

At a slightly earlier stage in the process of refining the project aims, the importance of accurately modelling the data was appreciated. The data model of Figure 7 was developed to show the ideal relationships between data entities, and was then modified in the interests of processing efficiency to that shown in Figure 8. Note; the development of these models is described more fully in section 5 of this thesis. This arrangement envisaged that the "authorized version" of the data be always held in a (relational, disk based) database application.

A requirement for assistance from a decision support system application to validate and adjust raw data was also identified; this requirement, plus the requirements for data storage, are detailed in section 5 of this thesis.

The concept for integration of the software packages (and particularly the data used by these packages) at this stage was as illustrated in Figure 11.

As with the earlier version, it was envisaged that the spreadsheet would export data to summary data files, which would be read by the decision support system, which in turn would export its results back to the spreadsheet (either directly, or via intermediate data files).



**FIGURE 11: SYSTEM INTEGRATION, VERSION 2**

## 6.2 DEVELOPMENT METHODS.

The prototype development, as described in sections 6.3 to 6.5, has followed a highly iterative and evolutionary path; attention is drawn to the statement at the start of section 6, to the effect that the order of presentation of these sections is logical, as opposed to strictly chronological.

The "development" of the project as a whole included several types of activity:

- Definition of high level aims;
- Evaluation of software packages;
- Definition of specific requirements (which at their final stages of refinement commonly became set of actual production rules in the knowledge base);
- Coding and debugging the application, and
- Evaluation of results.

Many of the steps of the development process were highly iterative, particularly those associated with the refinement of aims and specific requirements. Other steps were taken once only; the selection of the VP Expert software package was not reviewed at each prototype stage. It is interesting to note that Harmon and King [10] recommend the commitment to a software package as the first step in the development of a small "knowledge system", even prior to the definition of overall aims! The chapters in Harmon and King [10] are the only (semi) structured approach the author has found to the development of small knowledge systems, and this approach is far from being either rigorous or detailed. The majority of other literature (for example Weiss and Kulikowski [5]) surveyed suggested that development should proceed by the progressive refinement of an initial prototype (with no hint of the method used to design the initial prototype), based on the reactions of the human expert to the prototype.

It is also interesting to note that Harmon and King [10] distinguish between "expert systems" (designed to completely replace a human EXPERT), and smaller "knowledge systems" designed to systematize a simpler subject and to provide guidance to less-than-expert staff. This distinction seems a very useful one for a project such as this, and it is not hard to envisage a number of other relatively small subject areas (in terms of numbers of rules) to which a low cost expert system shell such as VP Expert could be applied effectively.

In so far as any method for the development of the specific prototypes can be recorded, development tended to follow the cycle of;

Consultation with the Expert,

Interpretation of results of above,  
Translation of requirements into rules, and  
then into code,  
Testing by developer, both for correctness in  
terms of program operation, and (as far as  
possible) for conceptual correctness,  
Further consultation with the expert.

The advice (discovered far too late in the project!) which has proved to be the most useful is contained in Weiss and Kulikowski [5], under the heading of "The art of designing an Expert Model", and reads as follows; "The single most important piece of advice that one can give to a model designer is to build a prototype model as soon as possible. Because expert reasoning problems are frequently poorly specified, one needs to have something concrete to view and 'lay hands on'. It is particularly important for the expert to see something running early ..... One of the sacrifices one has to make in building expert systems, is to be constantly told about the weaknesses and flaws in the system that is being designed."

Many refinements have also emerged as a result of an increasing knowledge of the strengths and weaknesses of the VP Expert, Symphony and other packages; Further refinements have emerged as a result of implementing some of the original aims, and observing the results. Examples of the latter include the development of the more extensive interactions between the decision support system, and the database files recording load movement.



### 6.3 DEVELOPMENT OF THE MODEL 1 SUPPORT TOOL, FOR HIGH LEVEL (ENERGY COST MANAGEMENT) DECISIONS.

#### 6.3.1 Development of Model 1 (the first prototype).

##### 6.3.1.1 Knowledge acquisition

Knowledge acquisition on the subject of energy cost management was approached from three directions:

Firstly, personal experience in the energy field (though not precisely in the field of energy cost management), provided background material;

Secondly, a limited amount of literature on the subject was available; and,

Finally, several meetings were held with Professor Monteith, with the object of determining the methods and techniques actually used by an Expert in this field.

On a slightly different vein, a questionnaire was prepared and issued to attendees of several of the Energy Cost Management Seminars run by Professor Monteith (see Appendix I) with the aim of determining users' requirements for a Decision Support system. Unfortunately, very few responses to this questionnaire were received, and the information gained was of no practical assistance.

This perhaps illustrates one of the classic problems of software development; that is, the difficulty Users have in accurately identifying the functions and facilities which will be of most use to them.

##### 6.3.1.2 Selection of ECM aspects to be offered Decision Support.

As detailed in section 4.2 of this thesis, the ECM application developed by Prof W Monteith (using Symphony) consists of several modules, each covering different aspects of ECM. It became evident at an early stage that the development of decision support application(s) to cover all aspects addressed by the Symphony application would require more time than was available, and also that some aspects of the Symphony ECM application offered higher potential benefits (from decision support expertise) than others.

Following discussion, it was decided to restrict the scope of this thesis work to the electrical aspects (as opposed to gas) of the spreadsheet model

##### 6.3.1.3 Requirements for decision support application

(identified at project definition stage);

a/ Relationship between decision support system and Symphony ECMES.

Since one of the aims of this first prototype was to clarify the final direction of the project, the

direct extraction of data from the spreadsheet was not implemented, rather the assumption was made that the user had the printed outputs of the Symphony ECM application available.

b/ Overall aims.

The higher level aim for this first prototype was to clarify objectives for latter stages of project, by providing a working prototype for the Expert to view and comment upon.

c/ Specific functions and aims of the decision support system;

To attempt to systematize the high level decisions which would need to be made within a business in the course of setting strategies for energy cost reductions, to provide a "smart checklist" for essential factors in each decision, and to provide a first approximation of the financial attractiveness of each proposed decision by the use of few carefully selected parameters.

### 6.3.2 Prototype development

#### 6.3.2.1 General

In keeping with the aims noted in section 6.3.1.3, the first pre-prototype decision support system (LJREA6.KBS, found in appendix J.1) took a very broad-brush approach to the provision of expert advice regarding ECM; The user of LJREA6.KBS is allowed to select from four aspects of ECM; MD control, load rescheduling, alternative energy, and alternative tariffs. As mentioned previously, these options were restricted to the electrical aspects of ECM. Within each of these options, the user is asked a series of questions regarding the nature of the energy demand, and the business environment in question; these result in a recommendation regarding the most fruitful area/method for energy cost reduction: A further (minimal) series of questions establishes the details of the probable energy saving, and at the end of a few questions regarding economic factors, the user is presented with an anticipated value for the annual cost savings, and the present worth of the option. Simple means are provided for the user to vary the value of the variables input, to explore the effect of changes.

Textbooks on expert system development (for example Harmon and King [10]) frequently note that attempts to apply (the current state of) expert system technology should not be made to an application in which a/ the problem would take more that about 30 minutes for a human expert to solve, and b/ there are more that a few tens of possible conclusions.

An initial assessment of the proposed scope of this prototype indicated that these two criteria were met.

### 6.3.2.2 Requirements analyses and development of rules

Having established the four "interest areas" in which decision support was to be provided, it was then necessary to develop the minimum set of production rules which would allow a conclusion to be reached.

#### a/ MD control.

In the area of Maximum Demand control, the questions asked by the expert systems are aimed at discovering the largest amount of load which can practically be removed from the current peak load occurrence.

#### b/ Load rescheduling.

Although this option makes comparatively minor use of the functions which are unique to expert system technology, it provides an illustration of the use of small quantities of information to provide a useful result. The only values required are the unit tariffs in both the zones between which load is being rescheduled, the actual annual load in the source tariff zone, and the proportion of load which is to be rescheduled. The annual savings can then be calculated simply; see Rule 38, file LJREA6.KBS, Appendix J. The use of expert system functions here is simply to check that the proportions of load proposed for rescheduling are consistent with the sizes of zone between which load is being shifted; for example, it is impractical to shift more than 40% of the load used during a 5-day working week to a 2-day weekend.

#### c/ Alternative energy.

Significant factors in this area include the availability of alternative fuels, the ratios of energy use for mechanical work, as opposed to production of heat, the opportunities for selling quantities of surplus heat locally, the temperatures at which heat is required (quality of heat) etc. The conclusions include such recommendations as "Investigate the use of cogeneration systems", and "consider alternative fuel fired heating".

#### d/ Alternative tariffs.

Rules covering this option were not completed within the limited time available.

Within each "area of interest", as soon as the expert system came to the point of suggesting a course of action, it proceeds directly to obtain (either from information already supplied, or by asking further questions) estimates of running costs, annual cost savings, economic evaluation period etc. From these comparative present worths of various options are calculated and presented.

### 6.3.3 Testing and results, Lessons learned.

The evaluation of LJREA6.KBS revealed two main conclusions; Firstly, although it was shown to be

possible to obtain useful results from the input of relatively small amounts of user data, it was recognised that the user input required was data of a type which would most likely not be immediately to hand. In this sense the usefulness of LJREA6.KBS would be more apparent as a preliminary step to the use of the Symphony ECM application, rather than as a supporting application to be applied after a preliminary analysis by the Symphony ECMES. It was therefore considered that a refined knowledge base which built on, and made as much use as possible of (derived) data from the Symphony ECMES, was needed. Secondly, doubt was expressed over the feasibility of designing a knowledge base which was sufficiently general as to be relevant to the (very wide) range of organisations interested in ECM, while containing sufficient detail to allow useful results to be achieved. Thirdly, (and especially in the case of the load rescheduling option), while potential savings could be identified and quantified, no more detailed analysis of the practicality of achieving these savings was possible.

The Expert advice on this problem was that it should be possible to avoid any reference to other than the demand and cost figures, and to leave the consideration of the specific business environment strictly to the user.

Several other observations were made by the Expert, relating to specific errors of concept within this knowledge base. One such error was the implicit assumption that the only way to effect reductions in MD was to shut down or reschedule a single, large load. It was pointed out that in many practical situations, the most practical way to effect a MD reduction is to arrange for the shutdown of a number of small (non-critical) loads at the time when a large and often critical load must operate. The appreciation of this point affected the design of the following prototypes.

A further item of advice placed greater emphasis on the Maximum Demand control aspect of the overall ECM issue.

#### 6.4 DEVELOPMENT OF MODEL 2, AS TOOL FOR MD CONTROL BY LOAD PATTERN ADJUSTMENT.

##### 6.4.1 Requirements analyses and development of rules.

Armed with the experience gained from Model 1 (LJREA6.KBS), and the recommendations of The Expert, the development of a second prototype (with the aim of retaining the good points of Model 1, and eliminating the bad) was undertaken.

A major decision at this point was taken to further restrict the scope of application of the decision support systems to the reduction of Maximum Demand charges; this decision was made on the basis of the Expert's advice (after viewing the first prototype) that this appeared to be the field in which the greatest potential savings from the use of expert systems would be available.

The solution to both of the weaknesses of LJREA6.KBS was to be found in extracting a quantity of data on monthly electricity consumption, maximum demand levels, load factors, and instantaneous demand figures (over a typical day), from the Symphony ECMES. The DSS could then derive useful suggestions and observations (NB, as opposed to recommendations) from this data, and secondly allow the user to interactively explore the effects on total energy costs of modifying DETAILS of the load patterns.

The specific requirement identified was that of adding a level of "intelligence" to the rescheduling of loads within a typical day, in such a way as to reduce the peak loading (and hence the maximum demand). It was envisaged that a relatively simple extension to this DSS would also allow evaluation of reductions in costs resulting from unit tariff rates. Note, the "cutoff line" facility developed using Lotus Symphony macros by Prof W Monteith allows a user to vary a proposed load-shed level, and observe the total units of power shed, the times of day during which shedding occurs, and the total cost savings; it does not, however, allow the user to experiment with changing the operating patterns of specific (blocks of) equipment.

The second prototype has several sections; WELCOME.KBS, MD\_CONTR.KBS, MD\_REP1.KBS, MD\_REF1.KBS, and the intermediate spreadsheet. Of these, the WELCOME.KBS knowledge base does no more than provide an entry point, and an initial menu system designed to direct the future user between knowledge bases designed for specific areas of interest.

The second knowledge base, MD\_CONTR.KBS is responsible for extracting the required data from the Symphony ECMES, and analysing the patterns of this

data. The analysis carried out by MD\_REPOR.KBS is primarily statistical, and has three aims; the evaluation of the relative "peaky-ness" of the various sets of data (based on the ratio of standard deviation to mean), the evaluation of maxima and minima which were needed for (eg) checks to ensure that load movements did not create new peak demands, and finally to obtain a coarse indication of the consistency of the data, by comparing the statistical parameters of the daily and monthly demand figures (thus going some way towards the "intelligent database" concept described in section 5.3). Note; with hindsight (plus the benefit of experience), it would probably have been more efficient to carry out some of these functions within the spreadsheet, as opposed to within the expert system application. VP Expert however has quite good facilities for handling numerical data, and the time to load the data is not excessive.

The third knowledge base, MD\_REP1.KBS, was designed as a prototype attempt at achieving the identification of aspects of the current energy usage which could profit from "management". As such, it is a very simplistic attempt, which calculates, for two possible types of "management changes", the expected annual savings in energy costs. The details of these "management changes" are explained to the user when the decision support system is consulted (calculation details can be found in Appendix J) and consist of calculating the savings possible by increasing the load factor (ratio of mean to peak demand) of all months which have load factors lower than the upper quartile figure, are raised to the upper quartile figure. The second possible saving is found by speculating on the possibility of rescheduling the complete monthly load pattern for all months with lower than average load factor to those months of the year when the maximum demand charge rate is also the lowest, an vice versa. A third possibility, rescheduling all of the peak-producing processes into one MD charge-period (and thus avoiding high MD charges in each charge period), is illustrated in Figure 6 but is not directly implemented. Although these suggestions are considered to be reasonable, the analysis is very simplistic, and the reader's attention is drawn to the sections in Appendix H (specification for future work), in which suggestions for improvement of this function are developed.

This analysis, and the presentation of two figures for possible savings at this (early) stage in a "consultation" has one very important function; that is, to "whet the appetite" of the user, and by demonstration the (considerable savings which can result from relatively "gentle" measures, persuade him/her to approach the whole subject of energy cost management constructively.

The final knowledge base, MD\_REF1.KBS was designed to allow the user to explore the effect of moving blocks of electrical load. The use of load rescheduling to reduce maximum demand charges are presented in section 4.1.

After some consideration of what was actually involved in "moving blocks of (electrical) load", the conclusion that movements of electrical load fall into four categories was reached: These categories are;

- 1/ Cases where a load is simply shut off; ie, a load which has been recognised as unnecessary, or avoidable (or for which an alternative energy source has been found).
- 2/ Cases where a load is to be rescheduled to/from a different time of day.
- 3/ Cases where a load is to be rescheduled to a different MD charge period.
- 4/ Cases where a load is to be imported from another MD charge period (this option is needed to balance occurrences of case 3, above).

It was therefore decided that a central element of the load movement procedure should be a request for the user to identify the load to be treated in each of these ways. Since Maximum Demand is commonly measured and charged for on a 30 minute basis (the highest load drawn over any 30 minute interval), load movements aimed at reducing the MD would also have to be made in multiples of 30 minute periods. In designing the decision support system, it was necessary to decide whether to allow the user to specify a period over which the load movement was to take place, or to build in a default period, (which would have to be equal to 30 minutes). Since the user was to be asked to specify several load categories, it was seen to be essential to constrain the system to always work with a single 30 minute load interval (which also contributed to making the system design less complex technically).

The method selected for the operation of load rescheduling can therefore be summarised as follows;

After selecting a time interval, the user is asked to nominate the load (kVA) to be treated in each of the above four ways; if a non-zero load is nominated for rescheduling, the user is asked the destination of the load. The instantaneous demand loads for the selected time intervals, and the totals of the loads resulting from cases 1,3, and 4 are then updated, and a check is made to ensure that the move has not resulted in the creation of a new peak load, and that the target for imported load has not been exceeded (warnings are given in each such case). In order to allow the user to maintain a mental grasp of the current position and the effect of the changes made, menu options are provided (available after each load movement

is completed) to display a summary of the current position (totals of loads moved for each of the four categories, the current peak load and the time at which it occurs), and a list of the loads in each time interval (over a 24 hr period). Additionally, after each load movement is completed, a "load movement summary" for that movement is displayed.

The reader is referred to Appendix J for a listing of the above knowledge bases. The syntax is very close to "natural English", and should present few problems.

#### 6.4.2 User interface development (principles, problems, solutions)

The ECM field can involve quite large quantities of data; the design of the human interface for any application operating in such a field runs two risks; that of losing the patience of the user by demands for huge quantities of data input, and that of distracting the user to the extent that he/she cannot keep track of the current position (and hence cannot make intelligent choices for the next action). Opportunity was seen for minimizing the quantity of data input required, while providing to the user the means of always knowing the current situation.

Three simple means have been provided to assist the user to keep track of the nett results of all changes proposed to the original load pattern; these are:

- a/ The facility to set targets, in terms of either a maximum demand figure, or a load factor. Note, the expert system checks a user's proposed target for feasibility by calculating a "cut to fill ratio" (which must be less than 1.00). A facility to nominate a further target, for the total load to be imported to this MD charge period, is also provided.
- b/ The facility to display (in a single table, for each 30 minute interval throughout a "typical day") the original maximum demand, the maximum demand resulting from the sum of all changes so far proposed, the target maximum demand, and the remaining difference between the "new" MD, and the target MD; and
- c/ The facility to have displayed a running total of all the loads moved under the above categories.

A further facility consists of a set of validity checking rules which are applied to each proposed load movement, and which warn the user of several possible events; in keeping with the philosophy of the "decision



support system", these checks do not actually prevent any load movement.

The checks warn the user if;

A load rescheduling move would result in the creation of a new peak demand (at some time of day different from the original peak location,

A load movement would leave a negative instantaneous demand at any time interval,

The total load imported exceeds the target figure.

#### 6.4.3 Testing and results, Lessons learned.

Although it was considered that the development was now on the correct track, and that a worthwhile product was emerging, the evaluation of MD\_REF1 identified several problems;

- 1/ The significance of the fact that the numerical values of the loads available for redistribution do not form a continuous function, but rather a set of discrete values was appreciated. The discrete values correspond to various permutations of the on, off and idle states of a finite number of items of equipment.

The lack of any constraint on the values of load moved in MD\_REF1, and the lack of any identification of loads with equipment was seen to be a conceptual fault in MD\_REF1.

The problem arising from this error is that there is no method of confirming that a load nominated for movement/rescheduling is a valid value, ie a value which corresponds to a real block of equipment.

- 2/ Secondly, having moved, shed, rescheduled etc loads to achieve a satisfactory daily demand curve, the user had no record of the individual actions which had lead to this satisfactory curve, (and hence a real problem in effecting the changes); Finally, there was no (non-human) means of ensuring that the same load was not shed (or exported, or rescheduled) from the same time more than once. In effect, there was no (computer) check on the logical validity of the proposed load movement.

APPENDIX J comprises a source code listing of the two pre-prototype versions of the decision support system; these are included both for completeness, and also to show the progression of capabilities and techniques in the DSS development process.

6.5 DEVELOPMENT OF MODEL 3, AS TOOL FOR MD CONTROL BY OPERATION RESCHEDULING. FINAL VERSION:  
MD\_REPOR.KBS, & MD\_REFIN.KBS

6.5.1 Requirements analyses and development of rules

The solution proposed to the problem 1/, noted in section 6.4.3 was to maintain a database of equipment identifiers, with corresponding load demands. This file is identical to the MACHINE entity identified by the data modelling exercise described in section 5.1.2 except for one small difference; the MACHINE entity of described in 5.1.2 does not distinguish between items of equipment which can or can not be operate independently; the above file implies that only (groups of) items which can be operated independently be recorded). There are two possible sources for this information; it would be possible for the file to be continuously updated/created as items are nominated by the user, or alternatively, the data could be downloaded directly from the inventory module of the Symphony ECMES (always presuming that the intended user has purchased this module). The prototype knowledge base uses the former method, however future versions might profitably use a combination of these two methods; ie, download "base data", and update from Decision Support System.

The solution to the second problem evidently requires that some record be kept of the (revised) state (ie, on, idle, or off) of items of equipment during particular time intervals. The file thus described is essentially identical to the MACHINE-SLOT entity identified in the data modelling exercise (described in section 5.1.2), with one vital difference; whereas the MACHINE-SLOT entity required the recording of the state of every item of equipment during every time interval (and required some 95 MBytes storage), the proposed file record only the changes to machine states. IT IS SUGGESTED THAT THIS IS THE ESSENCE OF THE DIFFERENCE BETWEEN A "BRUTE FORCE" (MATHEMATICAL OPTIMISATION) APPROACH TO A PROBLEM, AND AN EXPERT SYSTEM APPROACH TO THE SAME PROBLEM. The proposed file therefore records only the data which is essentially required by the user. This usage of the file assumes a certain a degree of common sense on the part of the user; for example, it assumes that the user will not propose rescheduling the operation of equipment from a time slot in which the equipment is not in use.

A file operated on the principles of the "MACHINE-SLOT" ENTITY described by the data model would, it is true, allow the state of a machine to be checked; however such a file is impractical due to its size, and the information is (in practice) almost entirely

redundant, since the user is intimately familiar with his equipment's current operation pattern (and can readily confirm any assumptions).

It is strongly suggested therefore that the gains of available by using the MACHINE-SLOT file in the "changes" mode (and eliminating the necessity for loading the 96 MBytes of base data) outweigh the advantages of using the file in the "current state" mode.

The configuration of the final version of the prototype decision support system is illustrated in Figure 12.

#### 6.5.2 User interface development (principles, problems, solutions).

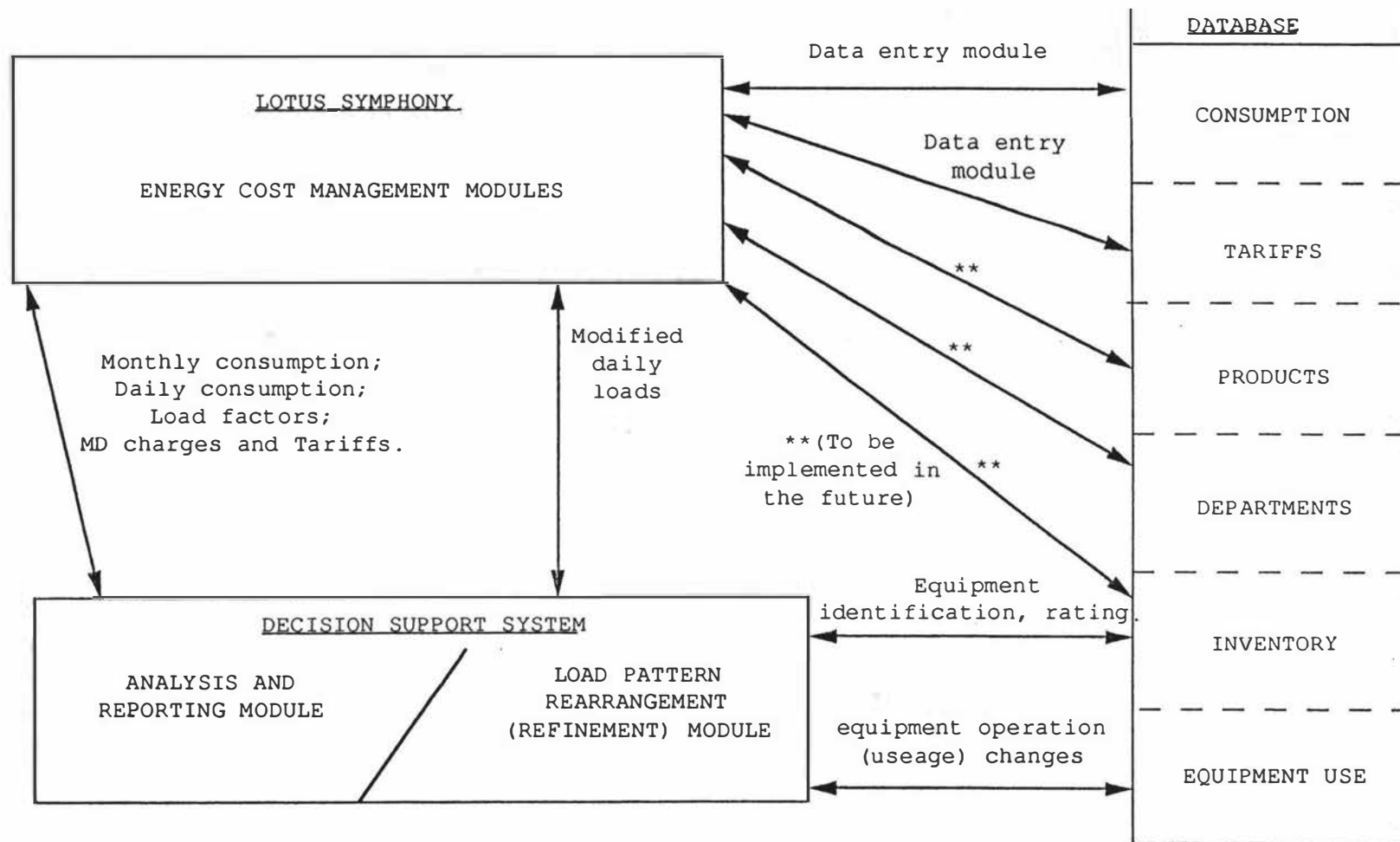
The user interface for this model is similar to that described in section 6.4.2, however several important features have been added.

These additional features consist of;

The prompts for information regarding equipment rating, should a previously unknown item be referred to, and confirmation of rating if a known item is referred to by the user;

Warning messages associated with load rescheduling proposals which appear to be either undesirable, or illogical; and,

The facility to review (on screen, or printer) the list of all individual proposals for load rescheduling made during a "consultation".



**FIGURE 12: ENERGY COST MANAGEMENT DECISION SUPPORT SYSTEM; FINAL CONFIGURATION**

## 6.6 PROTOTYPE DEVELOPMENT PROBLEMS AND SOLUTIONS.

The problems encountered by the author in this project fall into three categories;

1/ The conceptual problems associated with accurately appreciating the issues associated with ECM; these are covered in sections 6.3 to 6.5.

2/ The problems which were associated with the idiosyncrasies of VP Expert; These are covered in Appendix E, and examples are discussed in the Appendices D and J (source code of the prototype knowledge bases). Detailed information regarding VP Expert can be found in "The VP Expert manual [4], and the "READ.ME" files which Paperback Software use when updating their products.

3/ The "technical" problems of program development in a programming environment based on the use of "result addressable procedures", as opposed to "name addressable procedures" (author's terminology; see section 3.3.3.

The principle problem encountered in this category was that of ensuring that all possible permutations and combinations of factor values produce logical results. This type of problem arises when a knowledge base contains rules with large numbers of logical comparisons in their conditional sections. A simple mathematical comparison of the number of rules in a knowledge base, and the number of possible permutations and combinations of allowable values of all factors (variables) will frequently show that only a very small proportion of the possible permutations and combinations will result in the "triggering" of any rule. In the case of VP Expert, the failure to trigger a rule, or find a required value will drop the (now puzzled) user back to the system level, with no hint of the reason. Three approaches to solving this problem have been developed in the course of this project;

1/ Provide a catch-all default rule which displays a message such as "Your problem is beyond the power of this poor computer.. you had better consult the REAL expert".

Note; such a clause could be vitally important in (for example) a simple knowledge base designed to guide non-professional medical staff.

2/ Simply ensure that the combinations which would cause the application to collapse are so ridiculous that a collapse is about the only sensible result anyway! The practical difficulty with such an approach is that of ensuring that ALL non-ridiculous solutions have been covered.

3/ A further method proposed by the author for substantially eliminating this problem is firstly

to restrict the number of logical comparisons in the conditional section of any rule to two, of which at least one must be determined by the outcome of some other rule, and secondly to provide both a THEN and an ELSE options for every rule. With one factor set elsewhere, only two possible outcomes can result from the testing of the remaining comparison (true or false), and the rule produces a result in both cases. This method will therefore definitely eliminate the above problem. Due to VP Expert's handling of ELSE statements (see Appendix E), this proposal would need to be handled within VP Expert by using pairs of rules having complementary conditional sections.

In practice, various combinations of these methods have been tried. No foolproof method of ensuring that all illogical combinations have been covered has been found, but the method in 3/ above is suggested as the best method (particularly at the early design stage) to prevent problems. Any time a rule which has a large number of comparisons is encountered, questions should be triggered (in the mind of the designer) of what really are the conclusions associated with the other variable values, and whether intermediate conclusions (perhaps trivial, but valuable as links in the logical sequence) have been missed.

A second type of problem was encountered less frequently; expert systems shells such as VP Expert have no equivalent of the "local variables" found in general purpose programming languages; ALL variables are "global". This means that any value which is given to a variable during one part of a consultation, is available during all other parts of the consultation. In the case of a commonly used variable such as "time", the developer needs to consider carefully which "time" is to be used by the decision support system in each case. This type of problem is often conceptual in nature, caused by a either a variable or a rule which is not sufficiently tightly defined. This type of problem can be difficult to cure, but it is even more difficult to say with any certainty that all such have been eliminated.

## 6.7 TESTING AND EVALUATION (OF FINAL VERSION) .

### 6.7.1 Review of aims.

The aims developed in section 6.1 can be summarised as;

The improvement of the Energy Cost Management function by the integrated use of more than one software package, and in particular, the combination of Expert System with spreadsheet.

The use of the capabilities of an Expert System to identify aspects of current energy use likely to offer significant savings.

The analysis of possible methods of reducing total energy costs, particularly in the field of Maximum Demand control.

A further aim was to identify promising directions for future work.

### 6.7.2 Operation of final version of decision support system (model 3)

The reader is referred to APPENDIX C for a complete description of the operation, inputs and outputs of the final version of the decision support system.

The reader is further directed to APPENDIX D, which contains an annotated copy of the source code listing for the final version of all sections of the decision support system developed.

The final configuration of the decision support system is illustrated in Figure 12.

The functions of the final version of the decision support system can be summarised as follows;

Note; many of these functions are selected from menus, the user of the decision support system is not constrained to use them in the following order.

a/ Data on monthly electric energy consumption, daily instantaneous demand, load factor information, and Maximum Demand charge rates is extracted from an intermediate (spreadsheet) worksheet by the decision support system (the size of the main Symphony worksheet precludes direct use by VP Expert)

b/ The data extracted from the (intermediate) spreadsheet is analysed, and two types of conclusion are presented to the user; Firstly, the user is advised of the quality of correlation between the daily and the monthly figures. This is essential, since savings estimated on the basis of modifications to a daily load pattern will only be accurate if the day chosen is

typical for the month. Secondly, the user is offered the opportunity to set target figures (either in terms of a load factor to be achieved, or of a MD figure to be achieved) for the daily instantaneous demand pattern, and also for the total quantity of load to be "imported" into the current MD charge period.

c/ The user is presented with two annual cost savings figures, both of which are "intelligent estimates" of realistic goals, based on the consumption patterns input.

d/ During the phase of the consultation in which proposed cost saving measures are evaluated, the user is asked at each stage to;

Nominate an item of equipment whose load is to be rescheduled. The expert system then checks the MACHINE database file for an entry under that name; if an entry is found, the rating of the equipment is retrieved, if no entry is found the user is asked for the rating, and this information is added to the database.

Nominate the time slot within which the usage of the equipment is to be modified, and the modification required (turn off, reschedule within MD charge period, reschedule to outside MD charge period, turn on).

The expert system checks the MACHSLOT database file for any record of modification to the operation of that item of equipment within the specified time slot; if no entry is found, the proposed modification is recorded in the MACHSLOT database, if a record is found the modification proposed is checked to ensure that it is "allowable" (an example of a "non-allowable" modification is the turning off of equipment whose operation has already been rescheduled to another time).

In the case where the user proposes to reschedule a load, the expert system also checks the current load pattern to ensure that;

The proposed move has not created a new peak load (this is also checked whenever the user specifies a load to be turned on within a time slot),  
The target for total imported load has not been exceeded,

The existing demand within that period is larger than the rating of the equipment whose load is to be rescheduled (if not, the user is warned that the equipment could not have been "on" within that interval originally, so the proposed move is invalid).

e/ At any stage during the consultation, the user can obtain either a running total of the the loads whose operation has been modified (categorised according to the type of modification made), a list of all modifications (identifying equipment, time slot, and modification type), or a display showing , for each 30 minute interval, the original demand, the target



demand, the modified demand, and the remaining difference between target and modified demand.

f/ The use can also instruct the expert system to load the modified daily load pattern back to the (intermediate) spreadsheet.

### 6.7.3 Evaluation of final version against aims.

#### General;

All of the following evaluations need to be qualified by the fact that the final prototype has undergone only the first stages of testing.

#### 6.7.3.1 Integration of software packages

The final prototype version of the decision support system reads data from, and to, both spreadsheets and database files; the aim of "integration (of the functions) of software packages" has therefore been largely achieved.

In order for a user to perceive that close integration has been achieved between the operation of two packages, and to gain the maximum benefit from that integration, it is important for the user to have convenient access to the functions of both packages; for example, to be able to toggle quickly and conveniently between viewing a graph (within the spreadsheet) and consulting a decision support application (within the expert system shell).

The inability to "call" Lotus Symphony from within VP Expert, which is almost certainly related to the size of the Symphony program plus application, is a significant obstacle to achieving this aim.

#### 6.7.3.2 Identification of potential savings

As is noted in section 6.7.2, the present decision support system does suggest "realistic" target savings, basing these targets on the load patterns input; however the original aim of identifying specific features of the input load pattern, and directing the user to these, has not been achieved.

Significant progress towards the latter goal has however been made, and is described in section 6.7.3.4, and in Appendix H.

#### 6.7.3.3 Analysis of methods of achieving savings

The functions of the final prototype (model 3) are largely directed towards this aim. The operation of this application is described in section 6.7.2, which also demonstrates the large extent to which this aim has been achieved.

Several small weaknesses remain, however; The lack of facilities for other than extracting and replacing data associated with databases and spreadsheets has meant that the "list all movements" database (MACHSLOT) simply continues to grow; there is no facility for

deletion of (blocks of) records. A possible interim solution would be to provide a "session" field in the MACHSLOT database; the user could then identify a "session" at the time when changes were to be made, and all changes would be recorded against that "session"; The facility for a user to specify a period during which equipment is to be turned off has not been implemented, and would be desirable.

Possibly the most significant weakness is the inability to interactively make use of Symphony's graphics capabilities to display the "current state of affairs" as regards daily load pattern; this is a function of the size of the respective software packages, and will not be easily overcome.

#### 6.7.3.4 Specification for future work.

Many of the specification for future work have been developed in some detail: Examples include the case of planning for "pattern recognition", in which the data analysis spreadsheet has been prepared, sample data is available, and the method of approach has been decided; all that is required is development time. A further example is the implementation of the "intelligent database" functions, many of which have been specified.

## 7 CONCLUSIONS

### 7.1 THE VALUE OF INTEGRATED USE OF PC SOFTWARE PACKAGES

As has been noted several times in the text, it is POSSIBLE to implement almost any application with almost any of the "development tool" software packages; the question of which package(s) and strategy to use is determined by efficiency, ease of development etc.

The concept of "mixing and matching" software functions by the integrated use of software packages is attractive as a means of developing a complex application with minimal programming effort, however it suffers from several problems;

Firstly, the software packages are, with few exceptions, not really designed to be closely integrated, and may require some effort to ensure integration of data;

Secondly, the lack of sufficient memory capacity, and the lack of sufficient operating system capability may preclude the quick swapping between package usage which is necessary if an application is to give the appearance (to the user) of being well integrated.

Thirdly, unless developers' versions of packages are available, the cost of purchase of multiple single licence packages is always a disadvantage. Developers' versions are available for more and more products, the exception being spreadsheets; this is unfortunate, since spreadsheets are probably more likely than any other package to form a central element in an integrated application.

While the functional advantages of the integrated use of packages can be achieved with a wide range of combinations of packages, it is likely to be difficult to achieve good integration of operation unless considerable planning effort has been put into the selection of packages and functions at the outset of the project. This principle particularly affects cases where a commitment is made to one package, prior to the detailed consideration of issues of integration.

In spite of these difficulties, the final prototype has shown that good integration of functions is possible, and the experience gained has shown several ways in which still further value can be gained from integrated use of software products.

## 7.2 EVALUATION OF THE DECISION SUPPORT SYSTEM FOR ENERGY COST MANAGEMENT

### 7.2.1 Evaluation of the decisions regarding choice of software development strategy for ECMES.

a/ The choice of integration strategy is difficult to evaluate, since it was heavily influenced by the commitment to the Symphony spreadsheet application which existed at the outset of this project. Had the aims of the project been established before the commitment was made to the Symphony spreadsheet, the evaluation presented in section 4.3.3.2 suggests that advantages could have been gained by developing the application using the VP range of products (VP Info, VP Planner, and VP Expert) or, for a fully developed product for which a wide distribution was envisaged, the use of a TurboPascal toolbox module approach.

b/ The choice of the VP Expert package has been justified by the comparative ease of implementation of the decision support system.

### 7.2.2 Evaluation of the functions and usefulness of the decision support system for ECMES.

The final prototype provides a useful tool for exploring means of reducing the Maximum Demand charges incurred by an organisation, and the resolving of many of the basic issues regarding the interaction of software packages will facilitate the addition of further functions.

The original aim of identifying to the (non-expert) user the most profitable aspects of the current consumption pattern has not been fully realised, although the features built into the "reporting" section of the final prototype (see section 6.4.1 for details) do go some way towards this aim.

As previously mentioned, the experience gained with these prototypes has allowed the direction for future work on this function to be clearly identified.

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The value of the preliminary work, entitled "Application of expert systems to energy use management", carried out by P Greatorex in 1988 (as an B Tech honours research project) is also acknowledged.

APPENDIX A CURRENT ECM SPREADSHEET OUTPUTS

View tariff data

**TARIFFS** CONSUMPT COSTS PROJECTE LOAD CHA EDIT MAIN MEN OTHER

**MENU**

Welcome to ECMES

---

ENERGY  
COST  
MANAGEMENT  
EXPERT  
SYSTEM

**ELECTRICITY COST MANAGEMENT - V1.0**

WELCOME

12-Dec-89 12:59 PM

**Macro**

**Calc**

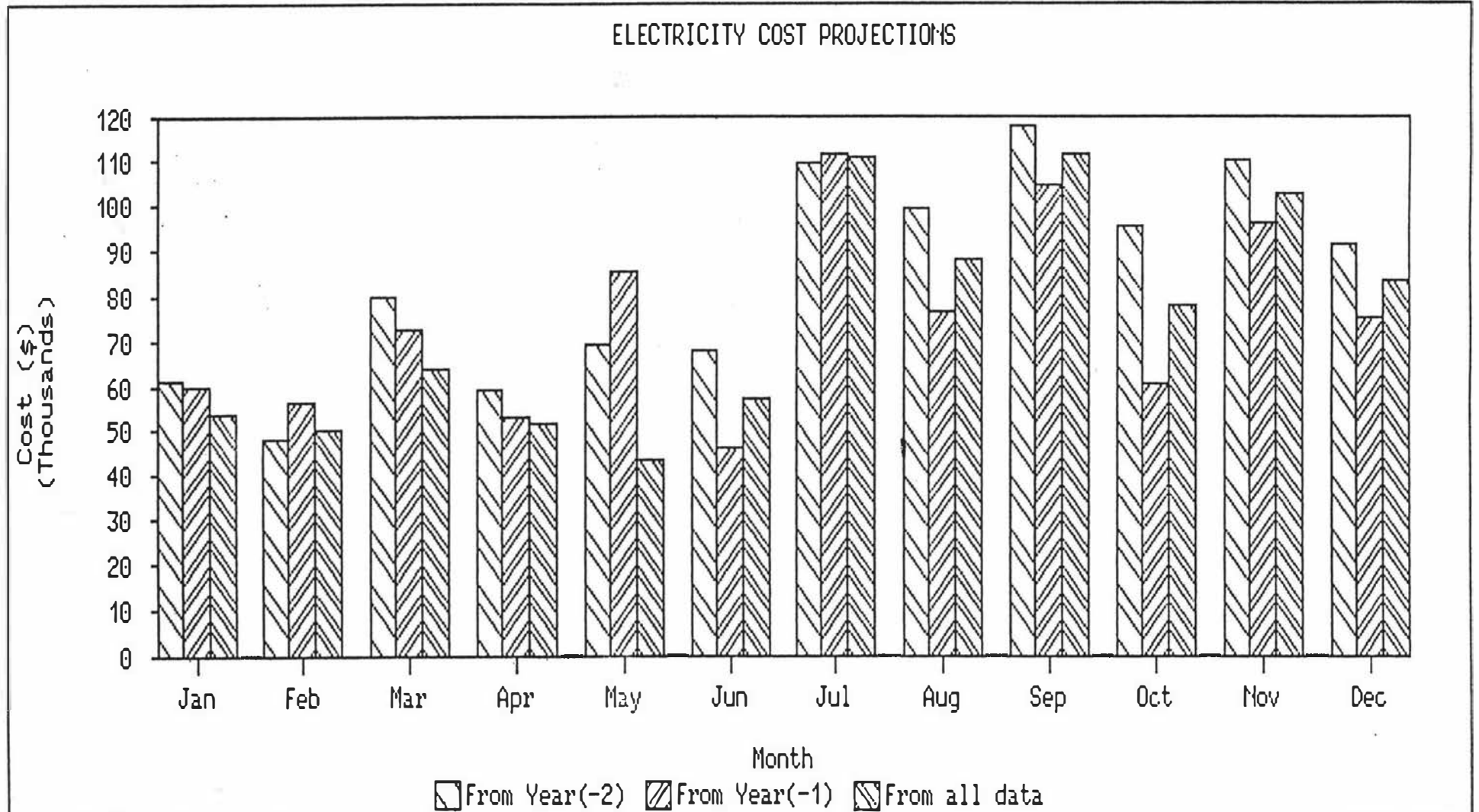
From all data and averages

PROJECTION(-2)

PROJECTION(-1)

AVERAGE COST PROJECTION

**COST PROJECTION GRAPH**



COST PROJECTION

COST PROJECTION

12-Dec-89 12:16 PM

Macro

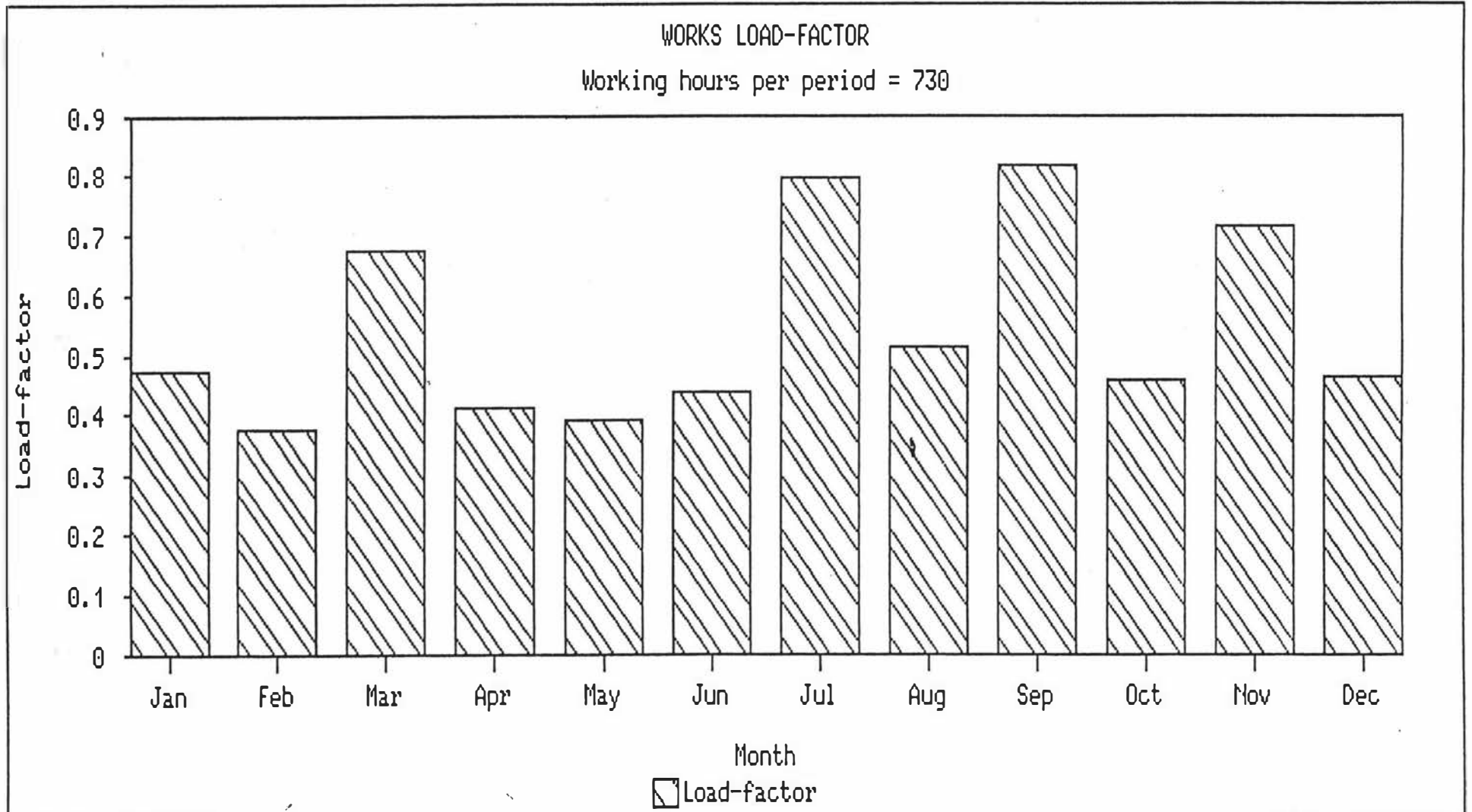
Calc



Load-factor GRAPH

**MENU**

HOURS **LOAD-FACT** WORKS LOA CONSUMPTI MAXIMUM D NIGHT/DAY LOAD CURV



LOAD-FACTOR

LOAD-FACTOR

12-Dec-89 12:17 PM

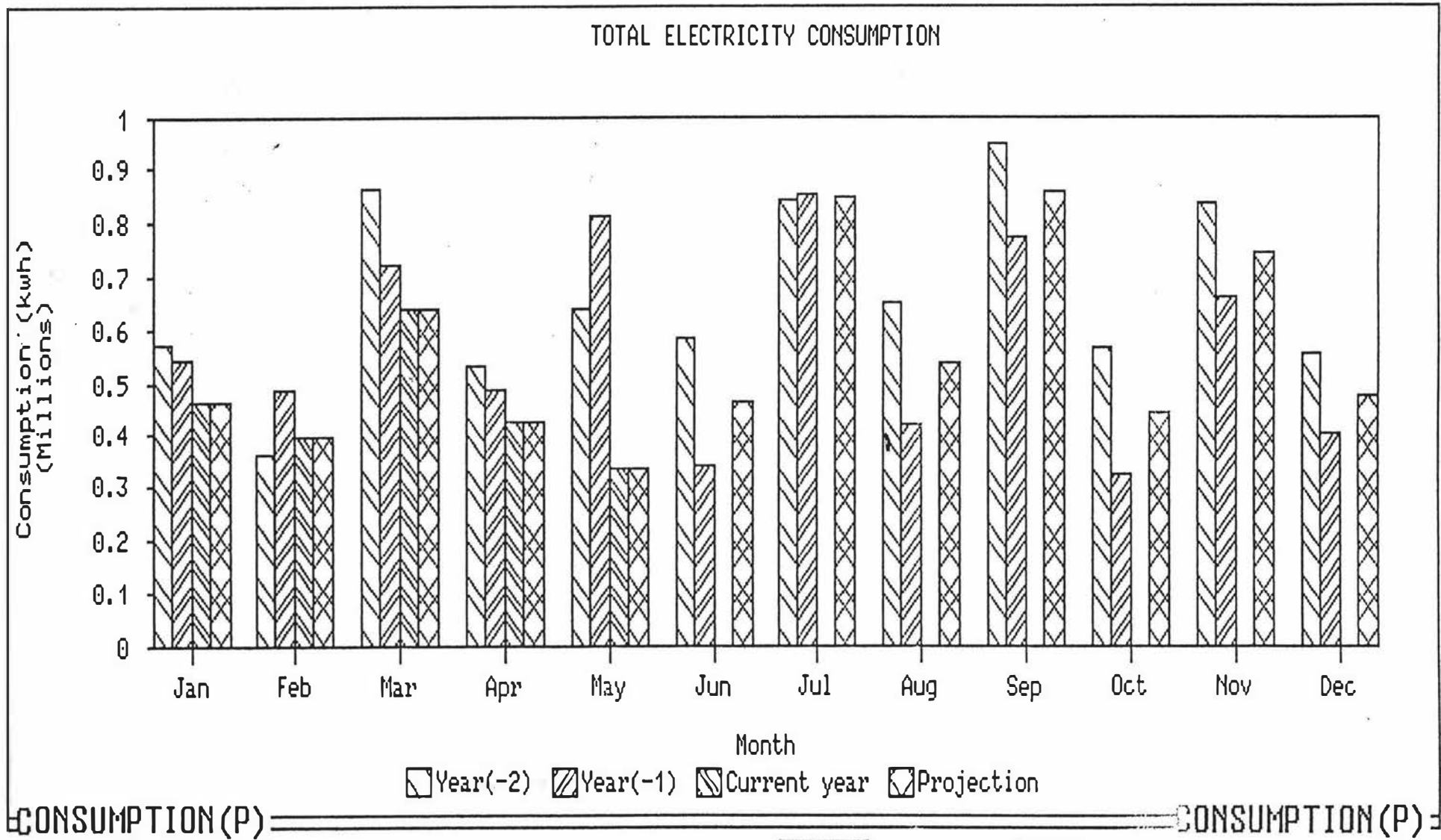
**Macro**

**Calc**

# Electricity consumption GRAPH

MENU

HOURS LOAD-FACT WORKS LOA **CONSUMPTI** MAXIMUM D NIGHT/DAY LOAD CURV



12-Dec-89 12:17 PM

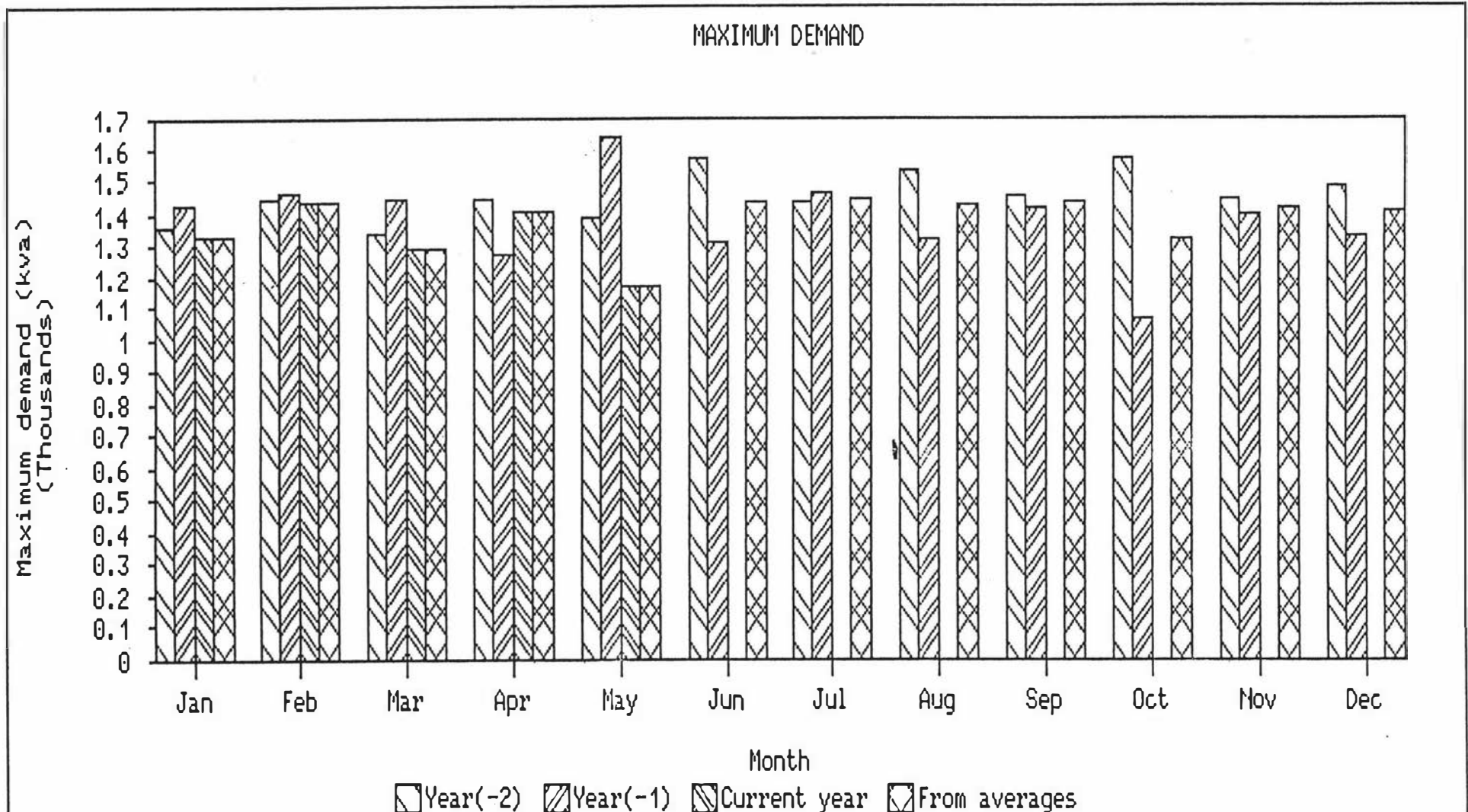
Macro

Calc

Maximum Demand GRAPH

MENU

HOURS LOAD-FACT WORKS LOA CONSUMPTI **MAXIMUM D** NIGHT/DAY LOAD CURV



MAXIMUM DEMAND

MAXIMUM DEMAND

12-Dec-89 12:17 PM

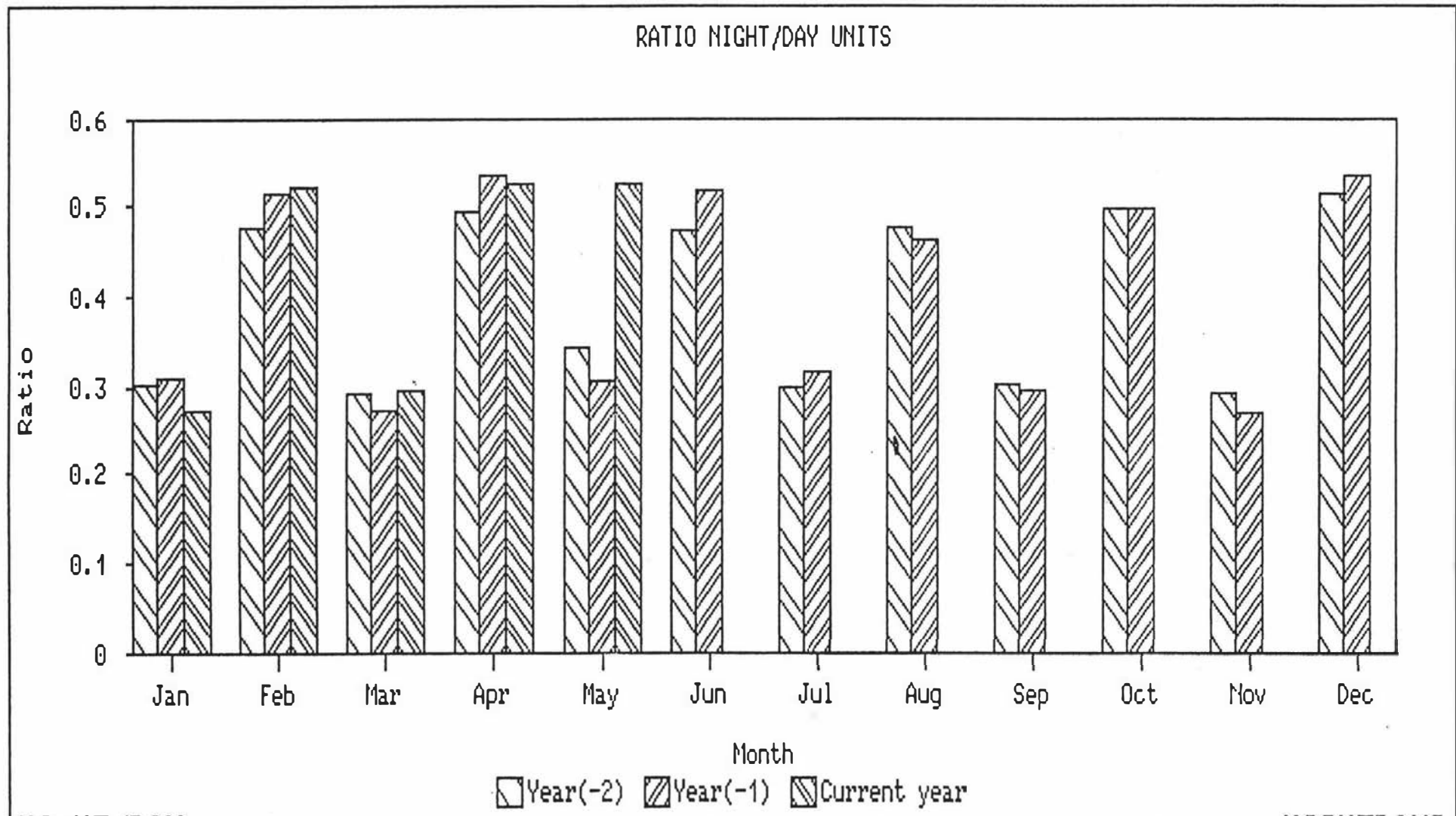
Macro

Calc

Ratio of Night/Day units GRAPH

**MENU**

NIGHT/DAY TABLE **NIGHT/DAY GRAPH** NIGHT/DAY SAVINGS



NIGHT/DAY

NIGHTDAYG

12-Dec-89 12:17 PM

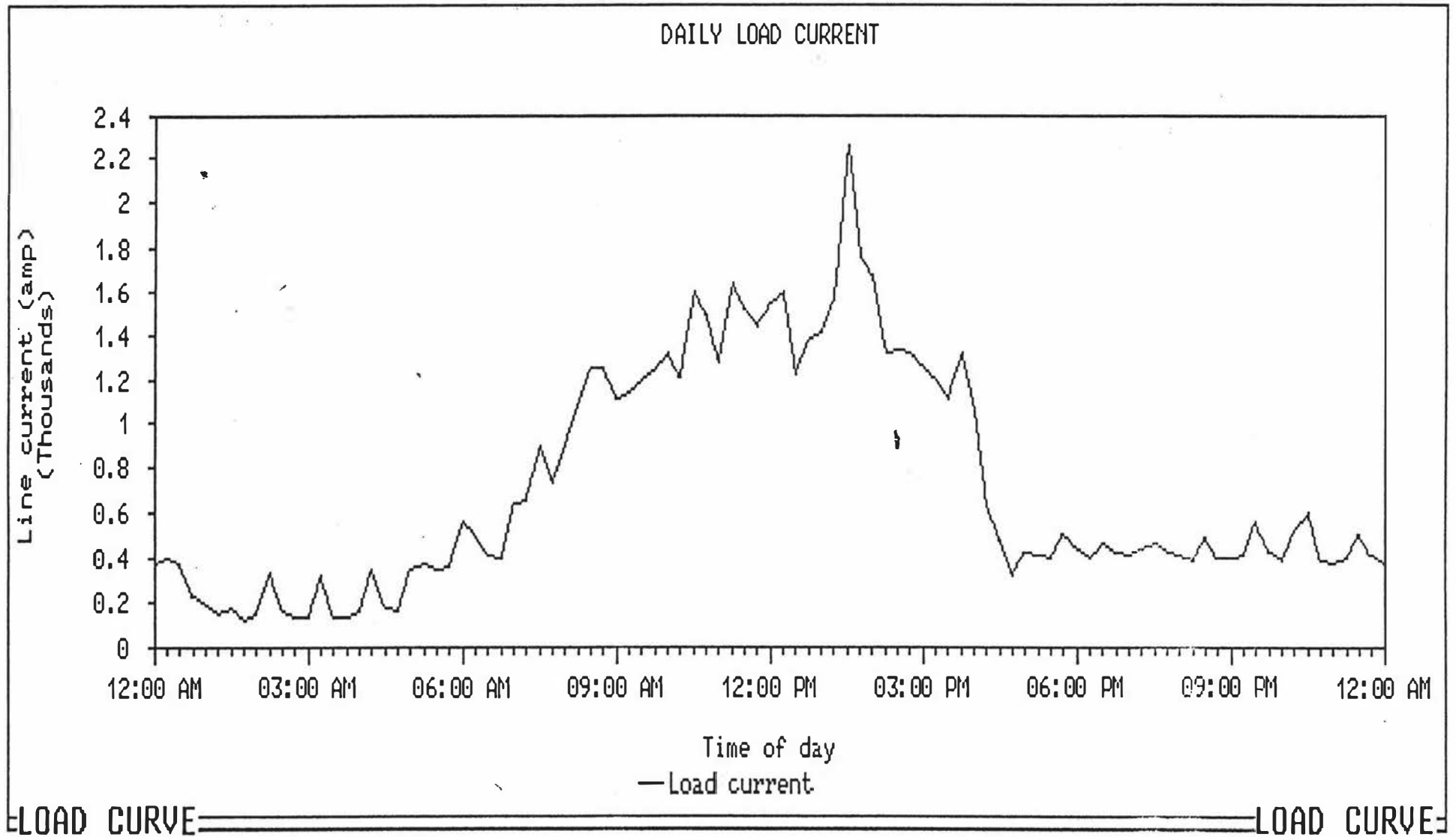
**Macro**

**Calc**

Graph of daily load curve

**MENU**

Load data TABLE **Load curve GRAPH** Daily Demand KVA GRAPH Max Dem Control



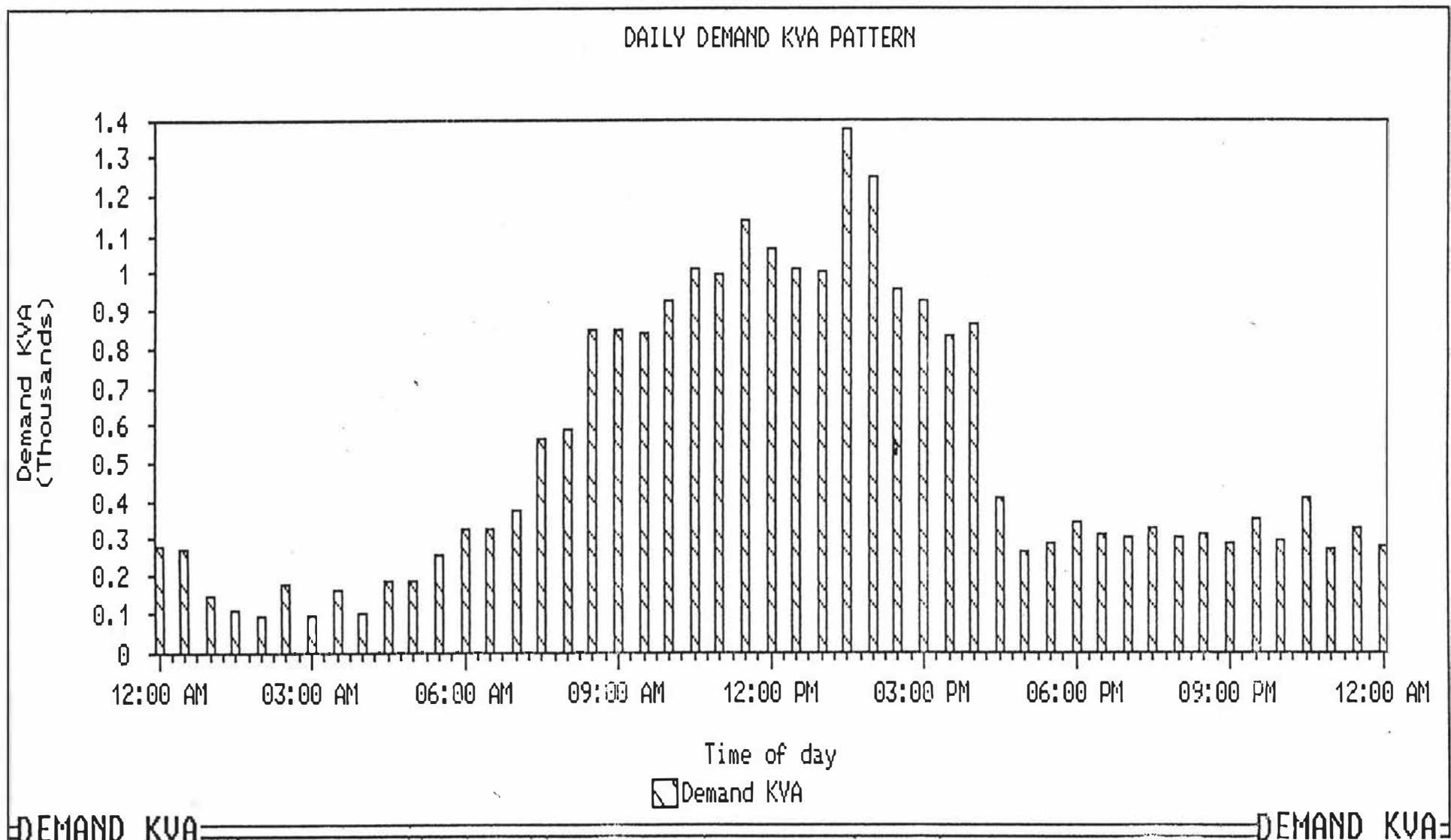
Graph of half-hour demand kva

MENU

Load data TABLE Load curve GRAPH

**Daily Demand KVA GRAPH**

Max Dem Control



DEMAND KVA 12-Dec-89 12:18 PM

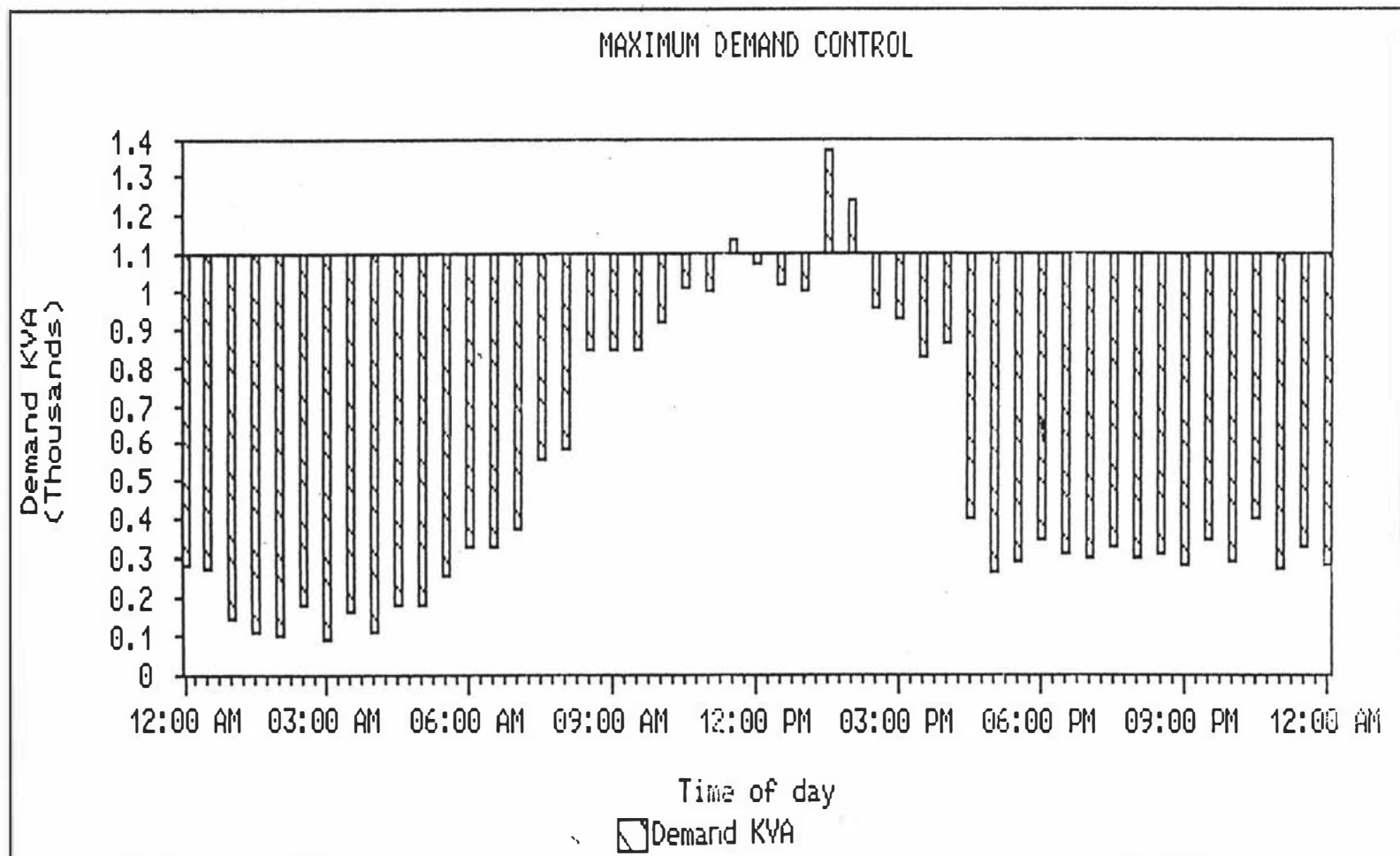
Macro

Calc

DEMAND KVA

"UP" arrow - increase MD limit:  
"ESC" - return to previous menu:

"DOWN" arrow - decrease MD limit:  
"CALC" (F8) - updates SAVING:



Saving (\$) =  
69936  
SAVINGMDC

Load shed  
= 275 KVA  
KVA SHED

## APPENDIX B DATA USED IN DECISION SUPPORT SYSTEM

This appendix presents the intermediate spreadsheet file LJRVAL4.WKS used by the decision support system (Ref appendix D) both for input data, and as the destination for data to be taken back into the Lotus Symphony application.

This spreadsheet was created by extracting values from the ECMDEMO spreadsheet of the Lotus Symphony application.

Attention is drawn to the small macro below the NEW DEM figures; data exported from VP Expert appears in spreadsheet cells as text strings, and needs to be parsed to produce numbers. The macro was developed using the public domain spreadsheet, ASEASYAS. The macro is implemented as an autoexecute macro (range name \0) so that it is activated whenever the spreadsheet is retrieved, eg by symphony.

The names at the heads of columns of figures are the same as the range names allocated to the columns.

## LJRVAL4.WKS

	UNIT	CONSM	MTH	L_FACT	MD_RATE
Jan	527100		1380	0.523	17.33
Feb	419034		1454	0.395	17.33
Mar	744570		1365	0.747	17.33
Apr	483828		1382	0.480	17.33
May	598767		1404	0.584	18.20
Jun	463555		1444	0.440	18.20
Jul	846450		1453	0.798	36.40
Aug	537805		1428	0.516	36.40
Sep	862200		1440	0.820	36.40
Oct	445625		1324	0.461	36.40
Nov	748350		1426	0.719	36.40
Dec	479965		1414	0.465	36.40
Total:	*****				
Average:	596437		1410	0.579	



		DEMAND			
		KVA			
DAY_FRACTI	DEM	KVA	DEM	NEW_DEM	
	0	371	283	0	282.84
0.010416	403			0.020833	278.168
0.020833	371	278		0.041666	148.069
0.03125	224			0.0625	113.927
0.041666	188	148		0.083333	97.754
0.052083	147			0.104166	182.211
0.0625	170	114		0.125	95.957
0.072916	125			0.145833	167.116
0.083333	147	98		0.166666	106.02
0.09375	341			0.1875	186.523
0.104166	166	182		0.208333	185.086
0.114583	138			0.229166	262.355
0.125	129	96		0.25	333.514
0.135416	327			0.270833	328.482
0.145833	138	167		0.291666	378.438
0.15625	134			0.3125	564.242
0.166666	161	106		0.333333	592.994
0.177083	345			0.354166	846.363
0.1875	174	187		0.375	851.036
0.197916	166			0.395833	844.567
0.208333	349	185		0.416666	925.07
0.21875	381			0.4375	1013.839
0.229166	349	262		0.458333	1001.261
0.239583	359			0.479166	1139.626
0.25	569	334		0.5	1073.498
0.260416	498			0.520833	1018.152
0.270833	416	328		0.541666	1008.089
0.28125	403			0.5625	1376.464
0.291666	650	378		0.583333	1247.443
0.302083	664			0.604166	955.977
0.3125	906	564		0.625	928.304
0.322916	740			0.645833	833.425
0.333333	910	593		0.666666	865.411
0.34375	1099			0.6875	407.908
0.354166	1256	846		0.708333	269.183
0.364583	1251			0.729166	292.903
0.375	1117	851		0.75	346.093
0.385416	1144			0.770833	312.31
0.395833	1206	845		0.791666	304.763
0.40625	1251			0.8125	327.045
0.416666	1323	925		0.833333	306.2
0.427083	1220			0.854166	317.341
0.4375	1601	1014		0.875	288.231
0.447916	1503			0.895833	352.562
0.458333	1283	1001		0.916666	297.575
0.46875	1646			0.9375	407.548
0.479166	1525	1140		0.958333	275.293
0.489583	1440			0.979166	327
0.5	1547	1073			
0.510416	1605				
0.520833	1228	1018	\0	DP	
0.53125	1395			E23..E70~	
0.541666	1410	1008		GTL	

0.552083	1565		X
0.5625	2265	1376	D23..D70~
0.572916	1781		A
0.583333	1690	1247	E23..E70~
0.59375	1319		V
0.604166	1341	956	
0.614583	1323		
0.625	1260	928	
0.635416	1198		
0.645833	1121	833	
0.65625	1327		
0.666666	1081	865	
0.677083	647		
0.6875	488	408	
0.697916	323		
0.708333	426	269	
0.71875	412		
0.729166	403	293	
0.739583	515		
0.75	448	346	
0.760416	403		
0.770833	466	312	
0.78125	426		
0.791666	422	305	
0.802083	440		
0.8125	470	327	
0.822916	430		
0.833333	422	306	
0.84375	385		
0.854166	498	317	
0.864583	399		
0.875	403	288	
0.885416	416		
0.895833	565	353	
0.90625	434		
0.916666	394	298	
0.927083	529		
0.9375	605	408	
0.947916	390		
0.958333	376	275	
0.96875	399		
0.979166	511	327	
0.989583	416		

## APPENDIX C DECISION SUPPORT SYSTEM OPERATION

### C.1 Introduction

This appendix presents a brief operations manual for the prototype Decision Support system.

### C.2 Explanation of files and functions

This application has been developed using the VP Expert version 1.2 expert system shell;

It is designed to interface with spreadsheet files created by Lotus Symphony (though other spreadsheet files, eg Lotus 1-2-3, VP Planner etc are also readable) and with database files of dBase format.

Data is transferred both to and from the spreadsheet and database files.

The application itself consists of two main, plus several minor, knowledge bases.

Control is passed from one knowledge base to another by the VP Expert "CHAIN" command, and data is transferred from one knowledge base to another by writing and reading variables from ASCII text files (these are not given file extensions by VP Expert).

## FILES

VPX.EXE (VP Expert program file)  
 VPX.CNF (VP Expert program file)  
 VPX.MSG (VP Expert program file)  
 VPXE.EXE (VP Expert program file)  
 VPXH.EXE (VP Expert program file)  
 VPXM.EXE (VP Expert program file)  
 VPXT.EXE (VP Expert program file)  
 VPXFR.DBF (VP Expert program file)

### WELCOME.KBS

This is the knowledge base through which the user initially accesses the decision support system; its function is simply to display welcome screens, and allow the user to select an aspect of ECM for investigation.

### DUMMY.KBS

Since decision support has only been developed for the Maximum Demand Control aspect of ECM the selection of any choice than max demand control invokes this knowledge base, which transfers control back to "WELCOME".

### INTEREST

This ASCII text file is created by the "WELCOME" knowledge base, and contains the name of the interest area selected.

### MD\_REPOR.KBS

This is the first of the two "main" knowledge bases; control is passed to it by the "WELCOME" knowledge base when "Maximum Demand Control" is selected as the field of interest. The first function of MD\_REPOR.KBS is to obtain the necessary raw data; options for obtaining data from spreadsheet, database, or manual input are offered, but only the spreadsheet option is currently implemented.

The principle function of this knowledge base is the non-interactive analysis of the raw data.

#### LJRVAL4.WKS

The raw data for the demonstration is contained in this spreadsheet.

#### MD\_CONTR

After processing by MD\_REPOR.KBS knowledge base, data is transferred to this text file.

#### MD\_REFIN.KBS

The function of the second of the two "main" knowledge bases is to allow the interactive investigation of options for reducing maximum demand charges.

#### MACHINE.DBF

This database file holds records of the equipment whose operating pattern is to be investigated; the file is read and updated by MD\_REFIN.KBS (it can be empty initially, or loaded with equipment details by exporting values from the Symphony "inventory" file).

#### MACHSLOT.DBF

Details of every movement of equipment load made by a user is recorded in this database file. The file is read prior to allowing a proposed move, and allowed moves are recorded. The file can be listed by MD\_REFIN.KBS to provide a record of load movements proposed.

### C.3 Startup

The application is started by typing "VPX WELCOME <ENTER>".

### C.4 Screen displays

The (principal) display screens used in this application are presented in approximately the order in which they are encountered within the application.

### C.5 User input

User input is almost entirely by menu selection, the main exception being the identification of equipment; Other minor exceptions include the input of equipment loads (only required on the first occasion the equipment is referred to), an optional target MD figure, a target import load, a number of days per month, and the identification of the MD rate for the month to which the proposed load changes apply.

### C.6 Outputs.

In view of the relatively minor volume of the user inputs, the screen displays shown in figs C.4.1 -C.4.18 are principally application outputs; these outputs can be grouped into five categories;

Firstly, the background information deduced from the (raw) input data, including figs C.4.6, and C.4.8.

Secondly, the information associated with the initial estimates of potential savings shown on fig C.4.7.

Thirdly, the essential output data, including the daily load pattern resulting from the sum of the changes proposed by the user (and the record of those changes). these include the displays of figs C.4.13 and C.4.14.

Fourthly, the displays designed to assist the user in keeping mental track of the changes proposed; these include the displays shown in figs C.4.12, C.4.13, and C.4.17.

Fifthly, and finally, there are a range of messages to advise the user that a proposed load change is either inadvisable, or impossible. Two such warnings are shown in fig C.4.19.

The development philosophy has been to prevent the user from making "impossible" load movements, but merely to warn that a proposed move is "inadvisable", and allow such a move to proceed.

Note the features added to improve readability and friendliness, including numbering of multi-screen displays (eg fig C.4.13) and the use of the countdown while to show the progress of (the lengthy process of) loading data from the spreadsheet.



```

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
? Which aspect of Energy Cost Management do you wish to          ?
?investigate ?                                                  ?
? Max demand control      Load scheduling      Alternative energy      ?
? Alternative tariffs      Call spreadsheet      Quit                  ?
?                                                                ?
?You have chosen to investigate Maximum Demand Control          ?
?Please press any key, & wait while the knowledge base relating to this subject?
? is loaded                                                    ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?                                                                ?
?XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

```

FIG C.4.3 SELECT ASPECT OF ECM FOR INVESTIGATION  
(SELECTION OF MAX DEMAND CONTROL  
SHOWN)





```

L#####
? ----- SUMMARY OF INPUT DATA -----
?
?
?KEY      ; MAXIMUM ; MINIMUM ; AVERAGE ; STD DEVIATION ;
?LF       ;    0.820    0.395    0.579    0.145
?MC (kWh) ; 862200    419034    596437    153963
?MD (kVA) ;   1454     1325     1410     38
?ID (kVA) ;   1376     96       261      364
?
?
?      KEY;
?
?      LF = Load factor (actual consumption / consumption based on MD load).
?      MC = The monthly consumption, in kWh.
?      MD = The maximum demand for the month, in kVA.
?      ID = The instantaneous demand, in kVA, (on a typical day).
?
?
?
?      Press any key to continue
?#####

```

FIG C.4.6 REPORTING OPTION; DISPLAY INPUT DATA.

```

L#####
? PRELIMINARY ESTIMATES OF SAVINGS POSSIBLE BY CONTROL OF MAXIMUM DEMAND
?
?An examination of the monthly load factors (ie, the ratio of average to peak
?consumptions) shows that these range from 0.820 to 0.395.
?Taken across a typical year, these appear to have an average of
?0.579, and standard deviation of 0.145.
?A not-unrealistic goal could be to raise the average load factor from the
?present level (0.579) to the upper-quartile figure (0.724).
?
?Assuming this proves to be feasible, the annual savings would be $ 92723.56.
?
?
?If the load patterns for all months with worse than average load-factors
?were moved to the period where the minimum MD charge rate applies,
?and the load patterns for months with better than average load factors
?were moved to the period where the maximum MD charge rate applies,
?then the annual saving would be $ 29138.06.
?
?
?      Press any key to continue
?#####

```

FIG C.4.7 REPORTING OPTION; DISPLAY SUMMARY RESULTS

```

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
?----- Detailed conclusions are:-----?
? - Sheet 1; comment on degrees of similarity of the daily load analysis,?
? vs monthly figures?
??
? The peak shown in the daily load figures is a little less?
? than that for the monthly MD figures.?
??
? How many of the 'typical' days are there per month?
? 31?
??
? The mean shown in the daily load figures is significantly less?
? than that for the monthly mean consumption figures.?
??
??
??
? Press any key to continue?
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

```

```

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
? - Sheet 2; Interpretation of the data?
??
?The minimum load recorded during the typical day is 96 kVA?
?this load probably corresponds to items which run 24 hrs / day?
??
?There is a moderate degree of uniformity between monthly unit loads.?
??
??
?There is a moderate degree of uniformity between the Maximum Demand figures?
? for the range of months.?
??
??
??
? Press any key to continue?
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

```

```

#####
? What do you want to do next ?
? Help           Set import load           Move [other] loads
? Current situation   Show all intervals       List all moves
? Load spreadsheet   Finish
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
#####
Enter to select   END to complete   /Q to Quit   ? for Unknown

```

FIG C.4.9 OPTIONS AVAILABLE UPON SELECTION OF "REFINEMENT OF MD SAVINGS" OPTION.

```

#####
? How much (if any) load from other MD charge periods do you
? want to (re) distribute within this MD charge period ?
?
? 100
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
#####
Enter to select   ? & Enter for Unknown   /Q to quit

```

FIG C.4.10 SET IMPORT LOAD

----- HELP! Max Demand Decision Support System ----- screen 1 of 2 ---  
? This section of the decision support system allows you to explore the effects  
?(on monthly and annual MD charges) of moving sections of electrical load  
?between 30 min time slots.  
?There are three basic categories of load movement which can influence the  
?MD charge; viz  
? a) Load can be simply shut off; this obviously offers the largest saving  
? b) Load can be moved between 30 min time slots so as to reduce the peak  
? load for the current MD charge period (Month, quarter, etc).  
? c) It may be possible to prevent a separate occurrence of an MD penalty  
? charge from being incurred each month by concentrating all the  
? primary peak-producing processes within one MD charge period.  
?  
?  
?  
?  
?  
?  
?  
?  
?Press any key for second screen  
-----

----- HELP! Max Demand Decision Support System ----- screen 2 of 2 ---  
? You will obviously need to first examine the current daily load curve  
?to determine where the peaks lie; it is suggested that you then start with  
?the 'peak-time', and work outwards (choosing time slots alternately before  
?and after), and using you specialised knowledge of the processes involved  
?to determine what loads can be rearranged.  
?  
? Bear in mind that loads which are currently 'waste' are obviously the  
?greatest source of saving, and that loads moved to a low-tariff time zone  
?offer unit as well as MD savings.  
?  
? Be careful not to move loads in such a way as to simply create a new  
?peak at a different time of day (the DSS will warn you if you do this).  
?  
?At any stage you can examine the 'overall picture' of the rearranged  
?load pattern you have created. This will also compare your (re) arrangement  
?with the 'suggested target' of the previous section of the DSS.  
?  
?  
?Press any key to continue.  
-----

FIG C.4.11 "HELP" SCREEN, SH 1 & 2.

```

VXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
? ----- SUMMARY OF CURRENT POSITION -----
?
?
?You have currently;
?
?   'Ditched' a total of 0 kVA,
?
?
?   Moved a total of 0 kVA to (an)other MD charge period(s),
?
?
?   And still have 100 kVA from other MD charge periods to be redistributed.
?
?Please wait a moment..
?   The new peak load is 1376.464 kVA
?   This (new) peak occurs at 1:30 pm
?
?   The cost savings from this MD change is expected to be $ -16.24
?
?
? Press any key to continue
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

```

FIG C.4.12 "SUMMARY OF CURRENT POSITION"  
 (DISPLAYS SITUATION RESULTING FROM A  
 SERIES OF HYPOTHESIZED LOAD  
 MOVEMENTS.)

```

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
? What do you want to do next ?
? Help                  Set import load          Move [other] loads
? Current situation    Show all intervals       List all moves
? Load spreadsheet    Finish
?
?What type of target do you want to set for yourself ?
? None                  Load factor              Maximum demand
?
?What Maximum Demand target figure (kVA) would you like to aim for ?
? 10000
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Enter to select      ? & Enter for Unknown      /0 to quit

```

```

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
? The following summarizes the proposed/targetted changes
?
?
? PERIOD          CURRENT LOAD      MODIFIED LOAD      TARGET LOAD      TARGET REDUCTION
? STARTING       kVA              kVA                kVA              kVA
?
?12:00 am        1073.498         1073.498          1000.000         73
?12:30 pm        1018.152         1018.152          1000.000         18
? 1:00 pm        1008.089         1008.089          1000.000         8
? 1:30 pm        1376.464         1376.464          1000.000         376
? 2:00 pm        1247.443         1247.443          1000.000         247
? 2:30 pm         955.977          955.977           955.977          0
? 3:00 pm         928.304          928.304           928.304          0
? 3:30 pm         833.425          833.425           833.425          0
? 4:00 pm         865.411          865.411           865.411          0
? 4:30 pm         407.908          407.908           407.908          0
? 5:00 pm         269.183          269.183           269.183          0
? 5:30 pm         292.903          292.903           292.903          0
?
?
?Press any key to see screen 4 of 4.
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

```

FIG C.4.13      SHOW ALL INTERVALS:  
 SH1, SEETING A TARGET MD;  
 SH 2, LOAD DETAILS, 1 OF 4.

```

L#####
? Time interval      Machine      Move-action      New machine state  ?
? -----
? 0:30 pm           LATHE        TURN OFF         OFF                ?
? 6:00 pm           PRESS        EXPORT           OFF                ?
? 1:00 pm           WELDER       TURN OFF         OFF                ?
? 3:00 am           PRESS        TURN OFF         OFF                ?
? 6:00 am           DRILL        EXPORT           OFF                ?
? 3:00 am           HOSE         TURN OFF         OFF                ?
? 6:00 am           MILLER       EXPORT           OFF                ?
? 3:00 am           PRESS        TURN OFF         OFF                ?
? 6:00 am           SPANNER      TURN OFF         OFF                ?
? 3:00 am           HOIST        TURN OFF         OFF                ?
? 6:00 am           JACK         TURN OFF         OFF                ?
? 3:00 am           PRESS        TURN OFF         OFF                ?
? 6:00 am           SPOT WELDER  TURN OFF         OFF                ?
? 3:00 am           RAM          TURN OFF         OFF                ?
? 6:00 am           SCREWDRIVER  TURN OFF         OFF                ?
? 3:00 am           WRENCH       TURN OFF         OFF                ?
? 6:00 am           SPANNER      TURN OFF         OFF                ?
? 9:00 am           NUT          TURN OFF         OFF                ?
?
? Press any key for the next screen
#####

```

FIG C.4.14 LIST ALL MOVES: DETAILS OF EACH HYPOTHESIZED LOAD MOVEMENT.

```

LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
? Change load patterns in which time interval ?           ?
?                                                         ?
? am, or pm ?                                           ?
? am                                                         ?
?                                                         ?
?What hour of day ?                                     ?
? 00                                                         01           02           ?
? 03                                                         04           05           ?
? 06                                                         07           08           ?
? 09                                                         10           11           ?
? 12                                                         ?
?                                                         ?
? How many minutes past the hour ?                       ?
? 00                                                         30           ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?
LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
Enter to select  END to complete  /Q to Quit  ? for Unknown

```

FIG C.4.15 SELECTION OF TIME INTERVAL WITHIN WHICH TO CHANGE A LOAD USAGE.

```

LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
?For the 30 minute interval starting at 4:0 am           ?
?Please identify the equipment you wish to deal with     ?
? CROPPER                                               ?
?                                                         ?
?I have no record of this machine, what is its power demand (kVA) ? ?
? 120                                                  ?
?                                                         ?
?What do you want to do with this load ?               ?
? Turn off           Export           Import           ?
? Reschedule                                               ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?                                                         ?
?
LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
Enter to select  END to complete  /Q to Quit  ? for Unknown

```

FIG C.4.16 IDENTIFICATION OF EQUIPMENT WHOSE LOAD USAGE IS TO BE CHANGED; IN THE CASE SHOWN THE EQUIPMENT IS NOT RECOGNISED BY THE DATABASE, SO THE ELECTRICAL DEMAND IS REQUESTED PRIOR TO UPDATING THE DATABASE. USER IS THEN ASKED TO SPECIFY HOW THIS EQUIPMENT'S USAGE IS TO BE CHANGED.



```

LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
? ----- SUMMARY OF LOAD MOVEMENT ----- ?
?
? PERIOD          CURRENT LOAD          PROPOSED LOAD          ?
?
? 3: 0 am         182.211           62.211                 ?
? 07:30 pm       327.045           447.045                 ?
?
? The operation of the CROPPER (demand = 120) has been Rescheduled.
?
?
?
?
?
?
?
?
?
?
? Press any key to continue
?
?
?
LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL

```

FIG C.4.17 LOAD MOVEMENT SUMMARY: IN THIS CASE, THE OPERATION OF AN ITEM OF EQUIPMENT WITH A 12 KVA DEMAND HAS BEEN RESCHEDULED FROM THE 30 MINUTE INTERVAL BEGINNING 9:00 am TO THE 30 MIN INTERVAL STARTING 10:30 pm.

```

LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
? What do you want to do next ? ?
? Help           Set import load           Move [other] loads ?
? Current situation Show all intervals       List all moves ?
? Load spreadsheet Finish ?
?
? This option will load the new values for daily demand back
? to the spreadsheet (the old spreadsheet values will not be
? overwritten.
? Do you wish to proceed ? ?
? Yes              No ?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
?
? Enter to select END to complete /Q to Quit ? for Unknown

```

FIG C.4.18 LOAD SPREADSHEET: THE DAILY INSTANTANEOUS LOAD PATTERN RESULTING FROM ALL THE LOAD MOVEMENTS IS RELOADED TO THE SPREADSHEET ( LJRVAL4.WKS, RANGE NAME ), WHERE THE SPREADSHEET'S GRAPHICS CAN BE USED TO DISPLAY THE DATA IN GRAPH FORM, AND TO COMPARE GRAPHICALLY WITH THE ORIGINAL INSTANTANEOUS DEMAND CURVE.

```

┌──────────────────────────────────────────────────────────────────────────────────┐
│For the 30 minute interval starting at 3:30 pm                                     │
│Please identify the equipment you wish to deal with                               │
│BLOOPER                                                                            │
│                                                                                   │
│I have no record of this machine, what is its power demand (kVA) ?             │
│2000                                                                                │
│                                                                                   │
│What do you want to do with this load ?                                         │
│Turn off                                Export                                Import  │
│Reschedule                               │                                  │
│                                                                                   │
│*****                                                                            │
│WARNING ! MOVING THIS LOAD HAS ACTUALLY CAUSED A PEAK WHICH                      │
│IS 1552.303955 kVA HIGHER THAN IN THE ORIGINAL DAILY PATTERN !!!                │
│*****                                                                            │
│*****                                                                            │
│YOU HAVE IMPORTED 2000 kVA MORE LOAD FROM OTHER CHARGE PERIGDS                  │
│THAN YOU ORIGINALLY INDICATED WAS NECESSARY                                    │
│*****                                                                            │
│                                                                                   │
│Press any key to continue                                                         │
└──────────────────────────────────────────────────────────────────────────────────┘

```

```

┌──────────────────────────────────────────────────────────────────────────────────┐
│For the 30 minute interval starting at 1:0 am                                     │
│Please identify the equipment you wish to deal with                               │
│LATHE                                                                              │
│                                                                                   │
│What do you want to do with this load ?                                         │
│Turn off                                Export                                Import  │
│Reschedule                               │                                  │
│                                                                                   │
│You have already turned this machine off within this interval                   │
│                                                                                   │
│                                                                                   │
│                                                                                   │
│                                                                                   │
│                                                                                   │
│                                                                                   │
│Press any key to continue                                                         │
│                                                                                   │
└──────────────────────────────────────────────────────────────────────────────────┘

```

FIG C.4.19 VARIOUS ERROR AND WARNING MESSAGES.

## APPENDIX D KNOWLEDGE BASE SOURCE CODE AND RULES.

ANNOTATED SOURCE CODE  
FOR FINAL VERSION OF DECISION SUPPORT SYSTEM.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!      WELCOME.KBS
!      ENERGY COST MANAGEMENT EXPERT SYSTEM
!      Decision support for MD control
!      L J Robertson
!      VP Expert version 1.2
!      Sept 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

```
!__ Initialise section _____
```

```
EXECUTE;
RUNTIME;
ENDOFF;
```

```
!__ Actions section _____
```

```
ACTIONS
```

```
!__ Opening screen section _____
```

```
CLS
DISPLAY " "
DISPLAY "W      W EEEEE L      CCC  OOOO  M      M  EEEEE"
DISPLAY "W      W E      L      C      O      O M M M M  E"
DISPLAY "W      W W EEE  L      C      0      0 M  M  M  EEE"
DISPLAY " W W W W  E      L      C      0      0 M      M  E"
DISPLAY "  W      W  EEEEE LLLL  CCC  OOOO  M      M  EEEEE"
DISPLAY " "
DISPLAY " "
```

```
DISPLAY "      TO THE"
DISPLAY " "
DISPLAY " "
```

```
DISPLAY "      ENERGY COST MANAGEMENT"
DISPLAY " "
DISPLAY " "
```

```
DISPLAY "      DECISION SUPPORT APPLICATION "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
```

```
DISPLAY " Press any key to continue.~"
```

```
CLS
!!!__Explanatory screen section _____
CLS
DISPLAY " "
DISPLAY "This application will assist you in:"
DISPLAY "   Selecting the most appropriate courses for
energy cost management,"
DISPLAY "   Evaluating the potential cost savings of
alternative actions,"
DISPLAY "   Suggesting factors to be taken account of in
implementing measures."

DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY "   You will be asked a series of questions, many
of which have alternative"
DISPLAY "   answers provided. In some cases you will need
to press <END> to confirm"
DISPLAY " your choice."
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "

DISPLAY " Press any key to continue.~"
CLS
```

```
!!!_____
```

```
NEWONE = NUMBER_ONE
RESET NEWONE
!! NB this shows that "reset" variables are not stored in
data files.
```

```
FIND DUMMY_INTEREST_AREA
```

```
SAVEFACTS INTEREST;
```

```
RULE 1
  IF      INTEREST_AREA = Max_demand_control
  THEN    DUMMY_INTEREST_AREA = INTEREST_AREA
          DISPLAY "   You have chosen to investigate
Maximum Demand Control"
          DISPLAY "   Please press any key, & wait
while the knowledge base
relating to this subject is
loaded~"
          CHAIN MD_REPOR;
```

```
RULE 2
IF
THEN
    INTEREST_AREA = Load_scheduling
    DUMMY_INTEREST_AREA = INTEREST_AREA
    DISPLAY "    You have chosen to investigate
            re-scheduling of load "
    DISPLAY "    Please press any key, & wait
            while the knowledge base
            relating to this subject is
            loaded~"
    CHAIN DUMMY;
```

```
RULE 3
IF
THEN
    INTEREST_AREA = Alternative energy
    DUMMY_INTEREST_AREA = INTEREST_AREA
    DISPLAY "    You have chosen to investigate
            the use of alternative energy
            sources "
    DISPLAY "    Please press any key, & wait
            while the knowledge base
            relating to this subject is
            loaded~"
    CHAIN DUMMY;
```

```
RULE 4
IF
THEN
    INTEREST_AREA = Alternative tariffs
    DUMMY_INTEREST_AREA = INTEREST_AREA
    DISPLAY "    You have chosen to investigate
            the use of alternative tariffs
            "
    DISPLAY "    Please press any key, & wait
            while the knowledge base
            relating to this subject is
            loaded~"
    CHAIN DUMMY;
```

```
RULE 5
IF
THEN
    INTEREST_AREA = Quit
    LOADFACTS INTEREST;
```

```
RULE 6
IF
THEN
    INTEREST_AREA = Call_spreadsheet
    DUMMY_INTEREST_AREA = INTEREST_AREA
    DISPLAY "    You have chosen to (re) call
            the spreadsheet application"
    DISPLAY "    Please press any key, & wait
            while the spreadsheet is
            loaded~"
    LOADFACTS INTEREST
    BCALL ECMSS;
```

```
!__ Ask statements _____  
!_____ General  
ASK INTEREST_AREA      : "Which aspect of Energy Cost  
                        Management do you wish to  
                        investigate ?";  
CHOICES INTEREST_AREA  :   Max_demand control,  
                        Load_scheduling,  
                        Alternative_energy,  
                        Alternative_tariffs,  
                        Call_spreadsheet, Quit ;
```

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!      DUMMY.KBS
!      ENERGY COST MANAGEMENT EXPERT SYSTEM
!      Decision support for MD control
!      L J Robertson
!      VP Expert version 1.2
!      Oct 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

```
! THIS DUMMY KNOWLEDGE BASE IS USED IN CONJUNCTION WITH
! "WELCOME.KBS" SO THAT A USER WHO SELECTS AN "AREA OF
! INTEREST" FOR WHICH NO KNOWLEDGE BASE HAS YET BEEN
! DEVELOPED, IS SIMPLY RETURNED TO THE "WELCOME" SCREEN
AND
! KNOWLEDGE BASE.
```

```
RUNTIME;
EXECUTE;
ACTIONS
```

```
CLS
DISPLAY "      Unfortunately, this knowledge base
           is still under"
DISPLAY "      development. Please press any key
           to return to the"
DISPLAY "      Main menu.~"
CHAIN WELCOME;
```

```

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!      MD_REPOR.KBS
!      ENERGY COST MANAGEMENT EXPERT SYSTEM
!      Decision support for MD control
!      L J Robertson
!      VP Expert version 1.2
!      Oct 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

```

```

! Reporting module of the ECM decision support system.
! This is the 'batch-mode' knowledge base which produces
the reports on the raw data imported from the
spreadsheet.

```

```

! GENESIS OF THIS FILE;
! MD_REPOR (NAME CHANGE 12 OCT 89) renamed from MD_C1
! MD_C1 is a concatenation of the old files MD_CONTR, &
  MD_REP1
! md_contr.kbs to use data from emcdemo.wks spreadsheet
!   alias ljrval4.wks

```

```

!-----
RUNTIME;
EXECUTE;
ENDOFF;

```

#### ACTIONS

```

CLS
LOADFACTS INTEREST

```

```

FIND SOURCE
!!if "spreadsheet" is selected, this results in the
  data being read
!!      in from the ECMDEMO.WKS spreadsheet

```

```

!!_____ calc mean and sd for monthly load factors _____
  X = 1
  TOTVAL = 0
  SQDEV = 0
  MAX_LOAD_FACT = 0
  MIN_LOAD_FACT = 1.0
  WHILEKNOWN CHECK12
    TOTVAL = (TOTVAL + MTH_LOAD_FACT[X])
    RESET MAX_LF
    FIND MAX_LF
    RESET MIN_LF
    FIND MIN_LF
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
  END

```



```

MEAN = (TOTVAL / (X - 1))      X = 1
SQDEV = 0
WHILEKNOWN CHECK12
    SQDEV = (SQDEV + ((MTH_LOAD_FACT[X] - MEAN)
                    * (MTH_LOAD_FACT[X] - MEAN)))
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
END

SD = (@SQRT((SQDEV / (X - 1))))

MEAN_MTH_LOAD_FACT = (MEAN)
SD_MTH_LOAD_FACT   = (SD)

!! _____ calc mean and sd for monthly unit consumptions _____
X = 1
TOTVAL = 0
MAX_MTH_CONSN = 0
MIN_MTH_CONSN = 9999999999
WHILEKNOWN CHECK12
    TOTVAL = (TOTVAL + MTH_CONSN[X])
    RESET MAX_MC
    FIND MAX_MC
    RESET MIN_MC
    FIND MIN_MC
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
END

MEAN = (TOTVAL / (X - 1))

X = 1
SQDEV = 0
WHILEKNOWN CHECK12
    SQDEV = (SQDEV + ((MTH_CONSN[X] - MEAN) *
                    (MTH_CONSN[X] - MEAN)))
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
END

SD = (@SQRT((SQDEV / (X - 1))))

MEAN_MTH_CONSN = (MEAN)
SD_MTH_CONSN   = (SD)

```

```

!!_____ Calc mean and SD for monthly MD figures _____
  X = 1
  TOTVAL = 0
  MAX_MTH_MD = 0
  MIN_MTH_MD = 9999999999
  WHILEKNOWN CHECK12
    TOTVAL = (TOTVAL + MTH_MD[X])
    RESET MAX_MM
    FIND MAX_MM
    RESET MIN_MM
    FIND MIN_MM
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
  END

  MEAN = (TOTVAL / (X - 1))

  X = 1
  SQDEV = 0
  WHILEKNOWN CHECK12
    SQDEV = (SQDEV + ((MTH_MD[X] - MEAN) *
(MTH_MD[X] - MEAN)))
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
  END

  SD = (@SQRT((SQDEV / (X - 1))))

  MEAN_MTH_MD = (MEAN)
  SD_MTH_MD = (SD)

!!_____ Calc mean and SD for instantaneous demand figures _____
  X = 1
  TOTVAL = 0
  MAX_INST_DEM = 0
  MIN_INST_DEM = 99999999999
  WHILEKNOWN CHECK96
    TOTVAL = (TOTVAL + INST_DEM[X])
    RESET MAX_ID
    FIND MAX_ID
    RESET MIN_ID
    FIND MIN_ID
    X = (X + 1)
    RESET CHECK96
    FIND CHECK96
  END

  MEAN = (TOTVAL / (X - 1))

```

```

X = 1
SQDEV = 0
WHILEKNOWN CHECK96
    SQDEV = (SQDEV + ((INST_DEM[X] - MEAN) *
        (INST_DEM[X] - MEAN)))
    X = (X + 1)
    RESET CHECK96
    FIND CHECK96
END

SD = (@SQRT((SQDEV / (X - 1))))

MEAN_INST_DEM = (MEAN)
SD_INST_DEM   = (SD)

!! _____ Calc max and min MD rates _____
X = 1
TOTVAL = 0
MAX_MD_RATE = 0
MIN_MD_RATE = 9999999999
WHILEKNOWN CHECK12
    RESET MAX_RATE
    FIND MAX_RATE
    RESET MIN_RATE
    FIND MIN_RATE
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
END

!! _____ Format all variables _____
!! NB; dimensioned variables are formatted within
rules
FORMAT MAX_LOAD_FACT,          4.3
FORMAT MAX_MTH_CONSN,         7.0
FORMAT MAX_MTH_MD,            4.0
FORMAT MAX_INST_DEM,          4.0
FORMAT MIN_LOAD_FACT,          4.3
FORMAT MIN_MTH_CONSN,         7.0
FORMAT MIN_MTH_MD,            4.0
FORMAT MIN_INST_DEM,          4.0
FORMAT MEAN_MTH_LOAD_FACT,     4.3
FORMAT SD_MTH_LOAD_FACT,       5.3
FORMAT MEAN_MTH_CONSN,         7.0
FORMAT SD_MTH_CONSN,           7.0
FORMAT MEAN_MTH_MD,            5.0
FORMAT SD_MTH_MD,              5.0
FORMAT MEAN_INST_DEM,          5.0
FORMAT SD_INST_DEM,            5.0

```

!! Calculate the savings available by increasing all load factors to the current upper quartile figure \_\_\_\_\_

```

LFUQ   = ((MEAN_MTH_LOAD_FACT) + (SD_MTH_LOAD_FACT))
LF_RED_SAV = 0
X = 1
WHILEKNOWN CHECK12
    RESET NEW_RED_SAV
    FIND NEW_RED_SAV
    LF_RED_SAV = (LF_RED_SAV + NEW_RED_SAV)
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
END
FORMAT LFUQ, 4.3
FORMAT LF_RED_SAV, 10.2

```

!! Calculate savings by moving all consumption details for months with below average Load Factors to month where MD\_Rate is lowest and all months with above average load factors to month with highest MD\_Rate.

```

LF_MOV_SAV = 0
X = 1
WHILEKNOWN CHECK12
    RESET NEW_MOV_SAV
    FIND NEW_MOV_SAV
    LF_MOV_SAV = ((LF_MOV_SAV) + (NEW_MOV_SAV))
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
END
FORMAT LF_MOV_SAV, 10.2

```

```

DISPLAY " "
DISPLAY " The preliminary analysis of the
          spreadsheet data is now complete."
DISPLAY " "

```

```
FIND HARDCOPY
```

!! Loop to allow display of values, or on/back chaining

```

WHILEKNOWN CCONTINUE
    RESET CCONTINUE
    RESET NEXT_ACTION
    RESET AACTION
    CLS
    FIND CCONTINUE

```

```

END
PRINTOFF

```

!! Save variables to data file \_\_\_\_\_  
SAVEFACTS MD\_CONTROL;

!! End of ACTIONS section \_\_\_\_\_

!! \_\_\_\_\_ RULES section \_\_\_\_\_

```

RULE SOURCE
  IF      WHEREFROM = Spreadsheet
  THEN    SOURCE = WHEREFROM
          CLS
          DISPLAY "      For this operation, a large
                    amount of data needs to be
                    read in from the"
          DISPLAY " spreadsheet, and then analysed."
          DISPLAY " "
          DISPLAY "      This will take about 50
                    seconds ( on a PC AT )      "
          DISPLAY " "
          WKS MTH_CONSN, NAMED = UNIT_CONSN, LJRVAL4
          DISPLAY "                                40 to go"
          WKS MTH_MD,     NAMED = MD_MTH,     LJRVAL4
          DISPLAY "                                30 to go"
          WKS MTH_LOAD_FACT, NAMED=L_FACT,   LJRVAL4
          DISPLAY "                                20 to go"
          WKS INST_DEM,   NAMED = KVA_DEM,   LJRVAL4
          DISPLAY "                                10 to go"
          WKS MD_RATE,   NAMED = MD_RATE,   LJRVAL4
          CLS
          DISPLAY " "
          DISPLAY "      All data has now been read;
                    please wait while it is
                    analysed.";

RULE DATABASE
  IF      WHEREFROM = Database
  THEN    SOURCE = WHEREFROM
          CLS
          DISPLAY "      For this operation, a large
                    amount of data needs to be
                    read in from the"
          DISPLAY " database, and then analysed."
          DISPLAY " "
          DISPLAY " NOT YET WRITTEN"
          DISPLAY "      This will take about 45
                    seconds ( on a PC AT )      "
          DISPLAY " Press any key to continue ~";

RULE MANUAL
  IF      WHEREFROM = Manual
  THEN    SOURCE = WHEREFROM
          CLS
          SOURCE = WHEREFROM
          DISPLAY "      No separate procedure is
                    available as yet;"
          DISPLAY "      You will have to get the data
                    into a spreadsheet"
          DISPLAY " "
          DISPLAY " Press any key to continue ~";

```

```

RULE CHECK96
  IF      X <= 96
  THEN    CHECK96 = FINISH;

RULE CHECK12
  IF      X <= 12
  THEN    CHECK12 = FINISH;

RULE MAX_LOAD_FACT
  IF      MTH_LOAD_FACT[X] > (MAX_LOAD_FACT)
  THEN    MAX_LOAD_FACT = (MTH_LOAD_FACT[X])
          FORMAT MTH_LOAD_FACT[X], 4.3
          MAX_LF = YES;

RULE MAX_MTH_CONSN
  IF      MTH_CONSN[X] > (MAX_MTH_CONSN)
  THEN    MAX_MTH_CONSN = (MTH_CONSN[X])
          FORMAT MTH_CONSN[X], 4.3
          MAX_MC = YES;

RULE MAX_MTH_MD
  IF      MTH_MD[X] > (MAX_MTH_MD)
  THEN    MAX_MTH_MD = (MTH_MD[X])
          FORMAT MTH_MD[X], 4.3
          MAX_MM = YES;

RULE MAX_INST_DEM
  IF      INST_DEM[X] > (MAX_INST_DEM)
  THEN    MAX_INST_DEM = (INST_DEM[X])
          FORMAT INST_DEM[X], 4.3
          MAX_ID = YES;

RULE MAX_MD_RATE
  IF      MD_RATE[X] > (MAX_MD_RATE)
  THEN    MAX_MD_RATE = (MD_RATE[X])
          MAX_RATE = YES;

RULE MIN_LOAD_FACT
  IF      MTH_LOAD_FACT[X] < (MIN_LOAD_FACT)
  THEN    MIN_LOAD_FACT = (MTH_LOAD_FACT[X])
          MIN_LF = YES;

RULE MIN_MTH_CONSN
  IF      MTH_CONSN[X] < (MIN_MTH_CONSN)
  THEN    MIN_MTH_CONSN = (MTH_CONSN[X])
          MIN_MC = YES;

```

```

RULE MIN_MTH_MD
  IF      MTH_MD[X]          < (MIN_MTH_MD)
  THEN    MIN_MTH_MD        = (MTH_MD[X])
          MIN_MM = YES;

RULE MIN_INST_DEM
  IF      INST_DEM[X]        < (MIN_INST_DEM)
  THEN    MIN_INST_DEM      = (INST_DEM[X])
          MIN_ID = YES;

RULE MIN_MD_RATE
  IF      MD_RATE[X]         < (MIN_MD_RATE)
  THEN    MIN_MD_RATE        = (MD_RATE[X])
          MIN_RATE = YES;

RULE NEW_RED_SAV
  IF      MTH_LOAD_FACT[X]   < (LFUQ)
  THEN    NEW_RED_SAV =      (MD_RATE[X] *
                              ((MTH_CONSN[X])/730) *
                              ((LFUQ) -
                               (MTH_LOAD_FACT[X])) /
                              ((LFUQ) *
                               (MTH_LOAD_FACT[X])))

  ELSE    NEW_RED_SAV = 0;

RULE NEW_MOVE_COST
  IF      MTH_LOAD_FACT[X]   > (MEAN_MTH_LOAD_FACT)
  THEN    NEW_MOV_SAV =      ((MTH_MD[X]) *
                              ((MD_RATE[X]) -
                               (MAX_MD_RATE)));

RULE NEW_MOVE_SAV
  IF      MTH_LOAD_FACT[X]   < (MEAN_MTH_LOAD_FACT)
  THEN    NEW_MOV_SAV =      ((MTH_MD[X]) *
                              ((MD_RATE[X]) -
                               (MIN_MD_RATE)));

RULE CCONT
  IF      NEXT_ACTION <> UNKNOWN
  THEN    CCONTINUE = YES;

```

```

RULE DDISP
  IF
  THEN
    AACTION = DISPLAY_INPUT_DATA
    NEXT_ACTION = Y
    CLS
    DISPLAY " --- SUMMARY OF INPUT DATA ----"
    DISPLAY " "
    DISPLAY " "
    DISPLAY "KEY          | MAXIMUM | MINIMUM |
                                | STD DEVIATION |"
AVERAGE
    DISPLAY "LF          ; {MAX_LOAD_FACT}
                                {MIN_LOAD_FACT}
                                {MEAN_MTH_LOAD_FACT}
                                {SD_MTH_LOAD_FACT}"
    DISPLAY "MC (kWh); {MAX_MTH_CONSN}
                                {MIN_MTH_CONSN} {MEAN_MTH_CONSN}
                                {SD_MTH_CONSN}"
    DISPLAY "MD (kVA); {MAX_MTH_MD}
                                {MIN_MTH_MD} {MEAN_MTH_MD}
                                {SD_MTH_MD}"
    DISPLAY "ID (kVA); {MAX_INST_DEM}
                                {MIN_INST_DEM}
                                {MEAN_INST_DEM}
                                {SD_INST_DEM}"
    DISPLAY " "
    DISPLAY " "
    DISPLAY "          KEY; "
    DISPLAY " "
    DISPLAY "          LF = Load factor (actual
consumption / consumption based on MD load)."
    DISPLAY "          MC = The monthly
                                consumption, in kWh.
                                "
    DISPLAY "          MD = The maximum demand
                                for the month, in
                                kVA."
    DISPLAY "          ID = The instantaneous
                                demand, in kVA, (on
                                a typical day)."
    DISPLAY " "
    DISPLAY " "
    DISPLAY " "
    DISPLAY " "
    DISPLAY "          Press any key to continue~";

RULE RETMAIN
  IF
  THEN
    AACTION = BACK_TO_MAIN_MENU
    NEXT_ACTION = Y
    CHAIN WELCOME;

RULE INV_MD_CONTR
  IF
  THEN
    AACTION = REFINE_MD_SAVINGS
    NEXT_ACTION = Y
    CHAIN MD_REFIN;

```



```

RULE SUMMARY
  IF          AACTION = DISPLAY_SUMMARY_RESULTS
  THEN       CLS
            NEXT ACTION = Y
DISPLAY "    PRELIMINARY ESTIMATES OF SAVINGS POSSIBLE BY
CONTROL OF MAXIMUM DEMAND "
DISPLAY " "
DISPLAY "    An examination of the monthly load factors
          (ie, the ratio of average to peak "
DISPLAY "    consumptions) shows that these range from
          {MAX_LOAD_FACT} to {MIN_LOAD_FACT}."
DISPLAY "    Taken across a typical year, these appear to
          have an average of "
DISPLAY "    {MEAN_MTH_LOAD_FACT}, and standard deviation
          of {SD_MTH_LOAD_FACT}. "
DISPLAY "    A not-unrealistic goal could be to raise the
          average load factor from the "
DISPLAY "    present level ({MEAN_MTH_LOAD_FACT}) to the
          upper-quartile figure ({LFUQ})."
DISPLAY " "
DISPLAY "    Assuming this proves to be feasible, the
          annual savings would be $ {LF_RED_SAV}."
DISPLAY " "
DISPLAY " "
DISPLAY "    If the load patterns for all months with
          worse than average load-factors"
DISPLAY "    were moved to the period where the minimum MD
          charge rate applies, "
DISPLAY "    and the load patterns for months with better
          than average load factors"
DISPLAY "    were moved to the period where the maximum MD
          charge rate applies, "
DISPLAY "    then the annual saving would be $
          {LF_MOV_SAV}."
DISPLAY " "
DISPLAY " "
DISPLAY "    Press any key to continue~";

```



```

DISPLAY " "
RESET CNV
FIND CNV
DISPLAY " "
DISPLAY " "
MD_VARTY    = (SD_MTH_MD / (MAX_MTH_MD -
                    MEAN_MTH_MD))

RESET MDV
FIND MDV
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY "    Press any key to continue~";

RULE CNV1
  IF      CONS_VARTY < 0.5
  THEN   CNV = FOUND
        DISPLAY "    There is a high degree of
                variability between monthly
                unit loads."
        DISPLAY " ";

RULE CNV2
  IF      CONS_VARTY > 1
  THEN   CNV = FOUND
        DISPLAY "    There is a high degree of
                uniformity between the monthly
                unit loads."
        DISPLAY " ";

RULE CNV3
  IF      CONS_VARTY >= 0.5
  AND     CONS_VARTY <= 1
  THEN   CNV = FOUND
        DISPLAY "    There is a moderate degree of
                uniformity between monthly
                unit loads."
        DISPLAY " ";

RULE MDV1
  IF      MD_VARTY > 1
  THEN   MDV = FOUND
        DISPLAY "    There is a high degree of
                uniformity between the MD
                figures for the range of
                months.";

RULE MDV2
  IF      MD_VARTY < 0.5
  THEN   MDV = FOUND
        DISPLAY "    There is a high degree of
                variability between the MD
                figures for the range of
                months.";

```

```

RULE MDV3
  IF      MD_VARTY >= 0.5
    AND   MD_VARTY <= 1
  THEN    MDV = FOUND
          DISPLAY "   There is a moderate degree of
                    uniformity between the Maximum
                    Demand figures"
          DISPLAY " for the range of months.";

RULE ABSPEAK1
  IF      MAX_INST_DEM > (MAX_MTH_MD)
  THEN    ABSPEAK = FOUND
          DISPLAY "   ** WARNING **; The peak demand
                    of the day chosen is higher "
          DISPLAY "   than the highest MD recorded!
                    this is inconsistent";

RULE ABSPEAK2
  IF      MAX_INST_DEM <= (MAX_MTH_MD)
  THEN    ABSPEAK = FOUND
          RESET RELPEAKA
          FIND  RELPEAKA
          RESET RELPEAKQ
          FIND  RELPEAKQ
          DISPLAY " "
          DISPLAY " "
          DISPLAY " The peak shown in the daily load
                    figures is {RELPEAKQ} {RELPEAKA} "
          DISPLAY " than that for the monthly MD
                    figures."
          RESET RELPEAKA
          RESET RELPEAKQ;

RULE RELPEAKQSM
  IF      SD_MTH_MD > (@ABS(MAX_INST_DEM - MEAN_MTH_MD))
  THEN    RELPEAKQ = a_little;

RULE RELMEANQSM
  IF      RCOMP > 1
  THEN    RMQ = a_little
          SAVEFACTS MD4;

RULE RELPEAKQSI
  IF      SD_MTH_MD >= (0.5 * (@ABS(MAX_INST_DEM - MEAN_MTH_MD)))
    AND   SD_MTH_MD <  (@ABS(MAX_INST_DEM - MEAN_MTH_MD))
  THEN    RELPEAKQ = significantly
          SAVEFACTS MD4;

RULE RELMEANQSI
  IF      RCOMP > 0.5
    AND   RCOMP <= 1
  THEN    RMQ = significantly
          SAVEFACTS MD4;

```

```

RULE RELPEAKQGR
  IF      SD_MTH_MD <= (0.5 * (@ABS(MAX_INST_DEM -
    MEAN_MTH_MD)))
  THEN    RELPEAKQ = very_much;

```

```

RULE RELMEANQGR
  IF      RCOMP < 0.5
  THEN    RMQ      = very_much;

```

```

RULE RELPEAKA
  IF      MAX_INST_DEM > (MEAN_MTH_MD)
  THEN    RELPEAKA = greater
  ELSE    RELPEAKA = less;

```

```

RULE RELMEANAA
  IF      ACOMP      >= 1
  THEN    RMA        = greater
  ELSE    RMA        = less;

```

```

RULE HARDCOPY
  IF      PPRINT = YES
  THEN    HARDCOPY = YES
         DISPLAY "Ensure that your printer is
connected & turned on"
         DISPLAY "Press any key to continue~"
         PRINTON;

```

```

!!-----
!!*****
!!_____ ASK statements _____

```

```

ASK WHEREFROM: "What is the source of the data for Max
Demand control ?";
CHOICES WHEREFROM: Spreadsheet, Database, Manual;

```

```

ASK AACTION : "What do you want to do next ? ";
CHOICES AACTION: Display_input_data,
                 Display_summary_results,
                 Display_conclusions, Back_to_main_menu,
                 Refine_MD_savings,Quit;

```

```

ASK PPRINT : " Do you want printed copy of the screen
statements ?";
CHOICES PPRINT : No,Yes;

```

```

ASK DPM : " How many of the 'typical' days are
there per month";

```

## COMMENTARY OF ACTIONS SECTION AND RULES

## ACTIONS SECTION

The actions section of this knowledge base has four main functions; Firstly, to control the reading-in of the raw data from the spreadsheet; secondly, a (statistical) analysis of this data; thirdly the setting of "realistic" targets for MD control (and the calculation of the resultant savings); and finally, the storage of the resulting data in a data (ASCII text) file for use by the MD\_REFIN knowledge base.

## RULES SECTION

RULE SOURCE, RULE DATABASE, and RULE MANUAL are used to import raw data to the decision support application; currently only the source (spreadsheet source) option has been developed.

RULE MAX\_LOAD\_FACT, RULE MAX\_MTH\_CONSN, RULE MAX\_MTH\_MD, RULE MAX\_INST\_DEM, RULE MAX\_MD\_RATE, RULE MIN\_LOAD\_FACT, RULE MIN\_MTH\_CONSN, RULE MIN\_MTH\_MD, RULE MIN\_INST\_DEM, and RULE\_MIN\_MD\_RATE establish the maxima and minima of the load factor, monthly Maximum Demand, monthly consumption, instantaneous demand figures.

RULE NEW\_RED\_SAV is used to calculate the savings possible by increasing the load factor to the upper quartile level of all monthly load factors observed.

RULE NEW\_MOVE\_COST, and RULE NEW\_MOVE\_SAV are used to determine the savings possible by moving MD peaks from high to low MD charge (rate) periods.

RULE DDISP; summarizes input data.

RULE RETMAIN returns control to the main "welcome" menu, allowing the user to select an alternative aspect of ECM to investigate.

RULE INV\_MD\_CONTR transfers control to the MD\_REFIN knowledge base, allowing the user to experiment with the effect of moving load patterns.

RULE SUMMARY Suggests achievable MD control targets, and displays the results (in cash saving terms) of achieving these targets.

RULE CONCL compares the sense and magnitude of the differences between the daily and monthly consumption and maximum demand figures. RULE CNV1, RULE CNV2, RULE CNV3, RULE MDV1, RULE MDV2, RULE MDV3, RULE ABSPEAK1, RULE ABSPEAK2, RULE RELPEAKQSM, RULE RELMEANQSM, RULE RELPEAKQSI, RULE RELMEANQSI, RULE RELPEAKQGR, RULE RELMEANQGR, RULE RELPEAKA, and RULE RELMEANAA are tested by rule CONCL.

RULE HARDCOPY is used to direct output to the printer, if required.

```

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!      MD_REFIN.KBS
!      ENERGY COST MANAGEMENT EXPERT SYSTEM
!      Decision support for MD control
!      L J Robertson
!      VP Expert version 1.2
!      31 Oct 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!! (OLD NEWLOOP1)
!! (OLD MD_REF1.KBS)
!! MD_REFIN.KBS

```

\*\*\*\*\* ACTIONS SECTION \*\*\*\*\*

```

RUNTIME;
EXECUTE;
ENDOFF;

```

#### ACTIONS

```

!! Get data from file loaded by MD_C1.KBS
DISPLAY "Please wait while data is loaded"
LOADFACTS MD_CONTR
DISPLAY "all data has now been loaded."

!! RESET ACCUMULATOR VARIABLES TO 0
TOT_EXT_MOVE = 0
TOT_DITCH    = 0

!! load the NEW_DEM dimensioned variable
CLS
DISPLAY " Just a second please.."
X = 1
WHILEKNOWN CHECK48
    FORMAT INST_DEM[X], 9.3
    NEW_DEM[X] = (INST_DEM[X])
    FORMAT NEW_DEM[X], 9.3
    RESET CHECK48
    FIND CHECK48
END
!! NB, from now on, all work will be done on NEW_DEM;
!! INST_DEM is left as an untouched record of original
state.
!! modify the instantaneous loads, monitoring peaks
etc
    WHILEKNOWN CONT
!! MENU, ALSO ALLOWS DISPLAY OF OVERALL LOAD PATTERN,
CURRENT POSITION
    RESET CONT
    RESET SATISFIED
    CLS
    FIND CONT
END

!! END OF ACTIONS BLOCK
CLS;
!!

```

---



```

RULE CONT1H
IF          SATISFIED = HELP
THEN       CONT = YES
          CLS
          DISPLAY "      -----  HELP! Max Demand
          Decision Support System -----
          screen 1 of 2 ---"
          DISPLAY " "
          DISPLAY "      This section of the decision
          support system allows you to
          explore the effects"
          DISPLAY "      (on monthly and annual MD
          charges) of moving sections of
          electrical load "
          DISPLAY "      between 30 min time slots."
          DISPLAY "      There are three basic
          categories of load movement
          which can influence the "
          DISPLAY "      MD charge; viz"
          DISPLAY "          a) Load can be simply
          shut off; this obviously
          offers the largest
          saving"
          DISPLAY "          b) Load can be moved
          between 30 min time slots
          so as to reduce the peak
          "
          DISPLAY "      load for the current MD charge
          period (Month, quarter, etc)."
```

DISPLAY " c) It may be possible to
 prevent a separate
 occurrence of an MD
 penalty "

DISPLAY " charge from being incurred
 each month by concentrating
 all the "

DISPLAY " primary peak-producing
 processes within one MD charge
 period."

DISPLAY " "

DISPLAY " "

DISPLAY " "

DISPLAY " "

DISPLAY " "

DISPLAY " "

DISPLAY " "

DISPLAY "Press any key for second screen~"

CLS

DISPLAY " ----- HELP! Max Demand
 Decision Support System -----
 screen 2 of 2 ---"

DISPLAY " "

DISPLAY " You will obviously need to
 first examine the current
 daily load curve "

DISPLAY " to determine where the peaks  
lie; it is suggested that you  
then start with"

DISPLAY " the 'peak-time', and work  
outwards (choosing time slots  
alternately before"

DISPLAY " and after), and using you  
specialised knowledge of the  
processes involved"

DISPLAY " to determine what loads can be  
rearranged."

DISPLAY " "

DISPLAY " Bear in mind that loads which  
are currently 'waste' are  
obviously the"

DISPLAY " greatest source of saving, and  
that loads moved to a  
low-tariff time zone "

DISPLAY " offer unit as well as MD  
savings."

DISPLAY " "

DISPLAY " Be careful not to move loads  
in such a way as to simply  
create a new "

DISPLAY " peak at a different time of  
day (the DSS will warn you if  
you do this)."

DISPLAY " "

DISPLAY " At any stage you can examine  
the 'overall picture' of the  
rearranged"

DISPLAY " load pattern you have created.  
This will also compare your  
(re) arrangement"

DISPLAY " with the 'suggested target' of  
the previous section of the  
DSS."

DISPLAY " "

DISPLAY " "

DISPLAY "Press any key to continue.~";

```

RULE CONT1
  IF SATISFIED = CURRENT_SITUATION
  THEN CONT = YES
!   Ask month-name, get MD rate for month, calc MD
  savings
    RESET THISMD1
    RESET THISMD
    FIND THISMD

!!  SUMMARY OF OVERALL CHANGE IN POSITION
!!  CALCULATE SAVINGS, DISPLAY
  CLS
  DISPLAY " -- SUMMARY OF CURRENT POSITION ---"
  DISPLAY " "
  DISPLAY " "
  DISPLAY "You have currently; "
  DISPLAY " "
  DISPLAY "          'Ditched' a total of
                    {TOT_DITCH} kVA, "
  DISPLAY " "
  DISPLAY " "
  DISPLAY "          Moved a total of
                    {TOT_EXT_MOVE} kVA to
                    (an)other MD charge period(s),
                    "
  DISPLAY " "
  DISPLAY " "
  DISPLAY "          And still have {TOT_IN_MOVE}
                    kVA from other MD charge
                    periods to be redistributed."
  DISPLAY " "
  DISPLAY "Please wait a moment.."

  X = 1
  NEWMAX = 0
  WHILEKNOWN CHECK48
    !! loop through day, find new peak, compare
    to old peak
    NMN = (NEWMAX - NEW_DEM[X])
    RESET MMAX_MM
    FIND MMAX_MM
    RESET CHECK48
    FIND CHECK48
  END
  X = (NEWPEAKTIME - 1)
  FORMAT NEWMAX, 9.3

!! CONVERT INTEGER TIME TO STANDARD FORMAT TIME
  RESET T_OF_D
  FIND T_OF_D
  HR = 0
  WHILEKNOWN INTHOUR
    RESET INTHOUR
    FIND INTHOUR
  END
  RESET MINTIME
  FIND MINTIME

```

```
DISPLAY "      The new peak load is {NEWMAX} kVA"
DISPLAY "      This (new) peak occurs at
              {HR}:{MINTIME} {T_OF_D} "
DISPLAY " "

MD_SAV = (THISMD * ( MAX_INST_DEM - NEWMAX))
FORMAT MD_SAV, 9.2
DISPLAY "      The cost savings from this MD
              change is expected to be $
              {MD_SAV}"

!      Recalculate unit costs, based on time interval
tariff rates (LATER)
DISPLAY " "
DISPLAY " "
DISPLAY " Press any key to continue~";
!!  END OF RULE CONT1
```

```

RULE CONT2
  IF      SATISFIED = SHOW_ALL_INTERVALS
  THEN    CONT = YES
          WHILEKNOWN FEASIBLE
            RESET TARG_TYPE
            RESET TARG_FOUND
            FIND  TARG_FOUND
          END
        CLS
        DISPLAY " The following summarizes the
  proposed/targeted changes"
        DISPLAY " "
        DISPLAY " "
        DISPLAY " PERIOD      CURRENT LOAD      MODIFIED LOAD
  TARGET LOAD      TARGET REDUCTION"
        DISPLAY " STARTING    kVA              kVA
  kVA              kVA"
        DISPLAY " "
        DISPLAY " 0:00 am      {INST_DEM[1]}
{NEW_DEM[1]}      {TARG_DEM[1]}      {TARG_REDN[1]}"
        DISPLAY " 0:30 am      {INST_DEM[2]}
{NEW_DEM[2]}      {TARG_DEM[2]}      {TARG_REDN[2]}"
        DISPLAY " 1:00 am      {INST_DEM[3]}
{NEW_DEM[3]}      {TARG_DEM[3]}      {TARG_REDN[3]}"
        DISPLAY " 1:30 am      {INST_DEM[4]}
{NEW_DEM[4]}      {TARG_DEM[4]}      {TARG_REDN[4]}"
        DISPLAY " 2:00 am      {INST_DEM[5]}
{NEW_DEM[5]}      {TARG_DEM[5]}      {TARG_REDN[5]}"
        DISPLAY " 2:30 am      {INST_DEM[6]}
{NEW_DEM[6]}      {TARG_DEM[6]}      {TARG_REDN[6]}"
        DISPLAY " 3:00 am      {INST_DEM[7]}
{NEW_DEM[7]}      {TARG_DEM[7]}      {TARG_REDN[7]}"
        DISPLAY " 3:30 am      {INST_DEM[8]}
{NEW_DEM[8]}      {TARG_DEM[8]}      {TARG_REDN[8]}"
        DISPLAY " 4:00 am      {INST_DEM[9]}
{NEW_DEM[9]}      {TARG_DEM[9]}      {TARG_REDN[9]}"
        DISPLAY " 4:30 am      {INST_DEM[10]}
{NEW_DEM[10]}     {TARG_DEM[10]}
{TARG_REDN[10]}"
        DISPLAY " 5:00 am      {INST_DEM[11]}
{NEW_DEM[11]}     {TARG_DEM[11]}
{TARG_REDN[11]}"
        DISPLAY " 5:30 am      {INST_DEM[12]}
{NEW_DEM[12]}     {TARG_DEM[12]}
{TARG_REDN[12]}"
        DISPLAY " "
        DISPLAY " "
        DISPLAY "Press any key to see screen 2 of 4.~"
        CLS

```

```

DISPLAY " The following summarizes the
proposed/targeted changes"
DISPLAY " "
DISPLAY " "
DISPLAY " PERIOD CURRENT LOAD MODIFIED LOAD
TARGET LOAD TARGET REDUCTION"
DISPLAY " STARTING kVA kVA"
kVA
DISPLAY " "
DISPLAY " 6:00 am {INST_DEM[13]}
{NEW_DEM[13]} {TARG_DEM[13]}
{TARG_REDN[13]}"
DISPLAY " 6:30 am {INST_DEM[14]}
{NEW_DEM[14]} {TARG_DEM[14]}
{TARG_REDN[14]}"
DISPLAY " 7:00 am {INST_DEM[15]}
{NEW_DEM[15]} {TARG_DEM[15]}
{TARG_REDN[15]}"
DISPLAY " 7:30 am {INST_DEM[16]}
{NEW_DEM[16]} {TARG_DEM[16]}
{TARG_REDN[16]}"
DISPLAY " 8:00 am {INST_DEM[17]}
{NEW_DEM[17]} {TARG_DEM[17]}
{TARG_REDN[17]}"
DISPLAY " 8:30 am {INST_DEM[18]}
{NEW_DEM[18]} {TARG_DEM[18]}
{TARG_REDN[18]}"
DISPLAY " 9:00 am {INST_DEM[19]}
{NEW_DEM[19]} {TARG_DEM[19]}
{TARG_REDN[19]}"
DISPLAY " 9:30 am {INST_DEM[20]}
{NEW_DEM[20]} {TARG_DEM[20]}
{TARG_REDN[20]}"
DISPLAY "10:00 am {INST_DEM[21]}
{NEW_DEM[21]} {TARG_DEM[21]}
{TARG_REDN[21]}"
DISPLAY "10:30 am {INST_DEM[22]}
{NEW_DEM[22]} {TARG_DEM[22]}
{TARG_REDN[22]}"
DISPLAY "11:00 am {INST_DEM[23]}
{NEW_DEM[23]} {TARG_DEM[23]}
{TARG_REDN[23]}"
DISPLAY "11:30 am {INST_DEM[24]}
{NEW_DEM[24]} {TARG_DEM[24]}
{TARG_REDN[24]}"
DISPLAY " "
DISPLAY " "
DISPLAY "Press any key to see screen 3 of 4.~"
CLS

```

```

DISPLAY " The following summarizes the
proposed/targeted changes"
DISPLAY " "
DISPLAY " "
DISPLAY " PERIOD      CURRENT LOAD      MODIFIED LOAD
TARGET LOAD      TARGET REDUCTION"
DISPLAY " STARTING      kVA              kVA
kVA              kVA"
DISPLAY " "
DISPLAY "12:00 am      {INST_DEM[25]}
{NEW_DEM[25]}      {TARG_DEM[25]}
{TARG_REDN[25]}"
DISPLAY "12:30 pm      {INST_DEM[26]}
{NEW_DEM[26]}      {TARG_DEM[26]}
{TARG_REDN[26]}"
DISPLAY " 1:00 pm      {INST_DEM[27]}
{NEW_DEM[27]}      {TARG_DEM[27]}
{TARG_REDN[27]}"
DISPLAY " 1:30 pm      {INST_DEM[28]}
{NEW_DEM[28]}      {TARG_DEM[28]}
{TARG_REDN[28]}"
DISPLAY " 2:00 pm      {INST_DEM[29]}
{NEW_DEM[29]}      {TARG_DEM[29]}
{TARG_REDN[29]}"
DISPLAY " 2:30 pm      {INST_DEM[30]}
{NEW_DEM[30]}      {TARG_DEM[30]}
{TARG_REDN[30]}"
DISPLAY " 3:00 pm      {INST_DEM[31]}
{NEW_DEM[31]}      {TARG_DEM[31]}
{TARG_REDN[31]}"
DISPLAY " 3:30 pm      {INST_DEM[32]}
{NEW_DEM[32]}      {TARG_DEM[32]}
{TARG_REDN[32]}"
DISPLAY " 4:00 pm      {INST_DEM[33]}
{NEW_DEM[33]}      {TARG_DEM[33]}
{TARG_REDN[33]}"
DISPLAY " 4:30 pm      {INST_DEM[34]}
{NEW_DEM[34]}      {TARG_DEM[34]}
{TARG_REDN[34]}"
DISPLAY " 5:00 pm      {INST_DEM[35]}
{NEW_DEM[35]}      {TARG_DEM[35]}
{TARG_REDN[35]}"
DISPLAY " 5:30 pm      {INST_DEM[36]}
{NEW_DEM[36]}      {TARG_DEM[36]}
{TARG_REDN[36]}"
DISPLAY " "
DISPLAY " "
DISPLAY "Press any key to see screen 4 of 4.~"
CLS

```

```

DISPLAY " The following summarizes the
proposed/targeted changes"
DISPLAY " "
DISPLAY " "
DISPLAY " PERIOD      CURRENT LOAD      MODIFIED LOAD
TARGET LOAD      TARGET REDUCTION"
DISPLAY " STARTING      kVA              kVA
kVA              kVA"
DISPLAY " "
DISPLAY " 6:00 pm      {INST_DEM[37]}
{NEW_DEM[37]}      {TARG_DEM[37]}
{TARG_REDN[37]}"
DISPLAY " 6:30 pm      {INST_DEM[38]}
{NEW_DEM[38]}      {TARG_DEM[38]}
{TARG_REDN[38]}"
DISPLAY " 7:00 pm      {INST_DEM[39]}
{NEW_DEM[39]}      {TARG_DEM[39]}
{TARG_REDN[39]}"
DISPLAY " 7:30 pm      {INST_DEM[40]}
{NEW_DEM[40]}      {TARG_DEM[40]}
{TARG_REDN[40]}"
DISPLAY " 8:00 pm      {INST_DEM[41]}
{NEW_DEM[41]}      {TARG_DEM[41]}
{TARG_REDN[41]}"
DISPLAY " 8:30 pm      {INST_DEM[42]}
{NEW_DEM[42]}      {TARG_DEM[42]}
{TARG_REDN[42]}"
DISPLAY " 9:00 pm      {INST_DEM[43]}
{NEW_DEM[43]}      {TARG_DEM[43]}
{TARG_REDN[43]}"
DISPLAY " 9:30 pm      {INST_DEM[44]}
{NEW_DEM[44]}      {TARG_DEM[44]}
{TARG_REDN[44]}"
DISPLAY "10:00 pm      {INST_DEM[45]}
{NEW_DEM[45]}      {TARG_DEM[45]}
{TARG_REDN[45]}"
DISPLAY "10:30 pm      {INST_DEM[46]}
{NEW_DEM[46]}      {TARG_DEM[46]}
{TARG_REDN[46]}"
DISPLAY "11:00 pm      {INST_DEM[47]}
{NEW_DEM[47]}      {TARG_DEM[47]}
{TARG_REDN[47]}"
DISPLAY "11:30 pm      {INST_DEM[48]}
{NEW_DEM[48]}      {TARG_DEM[48]}
{TARG_REDN[48]}"
DISPLAY " "
DISPLAY " "
!! calculate new savings,
!! comment on loads ditched (with unit cost
savings),
!! and external shifted load
DISPLAY "Press any key to continue~";

```



```

RULE CONT3
  IF          SATISFIED = MOVE_[OTHER]_LOADS
  THEN       CONT = YES
  !! ESTAB. TIME INTERVAL FROM WHICH LOAD IS TO BE
  SHIFTED
    CLS
    DISPLAY "Change load in which time interval?"
    DISPLAY " "
    RESET AM_PM
    RESET HOUR
    RESET HALF_HR
    RESET X
    RESET TIME
    FIND TIME
    FORMAT HOUR, 2.0
    FORMAT HALF_HR, 2.0
    C_HOUR = (HOUR)
    C_HALF_HR = (HALF_HR)
    C_AM_PM = (AM_PM)
    C_X = (X)
    CLS
    DISPLAY "For the 30 minute interval starting at
             {C_HOUR}:{C_HALF_HR} {C_AM_PM}
             X={C_X}, "
             OLDINSTDEM = (NEW_DEM[C_X])

    RESET MMACHNAME
    FIND MMACHNAME

  ! CHECK WHETHER MACHINE DETAILS ARE ALREADY KNOWN
  CLOSE MACHINE
  GET MMACHNAME = MACHNAME, MACHINE, ALL

  ! IF MACHINE IS NOT KNOWN, UPDATE THE DATABASE
  RESET UPDATEMC
  FIND UPDATEMC

  ! CHECK WHETHER THIS MACHINE HAS ALREADY BEEN
  ACTED ON WITHIN THIS TIME INTERVAL
  CLOSE MACHSLOT
  GET MMACHNAME = MACHNAME AND C_X= ST_TIME,
  MACHSLOT, ALL
  RESET OLDACTION
  FIND OLDACTION

  RESET LOADACT
  FIND LOADACT

  RESET ACTIONOK
  RESET RESULTA
  FIND RESULTA

  RESET MOVE_SUMMARY
  FIND MOVE_SUMMARY

  RESET NEW_PEAK_WARN
  FIND NEW_PEAK_WARN

```

```

RESET IMPORTCHECK
FIND IMPORTCHECK
DISPLAY "Press any key to continue ~";

```

```
RULE UPDATEMC1
```

```

IF      MACHNAME = UNKNOWN
THEN    UPDATEMC = YES
        MACHNAME = (MMACHNAME)
        FIND ONLOAD
        OFFLOAD = 0
        DEPT = ADMIN
        COSPHI = 1.0
        APPEND MACHINE
        PUT MACHINE
ELSE    MACHNAME = (MMACHNAME);

```

```
RULE DEFAULTACT
```

```

IF      MACTION = UNKNOWN
THEN    OLDACTION = NONE
ELSE    OLDACTION = (MACTION);

```

```
RULE RESULTAD
```

```

!! LOAD WHICH IS TO BE DITCHED FROM THIS INTERVAL
IF      LOADACT = TURN_OFF
      AND ACTIONOK = OK
THEN    MACTION = TURN_OFF
        NEWSTATE = OFF
        ST TIME = (C X)
        PRODUCT = WIDGET
        DDATE = 30 10 89
        APPEND MACHSLÖT
        PUT MACHSLOT

        DISPLAY " "
        DISPLAY " "
        NEW_DEM[C_X] = ((NEW_DEM[C_X]) - (ONLOAD))
        FORMAT NEW_DEM[X], 9.3
        TOT_DITCH = ((TOT_DITCH) + (ONLOAD))
        FORMAT TOT_DITCH, 6.0

        RESULTA = OK;

```

```
RULE NOT_OK_1
```

```

IF      LOADACT = TURN_OFF
      AND NEW_DEM[C_X] < (ONLOAD)
THEN    ACTIONOK = NO
        DISPLAY " The size of this machine's
        load shows that it cannot"
        DISPLAY " have been on during this time
        interval initially ";

```

```

RULE NOT_OK_2
  IF LOADACT = TURN OFF
     AND OLDACTION = EXPORT
  THEN ACTIONOK = NO
       DISPLAY " You have already moved this
                machine's operation out of
                this interval";

RULE NOT_OK_2A
  IF LOADACT = TURN OFF
     AND OLDACTION = TURN OFF
  THEN ACTIONOK = NO
       DISPLAY " You have already turned this
                machine off within this
                interval";

RULE NOT_OK_2B
  IF LOADACT = TURN OFF
     AND OLDACTION = RESCHEDULE
  THEN ACTIONOK = NO
       DISPLAY " You have already rescheduled
                this machine's operation to
                another time interval";

RULE ACTIONOK1
  IF LOADACT = TURN OFF
     AND NEW_DEM[C_X] >= (ONLOAD)
     AND OLDACTION <> EXPORT
     AND OLDACTION <> TURN OFF
     AND OLDACTION <> RESCHEDULE
  THEN ACTIONOK = OK;

RULE RESULTAX
  !! LOAD WHICH IS TO BE EXPORTED TO ANOTHER MD CHARGE
  PERIOD
  IF LOADACT = EXPORT
     AND ACTIONOK = OK
  THEN MACTION = EXPORT
       NEWSTATE = OFF
       ST_TIME = (C_X)
       PRODUCT = WIDGET
       DDATE = 30 10 89
       APPEND MACHSL0T
       PUT MACHSLOT

       DISPLAY " "
       DISPLAY " "

       NEW_DEM[C_X] = ((NEW_DEM[C_X]) - (ONLOAD))
       FORMAT NEW_DEM[X], 9.3
       TOT_EXT_MOVE = ((TOT_EXT_MOVE) + (ONLOAD))
       FORMAT TOT_EXT_MOVE, 6.0
       RESULTA = OK;

```

```
RULE NOT_OK_3
  IF      LOADACT = EXPORT
    AND   NEW_DEM[C_X] < (ONLOAD)
  THEN    ACTIONOK = NO
          DISPLAY "   The size of this machine's
                load shows that it cannot"
          DISPLAY "   have been on during this time
                interval initially   ";
```

```
RULE NOT_OK_4
  IF      LOADACT = EXPORT
    AND   OLDACTION = EXPORT
  THEN    ACTIONOK = NO
          DISPLAY "   You have already moved this
                machine's operation out of
                this interval";
```

```

RULE NOT_OK_5
  IF      LOADACT = EXPORT
    AND   OLDACTION = TURN_OFF
  THEN    ACTIONOK = NO
          DISPLAY "  You have already turned this
                    machine off within this
                    interval";

RULE NOT_OK_5A
  IF      LOADACT = EXPORT
    AND   OLDACTION = RESCHEDULE
  THEN    ACTIONOK = NO
          DISPLAY "  You have already rescheduled
                    this machine's operation to
                    another interval";

RULE ACTIONOK2
  IF      LOADACT = EXPORT
    AND   NEW_DEM[C_X] >= (ONLOAD)
    AND   OLDACTION <> RESCHEDULE
    AND   OLDACTION <> TURN_OFF
    AND   OLDACTION <> EXPORT
  THEN    ACTIONOK = OK;

RULE RESULTAI
  IF      LOADACT = IMPORT
  THEN    MACTION = IMPORT
          NEWSTATE = ON
          ST_TIME = (C_X)
          PRODUCT = WIDGET
          DDATE = 30_10_89
          APPEND MACHSLOT
          PUT MACHSLOT

          NEW_DEM[C_X] = ((NEW_DEM[C_X]) + (ONLOAD))
          TOT_IN_MOVE = ((TOT_IN_MOVE) - (ONLOAD))
          FORMAT NEW_DEM[C_X], 9.3
          FORMAT TOT_IN_MOVE, 6.0
          RESULTA = OK;

RULE RESULTAR
  IF      LOADACT = RESCHEDULE
    AND   ACTIONOK = OK
  THEN    MACTION = RESCHEDULE
          NEWSTATE = OFF
          ST_TIME = (C_X)
          APPEND MACHSLOT
          PUT MACHSLOT
          NEW_DEM[C_X] = ((NEW_DEM[C_X]) - (ONLOAD))
          FORMAT NEW_DEM[C_X], 9.3
          RESULTA = OK;

```

```

RULE NOT_OK_6
  IF      LOADACT = RESCHEDULE
    AND   NEW_DEM[C_X] < (ONLOAD)
  THEN    ACTIONOK = NO
          DISPLAY "   The size of this machine's
                load shows that it cannot"
          DISPLAY "   have been on during this time
                interval initially   ";

RULE NOT_OK_7
  IF      LOADACT = RESCHEDULE
    AND   OLDACTION = TURN_OFF
  THEN    ACTIONOK = NO
          DISPLAY "   You have already turned this
                machine off in this interval";

RULE NOT_OK_8
  IF      LOADACT = RESCHEDULE
    AND   OLDACTION = EXPORT
  THEN    ACTIONOK = NO
          DISPLAY "   You have already moved this
                machine's operation out of
                this interval";

RULE ACTIONOK4
  IF      LOADACT = RESCHEDULE
    AND   NEW_DEM[C_X] >= (ONLOAD)
    AND   OLDACTION <> EXPORT
    AND   OLDACTION <> TURN_OFF
  THEN    ACTIONOK = OK;

RULE CONT4
  IF      SATISFIED = LOAD_SPREADSHEET
  THEN    CONT = YES
          DISPLAY "   This option will load the new
                values for daily demand back"
          DISPLAY "   to the spreadsheet (the old
                spreadsheet values will not
                be"
          DISPLAY "   overwritten. "
          RESET CCONF
          RESET GOAHEAD
          FIND CCONF;

```

```

RULE CONT5
  IF          SATISFIED = SET_IMPORT_LOAD
  !! Get load to be added from other MD charge periods
  THEN
    CONT = YES
    CLS
    DISPLAY "    How much (if any) load from
              other MD charge periods do you
              "
    DISPLAY "    want to (re) distribute within
              this MD charge period ?"
    RESET IN_MOVE_TOT
    FIND  IN_MOVE_TOT
    TOT_IN_MOVE = (IN_MOVE_TOT)
  ELSE
    TOT_IN_MOVE = 0;

```

```

RULE CONT6
  IF          SATISFIED = LIST_ALL_MOVES
  THEN
    CONT = YES
    CLS
    DISPLAY "    Time interval          Machine
  Move-action      New machine state"
    -----
    DISPLAY "    -----"
    CLOSE MACHSLOT
    LINENO = 1
    WHILEKNOWN MACHNAME
      GET ALL, MACHSLOT, ALL

      X = (ST TIME)
      RESET XTIME
      FIND XTIME

      DISPLAY "      {HR}:{MINTIME} {T_OF_D}
                {MACHNAME} {MACTION} {NEWSTATE}"
      LINENO = (LINENO + 1)
      RESET NEWLINE
      FIND NEWLINE
    END
    DISPLAY "    These are all the load moves
              entered so far"
    DISPLAY "Press any key to continue~";

```

```

RULE NEWLINE
  IF          LINENO >= 19
  AND
  THEN
    SATISFIED = LIST_ALL_MOVES
    DISPLAY "    Press any key for the next
              screen~"

    CLS
    LINENO = 1
    DISPLAY "    Time interval          Machine
  Move-action      New machine state"
    -----
    DISPLAY "    -----"
    NEWLINE = FOUND;

```

```

RULE XTIME
  IF      SATISFIED = LIST_ALL_MOVES
  THEN    RESET T_OF_D
          FIND T_OF_D
          HR = 0
          WHILEKNOWN INTHOUR
            RESET INTHOUR
            FIND INTHOUR
          END
          RESET MINTIME
          FIND MINTIME
          XTIME = FOUND;

RULE CCONFIRM
  IF      GOAHEAD = YES
  THEN    CCONF = FOUND
          DISPLAY "Loading data to Spreadsheet"
          PWKS NEW_DEM, NAMED = NEW_DEM, LJRVAL4
          DISPLAY " All data has been loaded into
spreadsheet; press any key to continue~";

RULE CHECK48
  IF      X <= 47
  THEN    CHECK48 = KNOWN
          X = (X + 1);

RULE MORNING_TIME
  IF      AM_PM =AM
          AND HOUR <> UNKNOWN
          AND HALF_HR <> UNKNOWN
  THEN    X = ( 2 * HOUR + (HALF_HR / 30))
          TIME = KNOWN;

RULE AFTERNOON
  IF      AM_PM =PM
          AND HOUR <> UNKNOWN
          AND HALF_HR <> UNKNOWN
  THEN    X = ( 24 + (2 * HOUR + (HALF_HR / 30)))
          TIME = KNOWN;

RULE T_OF_D
  IF      X > 24
  THEN    T_OF_D = pm
          X = (X - 24)
  ELSE    T_OF_D = am;

RULE INTHOUR
  IF      X >= 2
  THEN    INTHOUR = FOUND
          X = (X - 2)
          HR = (HR + 1);

```



```
RULE INT_MIN
  IF      X = 1
  THEN    MINTIME = 30
  ELSE    MINTIME = 00;

RULE THISMD
  IF      THISMD1 > 0
  THEN    THISMD = FOUND;

RULE MAX_MM
  IF      NMN < 1
  THEN    NEWPEAKTIME = (X)
          NEWMAX      = (NEW_DEM[X])
          MMAX_MM     = FOUND;
```

```

RULE MOVE_SUMMARY
  IF      SATISFIED = MOVE_[OTHER]_LOADS
    AND   LOADACT = RESCHEDULE
    AND   ACTIONOK = OK
  THEN    CLS
          OLDTIME = (X)
          DISPLAY "Destination of this load (Time
interval) ?"
          RESET AM PM
          RESET HOUR
          RESET HALF_HR
          RESET X
          RESET TIME
          FIND TIME
          DEST_TIME = (X + 1)

          OLDDEMDEST = (NEW_DEM[DEST_TIME])

          !! DISPLAY LOAD MOVEMENT FOR THIS INTERVAL
          CLS
          DISPLAY " "
          DISPLAY " ----- SUMMARY OF LOAD
MOVEMENT ----- "
          DISPLAY " "
          DISPLAY " PERIOD CURRENT LOAD
PROPOSED LOAD"
          DISPLAY " "
          DISPLAY " {C_HOUR}:{C_HALF_HR} {C_AM_PM}
{OLDINSTDEM} {NEW_DEM[C_X]}"
          NEW_DEM[DEST_TIME] = ((NEW_DEM[DEST_TIME])
+ (ONLOAD))
          FORMAT NEW_DEM[DEST_TIME], 9.3
          DISPLAY " {HOUR}:{HALF_HR} {AM_PM}
{OLDDEMDEST} {NEW_DEM[DEST_TIME]}"

          !! LOAD INTO THE MACHSLOT DATABASE THE
FACT THAT THE MACHINE
          !! HAS NOW BEEN TURNED ON AT THIS
(DESTINATION) TIME
          MACTION = RESCHEDULE
          NEWSTATE = ON
          ST_TIME = (X)
          PRODUCT = WIDGET
          DDATE = 30_10_89
          APPEND MACHSLOT
          PUT MACHSLOT

          X = (OLDTIME)
          MOVE_SUMMARY = FOUND;

```

```

RULE MOVE_SUMMARY1
  IF      SATISFIED = MOVE_[OTHER]_LOADS
    AND   LOADACT <> RESCHEDULE
    AND   ACTIONOK = OK
  THEN
    CLS
    DISPLAY " "
    DISPLAY " -- SUMMARY OF LOAD MOVEMENT -- "
    DISPLAY " "
    DISPLAY "   PERIOD           CURRENT LOAD
PROPOSED LOAD"
    DISPLAY " "
    DISPLAY "   {C_HOUR}:{C_HALF_HR} {C_AM_PM}
      {OLDINSTDEM}           {NEW_DEM[C_X]}"
    MOVE_SUMMARY = FOUND
    DISPLAY " ";

RULE NEW_PEAK_WARN1
  IF      NEW_DEM[DEST_TIME] > (MAX_INST_DEM)
  THEN
    NEW_PEAK_WARN = FOUND
    PPK = (NEW_DEM[DEST_TIME] - MAX_INST_DEM)
    DISPLAY "*****"
    DISPLAY "   WARNING ! MOVING THIS LOAD HAS
      ACTUALLY CAUSED A PEAK WHICH "
    DISPLAY "   IS {PPK} kVA HIGHER THAN IN
      THE ORIGINAL DAILY PATTERN
      !!!"
    DISPLAY "*****";

RULE NEW_PEAK_WARN2
  IF      NEW_DEM[C_X] > (MAX_INST_DEM)
  THEN
    NEW_PEAK_WARN = FOUND
    PPK = (NEW_DEM[C_X] - MAX_INST_DEM)
    DISPLAY "*****"
    DISPLAY "WARNING ! MOVING THIS LOAD HAS
      ACTUALLY CAUSED A PEAK WHICH "
    DISPLAY "IS {PPK} kVA HIGHER THAN IN THE
      ORIGINAL DAILY PATTERN !!!"
    DISPLAY "*****"
  ELSE
    DISPLAY " "
    DISPLAY " "
    DISPLAY " "
    DISPLAY " ";

```

```

RULE IMPORTCHECK
  IF      TOT_IN_MOVE < 0
  THEN
    IMPORTCHECK = FOUND
    NEGTOT = ( -1 * TOT_IN_MOVE)
    DISPLAY "*****"
    DISPLAY "      YOU HAVE IMPORTED {NEGTOT} kVA
              MORE LOAD FROM OTHER CHARGE
              PERIODS"
    DISPLAY "      THAN YOU ORIGINALLY INDICATED
              WAS NECESSARY"
    DISPLAY "*****"
  ELSE
    DISPLAY " "
    DISPLAY " "
    DISPLAY " "
    DISPLAY " ";

RULE LF_TARG
  IF
  THEN
    TARG_TYPE = LOAD_FACTOR
    TARG_FOUND = YES
    RESET TARG_LOAD_FACT
    FIND TARG_LOAD_FACT
    TARG_MAX_DEM = ((MEAN_INST_DEM) /
                    (TARG_LOAD_FACT))
    X = 1
    CUT = 0
    FILL = 0
    WHILEKNOWN CHECK48
      RESET TARGETMD
      FIND TARGETMD
      FORMAT TARG_DEM[X], 9.3
      FORMAT TARG_REDN[X], 6.0
      RESET CHECK48
      FIND CHECK48
    END
    CUT_FILL_RATIO = ((CUT) / (FILL))
    RESET FEASIBLE
    FIND FEASIBLE;

```

```

RULE MD_TARG
  IF
  THEN
    TARG_TYPE = MAXIMUM_DEMAND
    TARG_FOUND = YES
    RESET TARG_MAX_DEM
    FIND TARG_MAX_DEM
    X = 1
    CUT = 0
    FILL = 0
    WHILEKNOWN CHECK48
      RESET TARGETMD
      FIND TARGETMD
      FORMAT TARG_DEM[X], 9.3
      FORMAT TARG_REDN[X], 6.0
      RESET CHECK48
      FIND CHECK48
    END
    CUT FILL RATIO = (@ABS((CUT) / (FILL)))
    RESET FEASIBLE
    FIND FEASIBLE;

RULE TARG_MD1
  IF
  THEN
    INST_DEM[X] > (TARG_MAX_DEM)
    TARGETMD = FOUND
    TARG_DEM[X] = (TARG_MAX_DEM)
    TARG_REDN[X] = (NEW_DEM[X] - TARG_MAX_DEM)
    CUT = (CUT + (INST_DEM[X] -
TARG_MAX_DEM));

RULE TARG_MD2
  IF
  THEN
    INST_DEM[X] <= (TARG_MAX_DEM)
    TARGETMD = FOUND
    TARG_DEM[X] = (INST_DEM[X])
    TARG_REDN[X] = 0
    FILL = (FILL + (TARG_MAX_DEM[X] -
INST_DEM[X]));

RULE NO_TARG
  IF
  THEN
    TARG_TYPE = NONE
    RESET FEASIBLE
    TARG_FOUND = YES
    X = 1
    WHILEKNOWN CHECK48
      TARG_DEM[X] = (INST_DEM[X])
      TARG_REDN[X] = 0
      FORMAT TARG_DEM[X], 9.3
      FORMAT TARG_REDN[X], 6.0
      RESET CHECK48
      FIND CHECK48
    END;

```

```
RULE FEASIBLE
  IF      CUT_FILL_RATIO > 1
  THEN    FEASIBLE = NO
  ELSE    RESET FEASIBLE;
          !! IE, MORE LOAD HAS BEEN CUT THAN CAN BE
          FILLED IN !!
          !! NB THIS IS NOT NECESSARILY IMPOSSIBLE; IT
          JUST MEANS THAT
          !! LOAD HAS TO BE MOVED TO OTHER MD CHARGE
          PERIODS !!
```

ASK SATISFIED: " What do you want to do next ?";  
CHOICES SATISFIED: Help, Set\_import\_load,  
Move\_[other]\_loads,  
Current\_situation,  
Show\_all\_intervals, List\_all\_moves,  
Load\_spreadsheet, Finish;

ASK HALF\_HR: " How many minutes past the hour ?";  
CHOICES HALF\_HR: 00,30;

ASK HOUR : "What hour of day ?";  
CHOICES HOUR : 00,01,02,03,04,05,06,07,08,09,10,11,12;

ASK AM\_PM : " am, or pm ?";  
CHOICES AM\_PM: am,pm;

ASK IN\_MOVE\_TOT : "";

ASK THISMD: "What is the MD rate (\$/kVA) for this month  
?";

ASK GOAHEAD : "Do you wish to proceed ?";  
CHOICES GOAHEAD : Yes,No;

ASK TARG\_TYPE: "What type of target do you want to set  
for yourself ?";  
CHOICES TARG\_TYPE: None, Load\_factor, Maximum\_demand;

ASK TARG\_LOAD\_FACT: "What load factor (target) would  
you like to aim for ?";

ASK TARG\_MAX\_DEM: "What Maximum Demand target figure  
(kVA) would you like to aim for ?";

ASK LOADACT: "What do you want to do with this load ?";  
CHOICES LOADACT: Turn\_off, Export, Import, Reschedule;

ASK ONLOAD: "I have no record of this machine, what is  
its power demand (kVA) ?";

ASK MMACHNAME: "Please identify the equipment you wish  
to deal with";

## COMMENTARY ON KNOWLEDGE BASE

## ACTIONS BLOCK

The ACTIONS block of this module has three main functions; to set initial values for several variables, to create a copy of the instantaneous demand figures (corresponding to each half hour period within 24 hrs) which will be the figures which are modified during the operation of this module, and finally to execute the "main program" which is simply an iteration loop allowing the user to choose between the various main options, (ie, Help, Set\_import\_load, Move\_[other]\_loads, Current\_situation, Show\_all\_intervals, List\_all\_moves, and Load\_spreadsheet) until "Finish" is selected.

## RULE CONT1H.

Two "help" screens giving basic information on the operation of the module.

## RULE CONT1

This rule displays a summary of the nett effects of all the load changes which have been carried out (prior to its invocation); in particular, the total loads which have been simply shed, the loads which have been moved to other MD charge periods, and the loads which have been "imported" from other MD charge periods. The current peak load, and the time at which it occurs is recalculated and displayed, and (after asking for the current MD charge rate) the apparent MD saving is calculated.

Note the assumption, which is inherent in the philosophy of the whole DSS; the user experiments with the load pattern of a "typical" day, the assumption is then made that any reduction in the peak load OF THAT DAY corresponds to an equal reduction in the Maximum Demand, over the MD charge period.

This assumption is necessary for the operation of the model, but it highlights the importance of the checks performed in MD\_REPOR.KBS to check the extent to which the "typical day" IS typical for a particular month or MD charge period.

## RULE MAX\_MM

This rule, in conjunction with the CHECK48 loop counter, is used to determine the peak daily load during the operation of the LIST SUMMARY RESULTS rule.

## RULE CONT2; SHOW ALL INTERVALS.

This rule has two main functions; firstly, for each half hour time interval over the (typical) day, the current energy demand is shown, and secondly (after asking the user to set a "target" (in terms of either a maximum demand, or a load factor figure), it calculates



and displays the load which has to be achieved, and the load reduction which has to be achieved for each period to meet this target.

Note 1; the load figure against which the "remaining load reduction" is calculated is the instantaneous demand figure, MODIFIED BY THE PREVIOUS LOAD CHANGES; the user can therefore monitor the progress being made towards achievement of the target.

Note 2; The visual effect of formatting the "remaining load reduction" figure to have no decimal places, is to draw attention to those time intervals in which load reductions need to be made.

Note 3; On a technical note, the VP Expert package places no limit on the size of the "conclusions" section of its rules, and only minor constraints on their contents; this rule has a single simple condition, and a conclusion section which includes some 97 lines of code, and a WHILEKNOWN..END loop (which in turn calls other rules).

The use of this latter technique is not at all well advertised within the VP Expert manual, but has been found to be invaluable, and almost essential to the production of a reasonably "tidy" knowledge base.

RULE LF\_TARG, RULE MD\_TARG, RULE TARG\_MD1, RULE TARG\_MD2, and RULE NO\_TARG are commonly referenced by this rule in the setting up of the "target" MD or Load Factor levels.

#### RULE FEASIBLE

This rule is used in conjunction with the SHOW ALL INTERVALS rule, to determine whether the target set by the user is realistic; this is done by summing the loads above the target level, and those below the target level; this ration must be less than 1, and in practice, a figure significantly below 1 is necessary to offer any reasonable chance of meeting the target.

#### RULE CONT3; MOVE (OTHER) LOADS

Arguably the rule which is most central to the operation of the whole decision support system, this rule manages the movement of the various loads between time intervals.

At the invocation of the rule, the user is first asked to identify the time interval of interest.

The module then asks the user to name the equipment of interest ( Note the terminology, this refers to any block of electrical load which has to be turned off or on together, as opposed to the electrical load of any particular machine).

Note also, there is no reason why a "generator", with a negative load demand, cannot be specified; the module will handle this correctly.

When the equipment is identified, the module searches the MACHINE database to see whether data is held on the electrical demand of this equipment; if the data is found, it is read into the module, if not the user is prompted for the demand, and the data is stored in the database for future reference.

Having established the electrical demand of the equipment, the user is then asked what is to be done with this load; four choices are provided; Simply shed the load, "export" the load to another MD charge period, "import" the load from another MD charge period, or reschedule the load (to a different half hour period within the typical day).

Upon identification of the desired action, the CONT3 rule first checks a whole series of other rules (all with names of the form NOT\_OK\_x, RESULTAx, or ACTIONOKx) whose object is to determine whether the proposed movement is feasible or not. There are two main types of reason why an action is not feasible/permisible; the first type involves an attempt to move from a time interval a (equipment) load which is larger than the load which exists in this time interval (ie, the load cannot have been connected during that interval initially). The second type of reason involves the attempt to move from an interval a load which has already (at an earlier stage) been moved out of that interval. This is detected by searching a second database, MACHSLOT, for a record of that equipment, during that interval, with an "action" of either "turn-off", "export", or "reschedule".

Should any of these conditions be found, the user is warned, and the action is not carried out.

Should no condition be found to preclude the proposed action, the load is added/subtracted/moved, the figures for the other time intervals are updated, the records of total load exported, imported and turned off are updated, and the MACHSLOT database is loaded with the equipment identification, the time interval identification, the action taken, and the new state of the equipment (on, or off).

The rule then displays a summary of the effects of the move (new total demands at "present" and "destination" (in the case of rescheduled loads) times.

Finally, the rule carries out two checks; to ensure that the move has not created a new peak demand (NB, the decision support system, as a matter of principle, does not prevent this situation, simply

warns of it), and to advise if the user has imported more load into the MD charge period than the original target figure (see rule CONT5, SET IMPORT LOAD).

The main trap associated with complex conclusions sections of rules is that one of the called rules will try to find a value for one of its variables by referencing the calling rule again - thus producing an infinite loop.

As an example of how this can occur, an earlier version of RULE CONT3 contained the statements

```
      GET MMACHNAME=MACHNAME AND
C_X=ST_TIME, MACHSLOT, ALL
      OLD ACTION = (MACTION) ...
```

```
      RESET ACTIONOK
      RESET RESULTA
      FIND RESULTA
```

in its conclusions section.

An unsuccessful "GET" operation (ie, one in which no record matching the database select criterion is found) resets the values of all the VP Expert variables corresponding to the database fields.

The NOT\_OK\_x rules are used to check that a user is not (for example) proposing to reschedule the operation of a machine which has been earlier turned off test the value of OLD ACTION (eg), and therefore check the value of OLD ACTION.

The problem arises when no previous action has been performed on the equipment; in this case the unsuccessful GET in rule CONT3 resets the value of MACTION (and hence M ACTION), and when rule NOT\_OK\_x finds that it needs a value for OLD ACTION, it backward-chains to the first rule in which OLD ACTION appears as a conclusion .... CONT3.

The solution in this case was the inclusion of the new rule DEFAULTACT, and the modification of the above construction of CONT3; in more general terms, the solution is simply to exercise care in situations where a variable may be reset (ie, to value = UNKNOWN) within the conclusion section of a rule; the fact that the variable is in the conclusions section means that it may theoretically be sought in a backward-chain search, and the fact that it is reset means that such a search will never be successful.

Rules which may be called by CONT3 include;

```
RULE UPDATEMC1 (update of MACHINE database)
```

```
RULE RESULTAD, RULE NOT_OK_1, RULE NOT_OK_2, RULE
NOT_OK_2A, RULE NOT_OK_2B, RULE ACTIONOK1, RULE
RESULTAX, RULE NOT_OK_3, RULE NOT_OK_4, RULE
NOT_OK_5, RULE NOT_OK_5A, RULE ACTIONOK2, RULE
RESULTAI, RULE RESULTAR, RULE NOT_OK_6, RULE
NOT_OK_7, RULE NOT_OK_8, and RULE ACTIONOK4 are all
required for checking the validity of a proposed
load movement;
```

RULE DEFAULTACT is required to ensure that a valid value for "the last action carried out on an item of equipment in this time interval" is always available.

RULE MORNING\_TIME, RULE AFTERNOON, RULE T OF D, RULE INT HOUR, RULE INT MIN, RULE THISMD, and RULE MAX MM are all associated with translating between values for time of day, expressed either in standard "hh:mm am/pm" format or as a number of 30 minute intervals since midnight.

RULE MOVE\_SUMMARY and RULE MOVE\_SUMMARY1 provide the display which summarises the results of moving a particular load; in the case of a load which is to be rescheduled, the former also obtains the destination time for the load.

RULE NEW PEAK WARN1, RULE NEW PEAK WARN2, and RULE IMPORTCHECK perform checks after each load movement has been completed to determine whether the movement has resulted in the creation of a new peak, or the exceeding of a previous target for load import.

#### RULE CONT4: LOAD SPREADSHEET

This rule transfers back to the spreadsheet the final daily load pattern after all changes have been completed by the user. RULE CCONFIRM is referenced by this rule.

#### RULE CONT5:SET IMPORT LOAD

Allows the user to nominate a target load to be imported from another maximum demand charge period.

#### RULE CONT6: LIST ALL MOVES

This rule presents (one screen at a time) a list of all the load movements made by the operator. RULE NEWLINE, and RULE XTIME are referenced by this rule.

#### RULE CHECK48

This rule simply implements a counter, allowing operations on the 48 values for the (half hourly) daily load demand figures.

#### RULE THISMD

Used to find the maximum demand charge rate for the period under investigation.

## APPENDIX E VP EXPERT TIPS TRICKS AND TRAPS

Note; the reader is also referred to section 5.6 of this thesis for comment on some more general problems found (and in some cases solved) in the development of these small decision support systems.

## E.1 Tips and tricks for DSS development with VPX

## E.1.1 Use of FIND &amp; WHILEKNOWN..END constructs within conclusions sections of rules.

The iteration construct offered by VP Expert is the WHILEKNOWN.. END construct; this construct is more similar to the DO UNTIL construct found in programming languages than the DO WHILE, since the loop is always actioned the first time it is encountered.

It differs from both the DO WHILE and DO UNTIL in one major respect though; the loop terminating condition is not a boolean expression (which must evaluate to false to terminate the loop); rather it is a variable which terminates the loop when its value ceases to exist (ie, when its value becomes UNKNOWN).

It is suspected that the main purpose envisaged for the WHILEKNOWN.. END construct by the designers of VP Expert is for extracting data from (eg) a database (ie, "extract records UNTIL no more exist").

Although the WHILEKNOWN..END syntax does allow any iteration condition to be constructed, it can be highly inconvenient for more general use, since the loop-terminating variable has to be set to "UNKNOWN", ie unavailable, at the termination of the loop.

It is not strictly theoretically necessary to ever use FIND, or WHILEKNOWN..END constructs in the conclusion sections of rules, for the purpose of finding simple results; the rules which are "found" as a result of these constructs could equally well be "found" by simply including the subject of the FIND clause within the conditions section of the rule. Furthermore, the use of such constructs for finding simple results adds a degree of redundancy to the backward chaining facility; the whole principle of backward chaining is that, if a value is needed, it is sought... there should be no need to tell the system when to start searching.

An example of an occasion where such a construct IS needed can be found in MD\_REFIN.KBS. The rules associated with converting a time (expressed as hh:mm am/pm) into an integer number of 30 minute periods from midnight are used by several different sections of the knowledge base. For example, they are used to determine the time interval from which load is to be shifted, and they are used to determine to time interval to which load is to be rescheduled (should this option be selected). One of the principles of a backward chaining facility however is that if a variable value is known,

it is not re-sought; this means that it would be impossible, in the above case, to persuade the ES to seek a new value for time (like the Goon show's Bluebottle, it already knows the time (x) so why look for it!). The solution is to use RESET X (which cannot be used in the conditional section of a rule) then FIND X, within the conclusions section of the rule.

The use of FIND and WHILEKNOWN..END constructs in rule conclusions are also useful in structuring the presentation of results, and in improving the readability of the knowledge base.

#### E.1.2 Chaining of knowledge bases.

This facility works well provided the EXECUTE command is used at the start of the "called" knowledge base; the chain facility is provided for use in the case "where the knowledge base is too large for the memory of your computer".. in practice it has been found that the memory of most PC's will accommodate a very large knowledge base, and a more common usage will possibly be to segment a large application into several smaller sections.

Note the problem caused by not being able to use a variable as the argument of a CHAIN command; see section E.2.1 below.

#### E.1.3 ACTIONS section

The actions section of a knowledge base provides a very restrictive form of flow control; it is not permitted to nest WHILEKNOWN..END loops, nor is it possible to return control to "higher" locations in the action section. It can be regarded as similar to the "main program" section of a Pascal program.

#### E.1.4 Numerical analysis.

Although VPX itself is not fast at number crunching, it does support dimensioned variables, and potential exists for efficient numerical analysis, by using rules to ensure that only those analyses which are really needed FOR A PARTICULAR CASE are performed. This is a case where the incorporation of processing algorithms within the conclusion section of rules can be used to advantage.

Note, another option is to use a numerical analysis "package" (possibly developed in "C", or other language), called by a CCALL, or BCALL statement. This would probably offer improved performance, especially for more complex calculations, and reduce the volume of data which needs to be handled by VPX.

## E.2 Traps and difficulties with VPX

### E.2.1 Problems with orthogonality;

A key goal in the design of programming languages is that of achieving the greatest possible level of orthogonality. The principle of orthogonality can be explained as follows; at ANY POINT where (eg) a character string is logically required, an ORTHOGONAL language will allow the substitution of AN EXPRESSION WHICH EVALUATES TO A CHARACTER STRING.

VP Expert lacks orthogonality in a number of aspects:

It is not possible to use variable names in "CHAIN" statements, only constants. This is a nuisance in cases where different knowledge bases need to be called, according to the value of a choice made in the "parent" knowledge base. The only solution found was a set of rules, each of which had a CHAIN in the conclusion, followed by a knowledge base name.

The use of computed fields in comparisons; eg "IF AA < (BB / (CC + DDD))" does not work as expected; the only solution found to this problem is to compute "DUMMY = (BB/(CC+DD))", then use "IF AA < DUMMY....".

As a further example, "IF INST DEM[X] > (TARG MAX DEM)" works fine, but IF TARG INST DEM < (INST DEM[X]) does not work; the comparison fails regardless of the values of INST DEM[X], and TARG MAX DEM. Some of the above errors cause bizarre effects, eg the creation of variables whose names and values consist of large chunks of machine code, copied from unknown memory locations!

### E.2.2 Problems with arbitrary rules & restrictions;

VP Expert contains a number of restrictions for which no reason can be found; many are minor, but all are irritating. Examples include;

The necessity of using WKS as the file extension for spreadsheet files. This is particularly annoying since Lotus Symphony files are correctly read by VP Expert after DOS renaming with ".WKS" extensions, but are cannot be read by VP Expert with the ".WR1" extension always created by Lotus Symphony.

On a similar theme, data files are not permitted to have a file extension (and are created by VP Expert without one); this causes a problem should one want to specify such files for action (eg backup) using DOS wildcard characters.

Appearance issues; if the "Execute" command is added to the knowledge base, (with the advantage of eliminating the messy appearance of having to issue the "GO" command), then the facility of the "WHATIF", and "WHY", "HOW" etc commands seems to be lost also.

### E.2.3 Missing functions/facilities

VP Expert seems to totally lack string handling facilities; even such simple functions as concatenation. This is one of the two most important lacks in the VP Expert package. (Note, VP Expert is very weakly typed throughout, although this is probably an advantage for an application of this type.)

Good screen handling facilities are also notably missing from VPX version 1.2; this has been corrected to some extent with the "smartforms" of version 2.0.

Arguably the greatest lack within VPX is that of graphics facilities.

One of the tests commonly applied to determine whether an application is suitable for Expert System application is to determine the quantity of data involved (too much data implies that another approach is preferable); while this test is evidently correct in principle, many useful "decision support" systems must utilise similar quantities of data to the ECM application, and for such data volumes graphics facilities would be a major advantage.

### E.2.4 Errors.

FORMAT does not just format the DISPLAY of a variable value (which is obviously stored as an ASCII string); it rounds the stored value of the variable. Therefore if two variables with identical values are taken and one is formatted then subtracted from the other, the result is a non-zero remainder. This can be demonstrated with the following simple knowledge base.

```
actions
  reset res
  reset z
  find res;

rule 1
  if    z > 0
  then y = (z)
        format y, 3.1
        res = (z - x)
        display " z = {z}"
        display " y = {y}"
        display " result = {res}";
ask z: "value of z";
```



### E.2.5 Syntax problems

Problems with the lack of facilities for grouping the "AND"'s and "OR"s within the predicate of a rule have been encountered; This reflects some lack of structuredness in the syntax.

The fact that IF..THEN loops cannot be effectively nested means that the use of ELSE is often impractical; cannot have the situation where, if the "parent" rule has passed, then the failure of the "child" rule operates the "ELSE"; with VPX, every time a rule is encountered which does not pass, an associated ELSE passes. This can be inconvenient with (eg) IF xx THEN PRINTON ELSE PRINTOFF.

In practice, it has been found easier to implement separate rules covering each permutation.

## APPENDIX F DATA DICTIONARY (PROPOSED DBMS)

Refer to the data model developed for the ECM application; Figure 12.

## COMPANY-SLOT

This entity records the energy usage of the whole organisation over each one month time-slot.

Company-Name  
 Year  
 Month-Name  
 Consumption (kWh)  
 Night-Units (not strictly needed, but desirable)  
 Day-Units ( " " " " " )  
 MD-Rate  
 CosPhi

## COMPANY-DAY

This entity records details of the energy usage of the organisation over each day; it corresponds to the "full version" of the daily instantaneous load figures held, for a single "typical" day, in the current ECM spreadsheet application.

Year  
 Month-Name  
 Date  
 (Day-type), ie weekday, or weekend etc.  
 Start-time (for 30 minute interval)  
 Consumption  
 CosPhi  
 Day-Unit\_cost  
 Night\_unit\_cost  
 (MD-costs)  
 Temperature (Inside, and outside?)

## PRODUCTION

The organisation's production record.

Product-Number  
 Year  
 Month-Name  
 Units-Produced  
 Regression-Coefficient

## MACHINE-SLOT

This is the "lowest common denominator" entity, and the one to which all others relate; it records the state (ie on, off, idle) of each item of

energy-using equipment within the organisation,  
over the entire study period.

Machine\_Number  
Year  
Month-Name  
Date  
Start-Time  
Product-Number  
Machine-State

#### TARIFF

This entity records the complete structure of  
(each) tariff of interest by relating rates to  
times of day (Start-times).

Tariff-Number  
Year  
Month-Name  
Day-Type  
Start-Time  
Buy-Rate  
Sell-Rate  
MD-Rate

#### DEPARTMENT-SLOT

Records energy usage by (each) Department within  
each monthly time-slot over the study period.

Department-Name  
Department-Number  
Yea Month-Name  
Consumption (kWh)  
(Utilisation)  
CosPhi

#### MACHINE

Record of operational information, and in  
particular the energy demand, of each item of  
equipment in the organisation

Machine-Number  
Department-Number  
In-Use-Consumption  
Idle-Consumption

APPENDIX G DATA ENTRY MODULE SOURCE CODE

---

## G.1 OVERVIEW

ECMDM is a simple data entry module developed to allow users to prepare data for use with the Lotus Symphony ECM modules, without having access to the Symphony application. It has been developed using a dBase look-alike package, DBman V, which has a developers version. This has allowed a runtime version to be prepared and issued.

## G.2 OPERATION

The following is the text of the READ.ME file issued with the data entry module disks.

```
*****  
      READ THIS  
  
DATA ENTRY MODULE FOR THE ENERGY COST MANAGEMENT  
      EXPERT SYSTEM.
```

---

The ECM4.RUN software package is designed to allow you to enter, edit, and printout your own energy consumption and cost data for future use in the Energy Cost Management Expert System.

## RUNNING THE SOFTWARE

If you have a hard disk, create a new directory (using the DOS MKDIR command) and load the contents of the floppy disk into this directory. If you only have a floppy drive, just insert the disk.

Type GLEXE ECM4.RUN <cr> to run the program.

Menu options are selected by using the arrow keys, or pressing the key corresponding to the first letter of your choice, followed by <cr>.

In every case, you will be asked to select the operation you wish to perform (edit/entry, printout, or quit), followed by the file on which you wish to perform the operation.

The file edit mode is terminated by pressing <cntrl-W>.

## DESCRIPTION OF FILES

Files TARIFF\_2, TARIFF\_1, AND CUR\_TARIFF

These files allow you to store details of the tariff rates you paid 2 yrs ago, 1 yr ago, and this year.

FIELD	UNITS	FORMAT	NOTES
MONTH	(already in)		
DAYRATE1	c/kWh	0.000	Four possible day tariffs can be entered.
DAYRATE2	as above		
DAYRATE3	as above		
DAYRATE4	as above		
NITERATE	as above		Night tariff rate
MDCHARGE	\$/kVA	00.00	Maximum demand rate

\* Note; The last four fields are not shown on the opening screen; they are displayed by scrolling across with the <cr> key.  
Remember; <Cntrl-W> to finish!

File CONSN\_2, CONSN\_1, AND CUR\_CONSN

These files allow you to enter details of your energy consumption for 2 years ago, 1 year ago, and this year.

FIELD	UNITS	FORMAT	NOTES
MONTH	already in		
D1UNITS	kWh	000000	Units consumed at DAYRATE1 tariff
D2UNITS	as above		" " " 2
			"
D3UNITS	as above		" " " 3
			"
D4UNITS	as above		" " " 4
			"
N_UNITS	as above		" " " Night tariff rate
MD_KWH	kWh	0000	kWh on which Max Dem tariff calc'd

Note; last few fields obtained by scrolling right.  
Remember; <cntrl-W> to finish!

## File NITERATE

This file allows you to specify the times at which the night tariff rate starts and finishes.

FIELD	UNITS	FORMAT	NOTES
YEAR		1989	three entries are provided for 2 yrs ago, 1 yr ago, & this year.
ST_TIME	hh:mm	am	Note position of "am" or "pm"
END_TIME		as above	

Remember; <cntrl-W> to finish.

## G.2 DATA ENTRY MODULE SOURCE CODE

```

* ECM data entry module
* DBman V developer's version
* L J Robertson
* 13 June 1989

* Initialize section
SET BREAK ON
SET CONSOLE ON
SET DEVICE TO SCREEN

STORE 1          TO FFNO
STORE 0          TO VVAR
STORE "          " TO FFNAME
STORE "          " TO DDESC
STORE ""         TO INFNAME
STORE ""         TO OUTFNAME
STORE "N"       TO AAPD

CLEAR SCREEN
ASSIGN FRAME(1,201,187,200,188,186,205)
ASSIGN POPWIND(0)
ASSIGN WINDOW(1,1,23,77)
ASSIGN WINDOW(1,17,23,77)
ASSIGN WINDOW(22,17,23,77)
ASSIGN WINDOW(1,17,23,77)

@ 1,1 CLEAR TO 18,59
@ 1,8 SAY "WELCOME TO THE DATA INPUT MODULE OF THE
ECMES!"
@ 2,8 SAY
"-----"
@ 4,4 SAY "This program is designed to allow you to
enter, edit"
@ 5,4 SAY "and print out all of the data which will be
required"
@ 6,4 SAY "in order to get the most benefit from the
'Energy  "

```

```
@ 7,4 SAY "Cost Management Expert System'."
@ 8,4
@ 9,4 SAY "You will be able to use the data files in
any order "
@ 10,4 SAY "you wish, and you will be able to enter and
edit the"
@ 11,4 SAY "data (in full-screen format) and obtain a
printout "
@ 12,4 SAY " when you are satisfied with your data.
"
@ 13,4
@ 14,4 SAY "When you elect to 'quit' this program, your
data "
@ 15,4 SAY "files will be converted into a format
suitable for "
@ 16,4 SAY "(automatic) reading by the 'symphony'
Expert System."
@ 17,4 SAY
@ 18,4 SAY "Press any key to continue."
WAIT
```

```

@ 1,1 CLEAR to 18,59
ASSIGN WINDOW(1,1,23,77)
@ 1,1 CLEAR TO 22,14

* Set up list of files for files menu; remove blanks
from FLIST.
STORE "" TO FMENU
USE FLIST
GOTO TOP
DELETE FOR TRIM(INFNAME) = ""
PACK
DO WHILE .NOT. EOF()
    STORE FMENU + INFNAME + "," TO FMENU
    SKIP
ENDDO
USE

* Main body of program
DO WHILE VVAR <> 4

    DO CASE
        CASE VVAR = 1
            ASSIGN WINDOW(22,17,23,77)
            @ 1,1 CLEAR TO 1,59
            IF TRIM(UPPER(AAPD)) = "Y"
                @ 1,1 SAY " Append records to
                    file "
                @ 1,28 SAY DDESC
                ASSIGN WINDOW(1,17,20,77)
                @ 1,1 CLEAR TO 17,59
                APPEND
            ELSE
                @ 1,1 SAY " This is a fixed
                    length file, press
                    any key to continue"

                WAIT
                ASSIGN WINDOW(1,17,20,77)
                @ 1,1 CLEAR TO 17,59
            ENDIF

        CASE VVAR = 2
            ASSIGN WINDOW(22,17,23,77)
            @ 1,1 CLEAR TO 1,59
            @ 1,1 SAY "Enter/edit data regarding "
            @ 1,28 SAY DDESC
            ASSIGN WINDOW(1,17,20,77)
            @ 1,1 CLEAR TO 17,59
            BROWSE
    
```



```

CASE VVAR = 3
  ASSIGN WINDOW(22,17,23,77)
  @ 1,1 CLEAR TO 1,59
  @ 1,1 SAY "Print out data regarding "
  @ 1,28 SAY DDESC
  ASSIGN WINDOW(1,17,23,77)
  @ 1,1 CLEAR TO 18,59
  SET DEVICE TO PRINT
  @ 1,1 say "Filename "
  @ 1,20 SAY FNAME
  @ 2,1 SAY DDESC
  @ 3,1 SAY CHR(13)
  LIST ALL TO PRINT
  @ 20,1 SAY CHR(13)
  SET DEVICE TO SCREEN

@ 1,1 SAY " "
@ 1,1 CLEAR TO 18,59
ENDCASE

* Setup main (operations) menu
ASSIGN WINDOW(22,17,23,77)
@ 1,1 CLEAR TO 1,59
@ 1,1 SAY " Main menu; (Operations are selected
           first, then filename)."
ASSIGN WINDOW(1,1,23,77)
@ 1,1 CLEAR TO 22,14
@ 1,1 SAY " Main menu "
@ 2,1 say "-----"
ASSIGN VMENU(' ',' 'Add,Edit,Print,Quit,' ,5,1,0,2,3)
STORE VMENU() TO VVAR

IF VVAR <> 4
* Setup menu of available files
  ASSIGN WINDOW(1,1,23,77)
  @ 1,1 CLEAR TO 22,14
  @ 1,1 SAY "Menu of files"
  @ 2,1 say "-----"
  ASSIGN VMENU(' ',' '&FMENU',3,1,0,1,3)
  STORE VMENU() TO FFNO

* Select file
  USE FLIST
  GO FFNO
  STORE INFNAME TO FNAME
  STORE DESC TO DDESC
  STORE APPD TO AAPD
  USE

```

```

* Open file
  IF FILE("&FNAME") = Y
    USE "&FNAME"
  ELSE
    STORE 0 TO VVAR
    ASSIGN WINDOW(22,17,23,77)
    @ 1,1 CLEAR TO 1,59
    @ 1,1 SAY "File not found, check your
disc;"
    @ 1,33 SAY "press any key to continue."
    WAIT
  ENDIF

ENDIF
ENDDO

* Convert files to delimited format
CLEAR SCREEN
ASSIGN WINDOW(1,1,23,77)
@ 1,1 CLEAR TO 22,14
ASSIGN WINDOW(22,17,23,77)
@ 1,1 CLEAR TO 1,59
@ 1,1 SAY "Converting files to (delimited) symphony
format"

USE
STORE "" TO IIFN
STORE "" TO OOFN

SELECT FJ
USE FLIST
GO TOP
DO WHILE .NOT. EOF()
  STORE INFNAME TO IIFN
  STORE OUTFNAME TO OOFN

  SELECT FK
    IF FILE("&IIFN") = Y
      USE &IIFN
      COPY DELIMITED TO &OOFN
    ENDIF

  SELECT FJ
  SKIP
ENDDO

* Shutdown section
@ 1,1 CLEAR TO 1,59
@ 1,1 SAY "End of program; return to calling program"
ASSIGN WINDOW(1,1,23,77)
@ 1,1 CLEAR TO 22,14
@ 12,20 SAY " FAREWELL"
USE
RELEASE ALL
CLOSE ALL
CANCEL

```

#### G.4 FILE FORMATS AND USE.

##### G.4.1 FLIST.DBF

STRUCTURE;

INFNAME	C	10
OUTFNAME	C	10
DESC	C	30
APPD	C	1

Note, this is the file which holds the list of data files to be used by the data entry module.

##### G.4.2 DATA FILES

DBman offers the option of specifying files strictly to the dBase III format, or its own (slightly different) format. The latter option is used in the above code; the option choice is easily changed.

##### G.4.3 OUTPUT FILES; SYMPHONY INPUT.

When the user indicates that data entry is complete, the ECMDM application converts the data files into "delimited" format, as shown below. Data in fields is enclosed in double quotes, and fields are delimited by commas; Records are delimited by carriage returns.

FILE NRATDEL.TXT;

```
"1989","12:00 pm","12:00 am"
"1988","12:00 pm","12:00 pm"
"1987","12:00 pm","12:00 am"
```

Files of this format can be imported by issuing the "File Import Structured" instruction, or incorporating FIS<filename> in a macro.

##### G.5 COMMENT ON SOURCE CODE

A menu file, FLIST.DBF, is used to store details of all data files used by ECMDM; this technique allows the data entry module to be used for any data files, simply by changing the contents of the menu file.

The information held in the menu file includes the names of the data files, the names of the delimited files to which data will be exported for use by the Lotus Symphony application, a description of the data file, and an indication of whether the Symphony application requires a fixed length data file. In the case where the Symphony application requires a fixed length file (eg, to be inserted in a fixed length range, the operator setting up the data entry module

must create a data file of the required length, filled with blanks, and place "N" in the APPD field of FLIST; ECMDM will then not allow the user to add records to this file.

The program is essentially simple, offering the user the options three options in addition to "quit";

    Add data; ie add records (only allowed if APPD field in FLIST does not contain a "N").

    Edit data (using a full screen browse, which is acceptable because of the relatively small size of the files involved)

    Print data; prints out selected file.







## APPENDIX H SPECIFICATION FOR FURTHER WORK

## H.1 Maximum Demand control Decision Support System.

System testing

The decision support application has not, as yet, been subjected to any formal testing; this needs to be done both to eliminate bugs, and to ascertain usefulness.

Pattern recognition

Design and implementation of much more sophisticated pattern recognition techniques. The procedure proposed for developing useful pattern recognition capabilities is;

- Obtain several sets of consumption data,
- Extract from these sets of data small numbers of values which characterise the data.
- Obtain The Expert's interpretation of the sets of data,
- Correlate the "characteristic values" and the "expert interpretation".

Three types of "characteristic value" are proposed.

The magnitude and phase of the fourier coefficients for the first six harmonics. In a 12 data point sample, higher harmonics are meaningless.

The slope and intercept of a "best fit" straight line. It is acknowledged that this presents no information not already available in the fourier analysis, but the information may be more easily correlated with The Expert's interpretation.

Statistical parameters consisting of maximum and minimum values, the mean and standard deviation of the values, and the ratio of mean to standard deviation.

A spreadsheet application to extract these "characteristic values" has been prepared; the fourier analysis is carried out using the "jump" method (see Kreyszig [13]), the line of best fit is determined by least squares method, while the statistical functions are built into the spreadsheet.

Sample data is available (in the form of data from past consultations using the Symphony application), but lack of time has meant that the application of this spreadsheet to the sample data and the correlation with the Expert's interpretation has not been carried out.

Economic analysis.

Some value is seen in extending the scope of the application to a more detailed economic analysis of the (effects of) proposals developed by the ECM user.



### Utility processes.

Batch process to remove records from the MACHSLOT database file at the start of a new "session".

### Session identification.

A useful additional facility would be that of nominating a "session" when considering load movements using the Decision support system; Such a facility would allow the user to build up several scenarios for comparison. This facility would not be difficult to implement, simply requiring the addition of a "session" field to the MACHSLOT database, and minor changes to the MD\_REFIN.KBS code.

### Variable time length intervals.

The current MD\_REFIN knowledge base constrains the user to always work with one 30 minute period at a time; it would be useful to allow the user to nominate a multiple of 30 minutes. More complex checking would be required to ensure that the proposed load movement was permissible within each of the intervals affected. This facility could be effected by introducing a single rule between the current CONT3 rule, and the NOT\_OK\_x etc rules; the single rule would obtain the period, and use a WHILEKNOWN..END loop in its conclusion to invoke the NOT\_OK\_x rules for each of the affected 30 minute intervals.

## H.1.2 System Integration

In order for the application to appear TO THE USER to be well integrated, it is very important that one of the techniques for integration of operation (outlined in section 3.4.3 of this paper) be implemented.

## H.1.3 Database

Implementation of the data structures developed in section 5 (whether within a dedicated database package, or within the spreadsheet application), in order to be better able to support future analyses (eg, consumption rescheduling under more complex (& possibly multiple) tariff structures).

Implementation of the "intelligent database" concept, with full reporting and data correcting functions; Note, whether the raw data is held in a dedicated database, or within the spreadsheet is a secondary issue.

## H.1.4 Spreadsheet

a/ Integrate database and spreadsheet; ie ensure that the spreadsheet data structure does not either allow data anomalies (which the data model has tried to eliminate), nor prevent extensions to the spreadsheet's

functions in the areas which have been identified with the help of the data model.

b/ Additional functions associated with the integrated package; including  
Numerical aspects of the pattern recognition and interpretation functions required by the decision support system (these have been developed, and undergone initial testing).  
Graphical (re)presentation of data, such as revised daily load patterns, output by the decision support system.  
Preparation of data specifically to suit the requirements of the decision support system.

## H.2 Development of decision support in other energy cost management areas;

One area which is considered to offer opportunity for significant savings is that of selection of alternative tariff structures;

The evaluation of a single load pattern under a single tariff structure is a tedious but straightforward mathematical process, but the evaluation of various load pattern scenarios and various tariff structures is very complex. It is suggested that this function may be able to be handled less accurately, but more usefully by an expert system application than by a very involved mathematical treatment.

APPENDIX I KNOWLEDGE ACQUISITION EXERCISE;  
QUESTIONNAIRE.

Questionnaire; Mark 1

\*\*\*\*\*

ENERGY COST MANAGEMENT EXPERT SYSTEM QUESTIONNAIRE

Dear course Attendee

The usefulness of the ECMES which you have been studying is dependent on the ECMES meeting your needs exactly and fully.

To assist us in assessing ECMES's usefulness to you, I would be very grateful if you could complete this following questionnaire and return it to;

Prof W Monteith  
Department of Production Technology  
Massey university  
Private Bag  
Palmerston North

Answers/ comments which you provide will be treated in strict confidence.

Any other comments on the application of the current version of the ECMES would also be appreciated.

QUESTIONS

- 1           What types of business decisions do you expect to make with the help of the ECMES (if possible give some examples).
- 2           What specific factors (general, or specific to your particular business), not currently addressed in the ECMES, will you need to take account of in the above decisions.
- 3           Are there any functions which you would like to see added to the current version of the ECMES.

\*\*\*\*\*

APPENDIX J SUPERSEDED KNOWLEDGE BASES

```

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!          LJREA6.KBS
!          ENERGY COST MANAGEMENT EXPERT SYSTEM
!          Decision support for high level ECM decisions
!          L J Robertson
!          VP Expert version 1.2
!          Sept 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

```

BROAD INTEREST AREA; BROAD SCOPE ECONOMIC EVALUATION

!\_\_ Initialise section \_\_\_\_\_

RUNTIME;
ENDOFF;

!\_\_ Actions section \_\_\_\_\_

ACTIONS

!\_\_ Opening screen section \_\_\_\_\_

```

CLS
DISPLAY " "
DISPLAY " W      W EEEEE L      CCC  0000  M      M  EEEEE"
DISPLAY " W      W E      L      C      0      0  M M M M  E"
DISPLAY " W      W W EEE   L      C      0      0  M  M  M  EEE"
DISPLAY " W W W W  E      L      C      0      0  M      M  E"
DISPLAY "  W  W  EEEEE LLLL  CCC  0000  M      M  EEEEE"
DISPLAY " "
DISPLAY " "

```

```

DISPLAY " TO THE"
DISPLAY " "
DISPLAY " "

```

```

DISPLAY "          ENERGY COST MANAGEMENT"
DISPLAY " "
DISPLAY " "

```

```

DISPLAY "          DECISION SUPPORT APPLICATION "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "

```

DISPLAY " Press any key to continue.~"
CLS

```
!!!_Explanatory screen section _____
CLS
DISPLAY " "
DISPLAY "This application will assist you in:"
DISPLAY "  - Selecting the most appropriate courses for energy cost
management,"
DISPLAY "  - Evaluating the potential cost savings of alternative
actions,"
DISPLAY "  - Suggesting factors to be taken account of in
implementing measures."
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " You will be asked a series of questions, many of which
have alternative"
DISPLAY " answers provided. In some cases you will need to press
<END> to confirm"
DISPLAY " your choice."
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " Press any key to continue.~"
CLS
!!!_
_____
      find INTEREST_AREA
      find OTHER_INTEREST_AREA
      find MD_DISPLAY
          ! Rules 10 to 29
      find SCHED_OPT_DISP
          ! Rules 30 to 49
      find ALT_OPT_DISP
          ! Rules 50 to 69
      find TARIFF_SELN_DISPLAY
          ! Rules 70 to 90

      find ANNUAL_$_SAVING_DIS
      find ANNUAL_UNIT_SAV_DIS
      find PRESENT_WORTH_DIS;
          ! Rule 200

! AUTOQUERY;
```

```

! __ Start of rules section _____
! __ Select area of interest & display results; Rules 0 to 9_
!
! NB, Selection of area of interest is accomplished by the ASK
! statement;

RULE 1
  IF      MD_OPTIONS <> UNKNOWN
  THEN    MD_DISPLAY = MD_OPTIONS
          DISPLAY "The recommended M-D control action is to
                  {MD_OPTIONS}";

RULE 3
  IF      SCHED_OPTIONS <> UNKNOWN
  THEN    SCHED_OPT_DISP = SCHED_OPTIONS
          DISPLAY "The expert says {SCHED_OPTIONS} to this
                  option's feasibility";

RULE 5
  IF      ALT_OPTIONS <> UNKNOWN
  THEN    ALT_OPT_DISP = ALT_OPTIONS
          DISPLAY "The alternative power option recommended is
                  to {ALT_OPTIONS}";

RULE 7
  IF      TARIFF_SELNS <> UNKNOWN
  THEN    TARIFF_SELN_DISPLAY = TARIFF_SELNS
          DISPLAY "The tariff recommended is identified as
                  {TARIFF_SELNS}";

RULE 8
  IF      ANNUAL_$_SAVING <> UNKNOWN
  THEN    ANNUAL_$_SAVING_DISP = ANNUAL_$_SAVING
          DISPLAY " The annual savings expected from this
                  measure is ${ANNUAL_$_SAVING}";

RULE 9
  IF      PRESENT_WORTH <> UNKNOWN
  THEN    PRESENT_WORTH_DISP = PRESENT_WORTH
          DISPLAY " "
          DISPLAY " The relative present worth estimated for this
                  alternative is;"
          DISPLAY " "
          FORMAT PRESENT_WORTH, 8.2
          DISPLAY " Alternative plant; $ {PRESENT_WORTH}"
          DISPLAY " "
          FORMAT PW_SAVED, 8.2
          DISPLAY " Electricity charges saved; $ {PW_SAVED}";

```

! \_\_\_\_\_ Maximum demand control; Rules 10 to 29 \_\_\_\_\_

RULE 10

!! Rule type "I", intermediate result

```

IF      INTEREST_AREA = Max_demand_control
  AND DAILY_MD > 0
  AND TOT_AVERAGE_DEMAND > 0
  AND WORST_PROCESS > 0
  !!!! NB The above three lines are just a fiddle to force
  VPX to obtain values for the variables
THEN
  PROCESS_DEPENDENCY = ((DAILY_MD - TOT_AVERAGE_DEMAND)
                        / (WORST_PROCESS));
  !!! This is a measure of the extent to which the MD is
  due to a single process.

```

RULE 11

!! Rule type "R", outputs a recommendation

```

IF      INTEREST_AREA = Max_demand_control
  AND AV_MONTHLY_MD <= 100
THEN
  MD_OPTIONS = do_nothing;

```

RULE 12

!! Rule type "R", outputs a recommendation

```

IF      INTEREST_AREA = Max_demand_control
  AND AV_MONTHLY_MD > 100
  AND MD_HEAT_COMPONENT = No
  AND PROCESS_DEPENDENCY < 3
  ! ie, a single process is principally responsible for the
  MD
  AND PROC_INTERDEP = Low
THEN
  MD_OPTIONS = Shut_down_worst_process_during_peaks;

```

RULE 13

!! Rule type "S", outputs an annual saving

```

IF      INTEREST_AREA = Max_demand_control
  AND MD_OPTIONS = Shut_down_worst_process_during_peaks
  AND MD_RATE > 0
  AND MD_CHARGE_PERIOD > 0
  AND PROCESS_SHIFT > 0
THEN
  ANNUAL_$_SAVING = ( MD_RATE * MD_CHARGE_PERIOD *
                      PROCESS_SHIFT);

```

## RULE 14

```
!! Rule type "R", outputs a recommendation
  IF      INTEREST_AREA = Max__demand_control
    AND AV_MONTHLY_MD > 100
    AND MD_HEAT_COMPONENT = No
    AND PROC_INTERDEP = Low
    AND PROCESS_DEPENDENCY > 3
    ! Conclude that a number of relatively independent
    processes are contributing to the MD.
  THEN
    MD_OPTIONS = Stagger_operation_of_processes;
```

## RULE 15

```
!! Rule type "S", outputs an annual saving
  IF      INTEREST_AREA = Max__demand_control
    AND MD_OPTIONS = Stagger_operation_of_processes
  THEN
    ANNUAL_$_SAVING = UNFINISHED_CALC;
```

## RULE 16

```
!! Rule type "R", outputs a recommendation
  IF      INTEREST_AREA = Max__demand_control
    AND AV_MONTHLY_MD > 100
    AND MD_HEAT_COMPONENT = No
    AND PROC_INTERDEP = High
    AND EXT_SCH_CONSTRAINT = No
  THEN
    MD_OPTIONS = Group_peaks_within_a_MD_period;
```

## RULE 17

```
!! Rule type "S", outputs an annual saving
  IF      INTEREST_AREA = Max__demand_control
    AND MD_OPTIONS = Group_peaks_within_a_MD_period
    AND MD_RATE > 0
    AND MOVEABLE_MD > 0
    AND MD_FREE_PERIODS > 0
    !!!! NB The above three lines are just a fiddle to force
    VPX to obtain values for the variables
  THEN
    ANNUAL_$_SAVING = (MD_RATE * MOVEABLE_MD *
    MD_FREE_PERIODS);
```

## RULE 20

```
!! Rule type "R", outputs a recommendation
  IF      INTEREST_AREA = Max__demand_control
    AND AV_MONTHLY_MD > 100
    AND ANNUAL_ENERGY_COST = High
    AND MD_RATIO > 1.5
    AND DAILY_MD_RATIO < 1.5
  THEN
    MD_OPTIONS = pf-control
    DISPLAY "MD charges must arise primarily as a result of
    days with uniformly high demand";
```



```

!RULE 21
!! Rule type "S", outputs an annual saving
!   IF      INTEREST_AREA = Max_demand_control
!   AND MD_OPTIONS = pf-control
!   THEN
!   ANNUAL_$_SAVING = 0;

```

```

RULE 24
!! Rule type "R", outputs a recommendation
IF      INTEREST_AREA = Max_demand_control
AND AV_MONTHLY_MD > 100
AND MD_HEAT_COMPONENT = Yes
THEN
INTEREST_AREA = Alternative_energy
MD_OPTIONS = Consider_alternative_power_for_heating;

```

```

RULE 27
!! Rule type "F", establishes economic factors
IF      MD_OPTIONS = pf-control
AND CAPITAL_COST > 0
THEN
TOT_RUN_COST = 0
ECONOMIC_FACTORS = Known;

```

```

RULE 28
!! Rule type "F", establishes economic factors
IF      INTEREST_AREA = Max_demand_control
AND MD_OPTIONS <> pf-control
AND MD_OPTIONS <> Do_nothing
THEN TOT_RUN_COST = 0
CAPITAL_COST = 0
ECONOMIC_FACTORS = Known;

```

```

RULE 29
!! Rule type "F", establishes economic factors
IF      INTEREST_AREA = Max_demand_control
AND MD_OPTIONS = Do_nothing
THEN TOT_RUN_COST = 0
CAPITAL_COST = 0
ECONOMIC_FACTORS = UNKNOWN;

```

! Re scheduling demand to lower tariff times; Rules 30 to 49 \_

RULE 31

```
!! Rule type "I", intermediate result
  IF      INTEREST_AREA = Load_scheduling
    AND   SCHED_SPLIT = Weekday
  THEN    PERIOD_LIMIT = 40;
```

RULE 32

```
!! Rule type "I", intermediate result
  IF      INTEREST_AREA = Load_scheduling
    AND   SCHED_SPLIT = Weekday
    AND   SCHED_RATIO > 40
  THEN
    PERIOD_LIMIT = 40
    SCHED_OPTIONS = No
    DISPLAY "The relative sizes of the periods limit shift to
             {PERIOD_LIMIT} % ";
```

RULE 33

```
!! Rule type "I", intermediate result
  IF      INTEREST_AREA = Load_scheduling
    AND   SCHED_OPTIONS = No
  THEN
    DISPLAY "The relative sizes of the periods limit shift to
             {PERIOD_LIMIT} % ";
```

RULE 37

```
!! Rule type "R", outputs a recommendation
  IF      INTEREST_AREA = Load_scheduling
    AND   SCHED_RATIO < 100
    AND   SCHED_SPLIT <> Weekday
  THEN
    PERIOD_LIMIT = 100
    SCHED_OPTIONS = Yes;
```

RULE 38

```
!! Rule type "S", outputs an annual saving
  IF      INTEREST_AREA = Load_scheduling
    AND   SCHED_OPTIONS = Yes
    AND   OLD_ZONE_LOAD > 0
    AND   OLD_ZONE_TARIFF > 0
    AND   NEW_ZONE_TARIFF > 0
  THEN
    ANNUAL_$_SAVING = (( SCHED_RATIO * OLD_ZONE_LOAD /
                          100 ) * (OLD_ZONE_TARIFF -
                          NEW_ZONE_TARIFF ));
```

RULE 39

```
!! Rule type "F", establishes economic factors
  IF      INTEREST_AREA = Load_scheduling
    AND   SCHED_OPTIONS = Yes
  THEN    TOT_RUN_COST      = 0
         CAPITAL_COST      = 0
         ECONOMIC_FACTORS = Known;
```

! \_\_\_\_\_ Alternative power options; Rules 50 to 69 \_\_\_\_\_  
 ! \_\_\_\_\_ Cogen option rules \_\_\_\_\_

RULE 52

```
!! Rule type "I", intermediate result
  IF      INTEREST_AREA = Alternative_energy
    AND ALT_FUEL_AVAIL = Yes
    AND ALT_FUEL_QUALITY = Yes
  THEN
    ALT_OPTIONS = Investigate_in-house_generation
    COGEN_POSSIBILITY = Yes;
```

RULE 50

```
!! Rule type "R", outputs a recommendation
  IF      INTEREST_AREA = Alternative_energy
    AND ALT_FUEL_AVAIL = No
    AND HEAT_TEMP_REQD = Low
  THEN ALT_OPTIONS = Passive_solar_heating
    ALT_OPTIONS = Heat_pumps;
```

RULE 51

```
!! Rule type "R", outputs a recommendation
  IF      INTEREST_AREA = Alternative_energy
    AND ALT_FUEL_AVAIL = Yes
    AND MD_HEAT_COMPONENT = Yes
  THEN
    ALT_OPTIONS = Alternative-fuel_fired_heating;
```

RULE 53

```
!! Rule type "R", outputs a recommendation
  IF      COGEN_POSSIBILITY = Yes
    AND HEAT_POWER_RATIO < 2.5
    AND HEAT_POWER_RATIO > 1.5
  THEN
    ALT_OPTIONS = Evaluate_cogeneration_plant;
```

RULE 54

```
!! Rule type "R", outputs a recommendation
  IF      COGEN_POSSIBILITY = Yes
    AND HEAT_POWER_RATIO <= 1.5
    OR HEAT_POWER_RATIO >= 2.5
    AND OTHER_POSSIBILITIES = Yes
  THEN
    ALT_OPTIONS = Evaluate_cogeneration_plant;
```

RULE 55

```
!! Rule type "S", outputs an annual saving
  IF      INTEREST_AREA = Alternative_energy
    AND TOT_AVERAGE_COST > 0
    AND TOT_AVERAGE_DEMAND > 0
    AND POWER_SAVED > 0
  THEN
    ANNUAL_$_SAVING = (POWER_SAVED * 12 * TOT_AVERAGE_COST /
      TOT_AVERAGE_DEMAND);
```

## RULE 56

!! Rule type "F", establishes economic factors

```

IF      INTEREST_AREA      = Alternative_energy
  AND  ALT_OPTIONS <> UNKNOWN
  AND  ALT_OPTIONS <> Heat_pumps
  AND  ALT_OPTIONS <> Passive_solar_heating
  AND  FUEL_VALUE          > 0
  AND  THERMAL_EFFY        > 0
  AND  CAPITAL_COST        > 0
  AND  RUNNING_COST        > 0
  AND  POWER_SAVED         > 0
THEN
  FUEL_COST      = ( POWER_SAVED * 0.36 * FUEL_VALUE /
                    THERMAL_EFFY)
  ! DISPLAY " FUEL COST      = {FUEL_COST}"
  TOT_RUN_COST   = (RUNNING_COST + FUEL_COST)
  ECONOMIC_FACTORS = Known;
!   TOT_AVERAGE_COST   = 0
!   TOT_AVERAGE_DEMAND = 0
!   FUEL_VALUE         = 0
!   THERMAL_EFFY       = 0;

```

## RULE 57

!! Rule type "F", establishes economic factors

```

IF      INTEREST_AREA      = Alternative_energy
  AND  ALT_OPTIONS <> UNKNOWN
  AND  ALT_OPTIONS <> Passive_solar_heating
  AND  CAPITAL_COST > 0
THEN
  TOT_RUN_COST = 0
  ECONOMIC_FACTORS = Known;

```

## RULE 58

!! Rule type "F", establishes economic factors

```

IF      INTEREST_AREA      = Alternative_energy
  AND  ALT_OPTIONS <> UNKNOWN
  AND  ALT_OPTIONS <> Heat_pumps
  AND  CAPITAL_COST > 0
  AND  COEF_OF_PERF > 0
THEN
  TOT_RUN_COST = ((ANNUAL $ SAVING / COEF_OF_PERF) +
                  RUNNING_COST)
  ECONOMIC_FACTORS = Known;

```

!\_\_\_ Alternative tariff structures; Rules 70 to 90 \_\_\_\_\_

RULE 70

```
!! Rule type "R", outputs a recommendation
  IF      INTEREST_AREA = Alternative_tariffs
  THEN    TARIFF_SELNS = No_work_done_here_yet;
```

RULE 71

```
!! Rule type "S", outputs an annual saving
  IF      INTEREST_AREA = Alternative_tariffs
  THEN    ANNUAL_$_SAVING = UNKNOWN;
```

RULE 72

```
!! Rule type "F", establishes economic factors
  IF      INTEREST_AREA = Alternative_tariffs
  THEN    ECONOMIC_FACTORS = UNKNOWN;
```

!\_\_\_ FIND OTHER INTEREST AREAS; IE "LATERAL THINKING" SECTION.

!RULE 100

```
!! Rule type "I", intermediate result
!   IF      ALT_FUEL_AVAIL <> UNKNOWN
!         AND ALT_FUEL_AVAIL = YES
!         OR  HEAT_TEMP_REQD <> UNKNOWN
!         AND HEAT_TEMP_REQD = LOW
!   THEN    OTHER_INTEREST_AREA = Alternative_energy
!           INTEREST_AREA = OTHER_INTEREST_AREA
!           OTHER_INTEREST_AREA = UNKNOWN;
!           NB method used here; dummy variable (alt_int_area)
!           used; need an unknown variable in order for VPX
!           to test the rule.
!
```

!! \_\_\_\_\_ Present worth section

RULE 200

!! Rule type "I", intermediate result

IF COST\_EVAL\_PERIOD > 0

AND DISCOUNT\_RATE > 0

THEN

SPCAF = ( @EXP (COST\_EVAL\_PERIOD \* ( @LOG (1 +  
DISCOUNT\_RATE / 100))) )

USPWF = ((SPCAF-1) / (DISCOUNT\_RATE \* SPCAF/100))

! DISPLAY " spcaf = {SPCAF}"

! DISPLAY " uspwf = {USPWF}"

EVALUATION\_FACTORS = Known;

RULE 210

!! Rule type "P", outputs a present worth

IF EVALUATION\_FACTORS = Known

AND ECONOMIC\_FACTORS = Known

AND ANNUAL\_\$\_SAVING > 0

THEN

PRESENT\_WORTH = (CAPITAL\_COST + (TOT\_RUN\_COST \* USPWF))

PW\_SAVED = (ANNUAL\_\$\_SAVING \* USPWF);

```

!__ Ask statements _____
!_____ General
ASK INTEREST_AREA      : " Which aspect of Energy Cost Management
                        do you wish to investigate ?";
CHOICES INTEREST_AREA  : Max__demand_control, Load_scheduling,
                        Alternative_energy,
                        Alternative_tariffs;

ASK COST_EVAL_PERIOD   : "Over how many years do you wish to
                        evaluate the economics of this
                        hypothesis";

ASK DISCOUNT_RATE     : "What is the real interest rate
                        (excluding inflation) to be used in the
                        evaluation ( % )";

!_____ Tariffs, MD's
ASK MD_RATE            : " What is the MD rate, in $/kVA ";

ASK MD_CHARGE_PERIOD   : "How many MD charge periods are there per
                        year";
CHOICES MD_CHARGE_PERIOD : 52, 12, 4, 1;

ASK AV_MONTHLY_MD      : "What is the average (over three years)
                        Monthly MD charge ($) ?";

ASK MD_CAUSE           : "Is the principle cause of the MD charge
intermittent operation of processes, or startup peaks";
CHOICES MD_CAUSE       : Startups, intermittent_procs;

ASK TARIFF             : "What is the current tariff rate (cents
                        per kWh)";

ASK TOT_AVERAGE_DEMAND : "What is the monthly demand (kWh),
                        averaged over (three) years";

ASK TOT_AVERAGE_COST   : " What is the monthly power cost ($),
                        averaged over (three) years";

! ASK ANNUAL_COST_CAT   : "Is the total annual energy cost; Low,
                        (<$50,000), Med !($50,000 to $500,000), or
                        High (>$500,000)";
! CHOICES ANNUAL_COST_CAT : High, Medium, Low;

```

```

! _____ MD_control
ASK MD_CALC_PERIOD      : "What measurement interval is used
                          for measuring MD";

ASK YEARLY_PEAKS        : "For how many months per year is MD > 1.5
                          * Annual average consumption";

ASK DAILY_MD            : "What is the highest daily peak demand,
                          kVA"; !! Within what period ??

!!! ASK DAILY_MD_RATIO  : "What is the ratio of the highest
                          daily peak to the daily average
                          consumption";

!!! ASK MD_RATIO        : "What is the average ratio of MD
                          charges to total unit charges (over
                          one year)";

ASK LOAD_FACTOR         : "What is the average ratio of MD
                          charges to total unit charges (over
                          one month)";
                          !! NB; LOAD_FACTOR *
                          TOT_AVERAGE_DEMAND = MD, if and only
                          if period over which
                          !! MD is charged = period used for
                          TOT_AVERAGE_DEMAND.

!!! ASK WORST_MD        : "What is the MD:MD-charge ratio for
                          the worst month of the year";

ASK WORST_PROCESS       : "kVA rating of the process (isolatable
                          load) with the highest (peak) demand";

ASK HEAT_PEAKS         : "Are the monthly peak consumption figures
                          primarily due to heating loads";
CHOICES HEAT_PEAKS      : Yes,No;

ASK MD_HEAT_COMPONENT   : " Is a significant part of the energy
                          demand for heat (as opposed to mechanical)
                          power";
CHOICES MD_HEAT_COMPONENT : Yes, No;

!!! ASK MONTHLY_VARIATION : " ";

ASK MOVEABLE_MD        : " What is the kVA load which can be
                          regrouped from one MD charge period into
                          another";

ASK MD_FREE_PERIODS     : " From how many MD charge periods per
                          year can the MD_producing processes be
                          regrouped";

ASK PROCESS_SHIFT       : " What is the capacity of the processes
                          (kVA) which can be shifted away from
                          the current peak demand time without
                          creating a new peak";

```



## ! \_\_\_\_\_ Rescheduling

ASK PROC\_INTERDEP : "Degree of interdependence of the process  
 operation with all other processes" ;  
 CHOICES PROC\_INTERDEP : High, Low;

ASK SCHED\_SPLIT : "Shift production between: Day (day to  
 night), Weekday (Weekday to weekend),  
 Month (Winter to summer)";  
 CHOICES SCHED\_SPLIT : Day, Weekday, Month;

ASK AVAIL\_LABOUR : "Is suitable labour available to allow  
 production to be shifted";  
 CHOICES AVAIL\_LABOUR : Yes, No;

ASK EXT\_SCH\_CONSTRAINT : "Are there any special reasons why  
 production cannot be shifted";  
 CHOICES EXT\_SCH\_CONSTRAINT : Yes, No;

ASK PERIOD\_LIMIT : "Limit on the % of production which can  
 be shifted to a time zone, by the time  
 zone size";

ASK OLD\_ZONE\_TARIFF : "What is the tariff (\$/kWh) in the time  
 zone from which load is being shifted";

ASK NEW\_ZONE\_TARIFF : "What is the tariff (\$/kWh) in the time  
 zone to which load is being shifted";

ASK OLD\_ZONE\_LOAD : "How many kWh were used in the tariff  
 zone from which load is being moved  
 last year";

ASK SCHED\_RATIO : "What percentage of production do you  
 wish to shift between time zones";

ASK PERIOD\_HEAT\_RATIO : "What is the ratio of night to  
 daytime heating requirements";

ASK WAGE\_HEAT\_RATIO : "What is the nett ratio of wage to  
 heating costs";

ASK PERIOD\_WAGE\_RATIO : "What is the nett ratio of night to  
 day shift wages";

! \_\_\_\_\_ Alternative power

ASK OTHER\_OPPORTUNITIES : "Are there opportunities for sale of power/heat which you might generate yourself";

CHOICES OTHER\_OPPORTUNITIES : Yes, No;

ASK ALT\_FUEL\_AVAIL : "Are there any alternative fuels available (eg gas)";

CHOICES ALT\_FUEL\_AVAIL : Yes, No;

ASK ALT\_FUEL\_QUALITY : "Is the quality of the alternative fuel available suitable for use in a prime mover?";

CHOICES ALT\_FUEL\_QUALITY : Yes, No;

ASK HEAT\_POWER\_RATIO : "What is the ratio of heat energy Requirement to power (mechanical) energy required";

ASK HEAT\_TEMP\_REQD : "Temperature heat is req'd at; (>1400'C = V\_High; 700 to 1400'C, High; 150 to 700'C = Medium ; < 150'C = Low";

CHOICES HEAT\_TEMP\_REQD : V\_High, High, Medium, Low;

ASK HEAT\_SALE\_OPTIONS : "For which grade of heat is there a sale opportunity; None, V\_High (>1400'C), High (700 to 1400'C, Medium (150 to 700'C), Low (<150'C)";

CHOICES HEAT\_SALE\_OPTIONS : None, V\_High, High, Medium, Low;

ASK HEAT\_SALE\_QTY : "What quantity of heat (per month) can be sold outside your organisation";

ASK POWER\_SALE\_QTY : "What quantity of heat (per month) can be sold outside your organisation";

ASK AREA\_AVAIL : "Area available for alternative power plant site (approximate), sq m";

ASK SKILL\_AVAIL : "Is sufficient skilled labour available for the planned operating mode of the alternative power plant";

CHOICES SKILL\_AVAIL : Yes, No;

ASK RUNNING\_COST : "What is the anticipated running cost of the alternative power plant (\$/year)";

ASK FUEL\_VALUE : "What is the cost (\$/GJ) of the alternative fuel (NB, \$1/GJ = 0.36 c/kWh)";

ASK THERMAL\_EFFY : "Power plant thermal efficiency (% of GCV available as electrical capacity)";

ASK CAPITAL\_COST : "What is the expected capital cost of this plant (in \$)";

ASK POWER\_SAVED : "What is the expected power saving,  
kWh/year)";  
ASK COEF\_OF\_PERF : "What is the coefficient of performance  
for the heat pump ?";

! \_\_\_\_\_ Tariff selection

ASK TARIFF\_ID : "What is the Name/Number of the tariff  
(structure) you wish to consider";

! \_\_\_\_\_ End of Ask statements \_\_\_\_\_

! \_\_\_\_\_ Plural statements \_\_\_\_\_

PLURAL : Interest\_area, OTHER\_INTEREST\_AREA;

PLURAL : MD\_OPTIONS, SCHED\_OPTIONS, ALT\_OPTIONS, TARIFF\_SELNS;

! PLURAL : MD\_DISPLAY, SCHED\_OPT\_DISP, ALT\_OPT\_DISP,  
TARIFF\_SELN\_DISPLAY;

! PLURAL : Heat\_temp\_reqd, Heat\_sale\_options;

! \_\_\_\_\_ End of Plural statements \_\_\_\_\_

```

!***** DEFUNCT RULES *****
!!!!   ???? DELETE THIS RULE   ??????
!RULE 20
!   IF           INTEREST_AREA = Max__demand_control
!   AND AV_MONTHLY_MD > 100
!   AND ALT_FUEL_AVAIL = YES
!   THEN
!   INTEREST_AREA = Alternative_energy;
!
!
!!!!   ?????? DELETE THIS RULE   ??????
!RULE 22
!   IF           INTEREST_AREA = Max__demand_control
!   AND HEAT_TEMP_REQD = LOW
!   THEN
!   INTEREST_AREA = Alternative_energy
!   DISPLAY "Consider passive (solar) heating";
!
!
!RULE 28
!   IF           INTEREST_AREA = Max__demand_control
!   AND AV_MONTHLY_MD > 100
!   AND ANNUAL_ENERGY_COST = HIGH
!   AND MD_BASIS = DAY
!   AND PROC_INTERDEP = HIGH
!   THEN
!   DISPLAY "
!
!
!RULE 50
!! Rule type "I", intermediate result
!   IF           INTEREST_AREA = Alternative_energy
!   AND ALT_FUEL_AVAIL = YES
!   AND HEAT_POWER_RATIO < 3
!   AND HEAT_POWER_RATIO > 0.5
!   THEN
!   COGEN_POSSIBILITY = YES;
!
!
!RULE 51
!! Rule type "I", intermediate result
!   IF           INTEREST_AREA = Alternative_energy
!   AND ALT_FUEL_AVAIL = YES
!   AND HEAT_POWER_RATIO > 0.5
!   AND OTHER_OPPORTUNITIES = YES
!   THEN
!   COGEN_POSSIBILITY = YES;
!
!
!RULE 52
!! Rule type "R", outputs a recommendation
!   IF           INTEREST_AREA = Alternative_energy
!   AND MD_RATIO < 1.5
!   ratio of MD to unit charges (over one year) < 1.5
!   AND MONTHLY_VARIATION = LOW
!   ie, demand is not seasonal
!   AND COGEN_POSSIBILITY = YES
!   Cogeneration is a technical feasibility
!   THEN
!   MD_OPTIONS = Install_Cogen_plant
!   DISPLAY "Consider purchase of generation (Cogen) plant";

```

```

!
!RULE 53
!! Rule type "R", outputs a recommendation
!   IF      INTEREST_AREA = Alternative_energy
!           AND MD_RATIO < 1.5
!           AND MONTHLY_VARIATION = HIGH
!           ie very seasonal demand, but not peaky within
!           seasons
!           AND OTHER_OPPORTUNITIES = YES
!           ie other organisations which may be interested in
!           joint
!           ventures to use the power generated
!           AND ALT_FUEL_AVAIL = YES
!           AND HEAT_POWER_RATIO > 1
!   THEN
!           MD_OPTIONS = Install_cogen_plant;
!
!RULE 54
!! Rule type "R", outputs a recommendation
!   IF      INTEREST_AREA = Alternative_energy
!           AND MD_RATIO < 1.5
!           AND MONTHLY_VARIATION = HIGH
!           AND OTHER_OPPORTUNITIES = NO
!           AND ALT_FUEL_AVAIL = YES
!           AND HEAT_POWER_RATIO > 1
!   THEN
!           MD_OPTIONS = Alternative_fueled_heaters
!           DISPLAY "    Consider use of alternatively fueled
!                   heating systems";
!
!RULE 55
!! Rule type "R", outputs a recommendation
!   IF      INTEREST_AREA = Alternative_energy
!           AND MD_RATIO < 1.5
!           AND MONTHLY_VARIATION = HIGH
!           AND OTHER_OPPORTUNITIES = NO
!           AND ALT_FUEL_AVAIL = NO
!           AND HEAT_TEMP_REQD = LOW
!           AND HEAT_POWER_RATIO > 1
!   THEN
!           MD_OPTIONS = Passive_solar_heating
!           DISPLAY "Consider passive (solar) heating";
!

```



```

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!      welcome.kbs
!      ENERGY COST MANAGEMENT EXPERT SYSTEM
!      Entry knowledge base; allows selection of interest area
!      L J Robertson
!      VP Expert version 1.2
!      Sept 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

```

```
!__ Initialise section _____
```

```
EXECUTE;
RUNTIME;
ENDOFF;
```

```
!__ Actions section _____
```

```
ACTIONS
```

```
!__ Opening screen section _____
```

```
CLS
DISPLAY " "
DISPLAY " W      W EEEEE L      CCC      0000      M      M EEEEE"
DISPLAY " W      W E      L      C      O      O      M M M M E"
DISPLAY " W      W W EEE      L      C      0      0      M M M EEE"
DISPLAY " W W W W E      L      C      O      O      M      M E"
DISPLAY " W      W EEEEE LLLLL CCC      0000      M      M EEEEE"
DISPLAY " "
DISPLAY " "
```

```
DISPLAY "          TO THE"
DISPLAY " "
DISPLAY " "
```

```
DISPLAY "          ENERGY COST MANAGEMENT"
DISPLAY " "
DISPLAY " "
```

```
DISPLAY "          DECISION SUPPORT"
APPLICATION "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
```

```
DISPLAY " Press any key to continue.~"
CLS
```

```
!!!__ Explanatory screen section _____
```

```
CLS
DISPLAY " "
DISPLAY "This application will assist you in:"
```

```
DISPLAY " - Selecting the most appropriate courses for energy cost
management,"
DISPLAY " - Evaluating the potential cost savings of alternative
actions,"
DISPLAY " - Suggesting factors to be taken account of in
implementing measures."
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " You will be asked a series of questions, many of which
have alternative"
DISPLAY " answers provided. In some cases you will need to press
<END> to confirm"
DISPLAY " your choice."
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " "
```

```
DISPLAY " Press any key to continue.~"
CLS
```

```
!!!
```

---

```
NEWONE = NUMBER_ONE
RESET NEWONE
!! NB this shows that "reset" variables are not stored in data
files.
```

```
FIND DUMMY_INTEREST_AREA
```

```
SAVEFACTS INTEREST;
```



```

RULE 1
  IF      INTEREST_AREA = Max_demand_control
  THEN    DUMMY_INTEREST_AREA = INTEREST_AREA
          DISPLAY " You have chosen to investigate Maximum
                Demand Control"
          DISPLAY " Please press any key, & wait while the
                knowledge base relating to this subject is
                loaded~"
          CHAIN MD_CONTR;

RULE 2
  IF      INTEREST_AREA = Load_scheduling
  THEN    DUMMY_INTEREST_AREA = INTEREST_AREA
          DISPLAY " You have chosen to investigate
                re-scheduling of load "
          DISPLAY " Please press any key, & wait while the
                knowledge base relating to this subject is
                loaded~"
          CHAIN DUMMY;

RULE 3
  IF      INTEREST_AREA = Alternative_energy
  THEN    DUMMY_INTEREST_AREA = INTEREST_AREA
          DISPLAY " You have chosen to investigate the use of
                alternative energy sources "
          DISPLAY " Please press any key, & wait while the
                knowledge base relating to this subject is
                loaded~"
          CHAIN DUMMY;

RULE 4
  IF      INTEREST_AREA = Alternative_tariffs
  THEN    DUMMY_INTEREST_AREA = INTEREST_AREA
          DISPLAY " You have chosen to investigate the use of
                alternative tariffs "
          DISPLAY " Please press any key, & wait while the
                knowledge base relating to this subject is
                loaded~"
          CHAIN DUMMY;

RULE 5
  IF      INTEREST_AREA = Quit
  THEN    LOADFACTS INTEREST;

RULE 6
  IF      INTEREST_AREA = Call_spreadsheet
  THEN    DUMMY_INTEREST_AREA = INTEREST_AREA
          DISPLAY " You have chosen to (re) call the
                spreadsheet application"
          DISPLAY " Please press any key, & wait while the
                spreadsheet is loaded~"
          LOADFACTS INTEREST
          BCALL ECMSS;

```

!\_\_ Ask statements  
!\_\_\_\_\_ General

---

ASK INTEREST\_AREA : " Which aspect of Energy Cost  
Management do you wish to  
investigate?";

CHOICES INTEREST\_AREA : Max\_demand\_control, Load\_scheduling,  
Alternative\_energy,  
Alternative\_tariffs,  
Call\_spreadsheet, Quit ;

```

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
! MD_CONTR.KBS
! ENERGY COST MANAGEMENT EXPERT SYSTEM
! Extracts info from spreadsheet
! (ECMDEMO.WR1 alias LJRVAL3.WKS), & analyses.
! L J Robertson
! VP Expert version 1.2
! Sept 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

```

```

!-----
RUNTIME;
EXECUTE;
ENDOFF;

```

## ACTIONS

```

CLS
LOADFACTS INTEREST

```

```

FIND SOURCE
!! if "spreadsheet" is selected, this results in the data
!! being read in from the ECMDEMO.WKS spreadsheet

```

```

!! _____ calc mean and sd for monthly load factors _____

```

```

X = 1
TOTVAL = 0
SQDEV = 0
MAX_LOAD_FACT = 0
MIN_LOAD_FACT = 1.0
WHILEKNOWN CHECK12
    TOTVAL = (TOTVAL + MTH_LOAD_FACT[X])
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
    RESET MAX_LF
    FIND MAX_LF
    RESET MIN_LF
    FIND MIN_LF

```

```

END

```

```

MEAN = (TOTVAL / (X - 1))

```

```

X = 1
SQDEV = 0
WHILEKNOWN CHECK12
    SQDEV = (SQDEV + ((MTH_LOAD_FACT[X] - MEAN) *
                    (MTH_LOAD_FACT[X] - MEAN)))
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12

```

```

END

```

```

SD = (@SQRT((SQDEV / (X - 1))))

```

```

MEAN_MTH_LOAD_FACT = (MEAN)
SD_MTH_LOAD_FACT = (SD)

```

```

!! _____ calc mean and sd for monthly unit consumptions _____
  X = 1
  TOTVAL = 0
  MAX_MTH_CONSN = 0
  MIN_MTH_CONSN = 9999999999
  WHILEKNOWN CHECK12
    TOTVAL = (TOTVAL + MTH_CONSN[X])
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
    RESET MAX_MC
    FIND MAX_MC
    RESET MIN_MC
    FIND MIN_MC
  END

  MEAN = (TOTVAL / (X - 1))

  X = 1
  SQDEV = 0
  WHILEKNOWN CHECK12
    SQDEV = (SQDEV + ((MTH_CONSN[X] - MEAN) * (MTH_CONSN[X]
      - MEAN)))
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
  END

  SD = (@SQRT((SQDEV / (X - 1))))

  MEAN_MTH_CONSN = (MEAN)
  SD_MTH_CONSN = (SD)

!! _____ Calc mean and SD for monthly MD figures _____
  X = 1
  TOTVAL = 0
  MAX_MTH_MD = 0
  MIN_MTH_MD = 9999999999
  WHILEKNOWN CHECK12
    TOTVAL = (TOTVAL + MTH_MD[X])
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
    RESET MAX_MM
    FIND MAX_MM
    RESET MIN_MM
    FIND MIN_MM
  END

  MEAN = (TOTVAL / (X - 1))

  X = 1
  SQDEV = 0
  WHILEKNOWN CHECK12
    SQDEV = (SQDEV + ((MTH_MD[X] - MEAN) * (MTH_MD[X] -
      MEAN)))

```

```

      X = (X + 1)
      RESET CHECK12
      FIND CHECK12
END

SD = (@SQRT((SQDEV / (X - 1))))
MEAN_MTH_MD = (MEAN)
SD_MTH_MD = (SD)

```

!! \_\_\_\_\_ Calc mean and SD for instantaneous demand figures \_\_\_\_\_

```

X = 1
TOTVAL = 0
MAX_INST_DEM = 0
MIN_INST_DEM = 9999999999
WHILEKNOWN CHECK96
    TOTVAL = (TOTVAL + INST_DEM[X])
    X = (X + 1)
    RESET CHECK96
    FIND CHECK96
    RESET MAX_ID
    FIND MAX_ID
    RESET MIN_ID
    FIND MIN_ID

```

END

```
MEAN = (TOTVAL / (X - 1))
```

```

X = 1
SQDEV = 0
WHILEKNOWN CHECK96
    SQDEV = (SQDEV + ((INST_DEM[X] - MEAN) * (INST_DEM[X] -
        MEAN)))
    X = (X + 1)
    RESET CHECK96
    FIND CHECK96

```

END

```
SD = (@SQRT((SQDEV / (X - 1))))
```

```
MEAN_INST_DEM = (MEAN)
SD_INST_DEM = (SD)
```

!! \_\_\_\_\_ Calc max and min MD rates \_\_\_\_\_

```

X = 1
TOTVAL = 0
MAX_MD_RATE = 0
MIN_MD_RATE = 9999999999
WHILEKNOWN CHECK12
    RESET MAX_RATE
    FIND MAX_RATE
    RESET MIN_RATE
    FIND MIN_RATE
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12

```

END

```
!! _____ Format all variables _____
!! NB; dimensioned variables are formatted within rules
FORMAT MAX_LOAD_FACT, 4.3
FORMAT MAX_MTH_CONSN, 4.3
FORMAT MAX_MTH_MD, 4.3
FORMAT MAX_INST_DEM, 4.3
FORMAT MIN_LOAD_FACT, 4.3
FORMAT MIN_MTH_CONSN, 4.3
FORMAT MIN_INST_DEM, 4.3
FORMAT MEAN_MTH_LOAD_FACT, 4.3
FORMAT SD_MTH_LOAD_FACT, 5.4
FORMAT MEAN_MTH_CONSN, 7.0
FORMAT SD_MTH_CONSN, 7.0
FORMAT MEAN_MTH_MD, 5.0
FORMAT SD_MTH_MD, 5.0
FORMAT MEAN_INST_DEM, 5.1
FORMAT SD_INST_DEM, 5.2
```

```
!! _____ Save variables to data file _____

SAVEFACTS MD_CONTROL
CHAIN MD_REPI;
```

```
!! _____ End of ACTIONS section _____
```

```
!! _____ RULES section _____
```

```
RULE 1
  IF          WHEREFROM = Spreadsheet
  THEN       SOURCE = WHEREFROM

  CLS
  DISPLAY " For this operation, a large amount of data
           needs to be read in from the"
  DISPLAY " spreadsheet, and then analysed."
  DISPLAY " "
  DISPLAY " This will take about 45 seconds ( on a PC AT )"
  WKS MTH_CONSN,      NAMED = UNIT_CONSN, LJRVAL4
  WKS MTH_MD,        NAMED = MD_MTH,     LJRVAL4
  WKS MTH_LOAD_FACT, NAMED = L_FACT,     LJRVAL4
  WKS INST_DEM,     NAMED = KVA_DEM,     LJRVAL4
  WKS MD_RATE,     NAMED = MD_RATE,     LJRVAL4
  DISPLAY " "
  DISPLAY " All data has now been read; please wait while
           it is analysed."

  ELSE
    SOURCE = WHEREFROM
    DISPLAY " YOU WILL HAVE TO GO & ENTER THE VALUES
            MANUALLY~";
```

```

RULE CHECK12
  IF      X <= 12
  THEN    CHECK12 = FINISH;

RULE CHECK96
  IF      X <= 96
  THEN    CHECK96 = FINISH;

RULE MAX_LOAD_FACT
  IF      MTH_LOAD_FACT[X] > (MAX_LOAD_FACT)
  THEN    MAX_LOAD_FACT = (MTH_LOAD_FACT[X])
          FORMAT MTH_LOAD_FACT[X], 4.3
          MAX_LF = YES;

RULE MAX_MTH_CONSN
  IF      MTH_CONSN[X] > (MAX_MTH_CONSN)
  THEN    MAX_MTH_CONSN = (MTH_CONSN[X])
          FORMAT MTH_CONSN[X], 4.3
          MAX_MC = YES;

RULE MAX_MTH_MD
  IF      MTH_MD[X] > (MAX_MTH_MD)
  THEN    MAX_MTH_MD = (MTH_MD[X])
          FORMAT MTH_MD[X], 4.3
          MAX_MM = YES;

RULE MAX_INST_DEM
  IF      INST_DEM[X] > (MAX_INST_DEM)
  THEN    MAX_INST_DEM = (INST_DEM[X])
          FORMAT INST_DEM[X], 4.3
          MAX_ID = YES;

RULE MAX_MD_RATE
  IF      MD_RATE[X] > (MAX_MD_RATE)
  THEN    MAX_MD_RATE = (MD_RATE[X])
          MAX_RATE = YES;

RULE MIN_LOAD_FACT
  IF      MTH_LOAD_FACT[X] < (MIN_LOAD_FACT)
  THEN    MIN_LOAD_FACT = (MTH_LOAD_FACT[X])
          MIN_LF = YES;

RULE MIN_LOAD_FACT
  IF      MTH_CONSN[X] < (MIN_MTH_CONSN)
  THEN    MIN_MTH_CONSN = (MTH_CONSN[X])
          MIN_MC = YES;

```

```

RULE MIN_MTH_MD
  IF      MTH_MD[X]      < (MIN_MTH_MD)
  THEN    MIN_MTH_MD    = (MTH_MD[X])
          MIN_MM = YES;

```

```

RULE MIN_INST_DEM
  IF      INST_DEM[X]    < (MIN_INST_DEM)
  THEN    MIN_INST_DEM  = (INST_DEM[X])
          MIN_ID = YES;

```

```

RULE MIN_MD_RATE
  IF      MD_RATE[X]     < (MIN_MD_RATE)
  THEN    MIN_MD_RATE    = (MD_RATE[X])
          MIN_RATE = YES;

```

!! \_\_\_\_\_ ASK statements \_\_\_\_\_

ASK WHEREFROM: "What is the source of the data for Max Demand control ?";

CHOICES WHEREFROM: Spreadsheet, Manual;



```

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!           MD_REP1.KBS
!           ENERGY COST MANAGEMENT EXPERT SYSTEM
!           Examines the data extracted from the spreadsheet
!           L J Robertson
!           VP Expert version 1.2
!           Sept 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

```

```

!! this KB examines the data extracted from the ECMDEMO spreadsheet
!! by the MD_CONTR KBS, and produces the following
!!   a) A report, either printed or on screen, of the DSS's
!!       observations on the available data.
!!   b) An initial estimate of the savings which could be
!!       reasonably expected by MD control measures.
!!   c) ?? menu options for refinement.

```

```

RUNTIME;
EXECUTE;
ENDOFF;

```

#### ACTIONS

```

CLS
DISPLAY " "
DISPLAY " Please wait while data is read into the decision
        support system"
DISPLAY " "
LOADFACTS MD_CONTROL

```

```

!! Calculate the savings available by increasing all load factors _
!! ___ to the current upper quartile figure _____

```

```

LFUQ   = ((MEAN_MTH_LOAD_FACT) + (SD_MTH_LOAD_FACT))
LF_RED_SAV = 0
X = 1
WHILEKNOWN CHECK12
    RESET NEW_RED_SAV
    FIND NEW_RED_SAV
    LF_RED_SAV = (LF_RED_SAV + NEW_RED_SAV)
    X = (X + 1)
    RESET CHECK12
    FIND CHECK12
END
FORMAT LFUQ, 4.3
FORMAT LF_RED_SAV, 10.2

```

!!Calculate savings by moving all consumption details for months  
 !!with below average Load Factors to month where MD\_Rate is lowest,  
 !!and all months with above average load factors to month with  
 !!highest MD\_Rate.

```

LF_MOV_SAV = 0
X = 1
WHILEKNOWN CHECK12
  RESET NEW_MOV_SAV
  FIND NEW_MOV_SAV
  LF_MOV_SAV = ((LF_MOV_SAV) + (NEW_MOV_SAV))
  X = (X + 1)
  RESET CHECK12
  FIND CHECK12
END
FORMAT LF_MOV_SAV, 10.2

```

```

DISPLAY " "
DISPLAY " The preliminary analysis of the spreadsheet data is
        now complete."
DISPLAY " "

```

```
FIND HARDCOPY
```

!!\_\_\_\_\_ Loop to allow display of values, or on/back chaining\_\_\_\_\_

```

!   SAVEFACTS MD_CONTROL

WHILEKNOWN CCONTINUE
  RESET CCONTINUE
  RESET NEXT_ACTION
  RESET AACTION
  CLS
  FIND CCONTINUE
END

PRINTOFF;

```

!!\_\_\_\_\_ End of ACTIONS section \_\_\_\_\_

!! \_\_\_\_\_ RULES section \_\_\_\_\_

---

```

RULE CHECK12
  IF      X <= 12
  THEN    CHECK12 = FINISH;

RULE NEW_RED_SAV
  IF      MTH_LOAD_FACT[X] < (LFUQ)
  THEN    NEW_RED_SAV=(MD_RATE[X]*(((MTH_CONSN[X])/730)*(((LFU
    Q)-(MTH_LOAD_FACT[X]))/((LFUQ)*(MTH_LOAD_FACT[X]))))
  )
  ELSE    NEW_RED_SAV = 0;

RULE NEW_MOVE_COST
  IF      MTH_LOAD_FACT[X] > (MEAN_MTH_LOAD_FACT)
  THEN    NEW_MOV_SAV = ((MTH_MD[X]) * ((MD_RATE[X]) -
    (MAX_MD_RATE)));

RULE NEW_MOVE_SAV
  IF      MTH_LOAD_FACT[X] < (MEAN_MTH_LOAD_FACT)
  THEN    NEW_MOV_SAV = ((MTH_MD[X]) * ((MD_RATE[X]) -
    (MIN_MD_RATE)));

RULE CCONT
  IF      NEXT_ACTION <> UNKNOWN
  THEN    CCONTINUE = YES;

RULE DDISP
  IF      AACTION = DISPLAY_INPUT_DATA
  THEN    NEXT_ACTION = Y
  DISPLAY "          | AVERAGE          |      STD DEVIATION
  |
  MAXIMUM  |"
  DISPLAY " load factors;      -      {MEAN_MTH_LOAD_FACT}
  {SD_MTH_LOAD_FACT}  {MAX_LOAD_FACT}  {MIN_LOAD_FACT}"
  DISPLAY " consumption (kWh) {MEAN_MTH_CONSN}
  {SD_MTH_CONSN}      {MAX_MTH_CONSN}  {MIN_MTH_CONSN}"
  DISPLAY " Max Dem          (kVA)  {MEAN_MTH_MD}
  {SD_MTH_MD}        {MAX_MTH_MD}  {MIN_MTH_MD}"
  DISPLAY " Inst. demand; (kVA) {MEAN_INST_DEM}
  {SD_INST_DEM}      {MAX_INST_DEM}  {MIN_INST_DEM}"
  DISPLAY " "
  DISPLAY "      Press any key to continue~";

```

```

RULE RETMAIN
  IF      AACTION = BACK_TO_MAIN_MENU
  THEN    NEXT_ACTION = Y
          CHAIN WELCOME;

RULE INV_MD_CONTR
  IF      AACTION = REFINE_MD_SAVINGS
  THEN    NEXT_ACTION = Y
          CHAIN MD_REF1;
!        CHAIN LOOP1;

RULE SUMMARY
  IF      AACTION = DISPLAY_SUMMARY_RESULTS
  THEN    CLS
          NEXT_ACTION = Y
          DISPLAY " PRELIMINARY ESTIMATES OF SAVINGS POSSIBLE
                  BY CONTROL OF MAXIMUM DEMAND "
          DISPLAY " "
          DISPLAY " An examination of the monthly load factors
                  (ie, the ratio of average to peak "
          DISPLAY " consumptions) shows that these range from
                  {MAX_LOAD_FACT} to {MIN_LOAD_FACT}."
          DISPLAY " Taken across a typical year, these appear
                  to have an average of "
          DISPLAY " {MEAN_MTH_LOAD_FACT}, and standard
                  deviation of {SD_MTH_LOAD_FACT}. "
          DISPLAY " A not-unrealistic goal could be to raise
                  the average load factor from the "
          DISPLAY " present level ({MEAN_MTH_LOAD_FACT}) to
                  the upper-quartile figure ({LFUQ})."
          DISPLAY " "
          DISPLAY " Assuming this proves to be feasible, the
                  annual savings would be $ {LF_RED_SAV}."
          DISPLAY " "
          DISPLAY " "
          DISPLAY " If the load patterns for all months with
                  worse than average load-factors"
          DISPLAY " were moved to the period where the minimum
                  MD charge rate applies, "
          DISPLAY " and the load patterns for months with
                  better than average load factors"
          DISPLAY " were moved to the period where the maximum
                  MD charge rate applies, "
          DISPLAY " then the annual saving would be $
                  {LF_MOV_SAV}."
          DISPLAY " "
          DISPLAY " "
          DISPLAY "   Press any key to continue~";

!RULE CONCL
!  IF      AACTION = DISPLAY_CONCLUSIONS
!  THEN    NEXT_ACTION = Y
!          DISPLAY "The detailed conclusions are: ";

```

```
RULE HARDCOPY
  IF      PPRINT = YES
  THEN    HARDCOPY = YES
          DISPLAY " Ensure that your printer is connected &
                  turned on"
          DISPLAY "Press any key to continue~"
          PRINTON;
```

!! \_\_\_\_\_ ASK statements \_\_\_\_\_

```
ASK AACTION      : "What do you want to do next ? ";
CHOICES AACTION  : Display_input_data, Display_summary_results,
                  Back_to_main_menu, Refine_MD_savings, Quit;

ASK PPRINT       : "Do you want printed copy of the screen
                  statements ?";
CHOICES PPRINT   : Yes,No;
```

```

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!           MD_REF1.KBS  (OLD NEWLOOP1)
!           ENERGY COST MANAGEMENT EXPERT SYSTEM
!           VERSION 1 OF INTERACTIVE DSS MODULE; MD_REF1.KBS
!           NO DATABASE ACCESS, BUT SIMILAR TO FINAL VERSION.
!           L J Robertson
!           VP Expert version 1.2
!           Sept 1989
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

```

```

RUNTIME;
EXECUTE;
ENDOFF;
ACTIONS

```

```

!! Get data from file loaded by MD_C1.KBS
DISPLAY "Please wait while data is loaded"
LOADFACTS MD_CONTR
DISPLAY "all data has now been loaded."

```

```

SATISFIED = HELP
FIND CONT
RESET SATISFIED
RESET CONT

```

```

!!  RESET ACCUMULATOR VARIABLES TO 0
TOT_EXT_MOVE = 0
TOT_DITCH    = 0

```

```

!!  load the NEW_DEM dimensioned variable
CLS
DISPLAY " Just a second please.."
X = 1

```

```

WHILEKNOWN CHECK48
  FORMAT INST_DEM[X], 9.3
  NEW_DEM[X] = (INST_DEM[X])
  FORMAT NEW_DEM[X], 9.3
  RESET CHECK48
  FIND CHECK48

```

```

END

```

```

!! NB, from now on, all work will be done on NEW_DEM;
!! INST_DEM is left as an untouched record of original state.

```

```

!!  modify the instantaneous loads, monitoring peaks etc
WHILEKNOWN CONT
  !!  MENU, ALSO ALLOWS DISPLAY OF OVERALL LOAD
  PATTERN, CURRENT POSITION
  RESET CONT
  RESET SATISFIED
  CLS
  FIND CONT

```

```

END

```

```

!!  END OF ACTIONS BLOCK
CLS;

```

!! Start of rules section

```

RULE CONT1H
  IF      SATISFIED = HELP
  THEN    CONT = YES
          CLS
          DISPLAY " ----- HELP! Max Demand Decision Support
                System ----- screen 1 of 2 ----"
          DISPLAY " "
          DISPLAY " This section of the decision support
                system allows you to explore the effects"
          DISPLAY " (on monthly and annual MD charges) of
                moving sections of electrical load "
          DISPLAY " between 30 min time slots."
          DISPLAY " There are three basic categories of load
                movement which can influence the "
          DISPLAY " MD charge; viz"
          DISPLAY "      a) Load can be simply shut off; this
                obviously offers the largest saving"
          DISPLAY "      b) Load can be moved between 30 min
                time slots so as to reduce the peak "
          DISPLAY "      load for the current MD charge period
                (Month, quarter, etc)."
          DISPLAY "      c) It may be possible to prevent a
                separate occurrence of an MD penalty
                "
          DISPLAY "      charge from being incurred each month
                by concentrating all the "
          DISPLAY "      primary peak-producing processes
                within one MD charge period."
          DISPLAY " "
          DISPLAY " "
          DISPLAY " "
          DISPLAY " "
          DISPLAY " "
          DISPLAY " "
          DISPLAY " "
          DISPLAY " "
          DISPLAY "Press any key for second screen~"
          CLS
          DISPLAY " ----- HELP! Max Demand Decision Support
                System ----- screen 2 of 2 ----"
          DISPLAY " "
          DISPLAY " You will obviously need to first examine
                the current daily load curve "
          DISPLAY " to determine where the peaks lie; it is
                suggested that you then start with"
          DISPLAY " the 'peak-time', and work outwards
                (choosing time slots alternately before"
          DISPLAY " and after), and using you specialised
                knowledge of the processes involved"
          DISPLAY " to determine what loads can be
                rearranged."
          DISPLAY " "
          DISPLAY "      Bear in mind that loads which are
                currently 'waste' are obviously the"
          DISPLAY " greatest source of saving, and that loads
                moved to a low-tariff time zone "

```

```

DISPLAY " offer unit as well as MD savings."
DISPLAY " "
DISPLAY "      Be careful not to move loads in such
a way as to simply create a new "
DISPLAY " peak at a different time of day (the DSS
will warn you if you do this)."
DISPLAY " "
DISPLAY " At any stage you can examine the 'overall
picture' of the rearranged"
DISPLAY " load pattern you have created. This will
also compare your (re) arrangement"
DISPLAY " with the 'suggested target' of the
previous section of the DSS."
DISPLAY " "
DISPLAY " "
DISPLAY " Press any key to continue.~";

```

RULE CONT1

```
IF SATISFIED = CURRENT_SITUATION
```

```
THEN CONT = YES
```

```
! Ask month-name, get MD rate for month, calc MD savings
```

```
RESET THISMD1
```

```
RESET THISMD
```

```
FIND THISMD
```

```
!! SUMMARY OF OVERALL CHANGE IN POSITION
```

```
!! CALCULATE SAVINGS, DISPLAY
```

```
CLS
```

```
DISPLAY " -- SUMMARY OF CURRENT POSITION----"
```

```
DISPLAY " "
```

```
DISPLAY " "
```

```
DISPLAY "You have currently; "
```

```
DISPLAY " "
```

```
DISPLAY "      'Ditched' a total of {TOT_DITCH} kVA, "
```

```
DISPLAY " "
```

```
DISPLAY " "
```

```
DISPLAY "      Moved a total of {TOT_EXT_MOVE} kVA to
(an)other MD charge period(s), "
```

```
DISPLAY " "
```

```
DISPLAY " "
```

```
DISPLAY " And still have {TOT_IN_MOVE} kVA from other MD
charge periods to be redistributed."
```

```
DISPLAY " "
```

```
DISPLAY " Please wait a moment.."
```

```
X = 1
```

```
NEWMAX = 0
```

```
WHILEKNOWN CHECK48
```

```
!! loop through day, find new peak, compare to old
peak
```

```
NMN = (NEWMAX - NEW_DEM[X])
```

```
RESET MMAX_MM
```

```
FIND MMAX_MM
```

```
RESET CHECK48
```

```
FIND CHECK48
```

```
END
```



```

X = (NEWPEAKTIME - 1)
FORMAT NEWMAX, 9.3

!! CONVERT INTEGER TIME TO STANDARD FORMAT TIME
RESET T_OF_D
FIND T_OF_D
HR = 0
WHILEKNOWN INTHOUR
    RESET INTHOUR
    FIND INTHOUR
END
RESET MINTIME
FIND MINTIME
DISPLAY " The new peak load is {NEWMAX} kVA"
DISPLAY " This (new) peak occurs at {HR}:{MINTIME}
        {T_OF_D} "
DISPLAY " "

MD_SAV = (THISMD * ( MAX_INST_DEM - NEWMAX))
FORMAT MD_SAV, 9.2
DISPLAY " The cost savings from this MD change is
        expected to be $ {MD_SAV}"

! Recalculate unit costs, based on time interval tariff
rates (TO BE DEVELOPED LATER)

DISPLAY " "
DISPLAY " "
DISPLAY " Press any key to continue~";
!! END OF RULE CONT1

```

```

RULE CONT2
  IF      SATISFIED = SHOW_ALL_INTERVALS
  THEN    CONT = YES
          WHILEKNOWN FEASIBLE
          RESET TARG_TYPE
          RESET TARG_FOUND
          FIND  TARG_FOUND
          END

  CLS
  DISPLAY " The following summarizes the proposed/targeted
           changes"

  DISPLAY " "
  DISPLAY " "
  DISPLAY " PERIOD      CURRENT LOAD      MODIFIED LOAD TARGET
LOAD  TARG TARGET REDUCTION"
  DISPLAY " STARTING      kVA              kVA          kVA
         kVA"
  DISPLAY " "
  DISPLAY " 0:00 am      {INST_DEM[1]}      {NEW_DEM[1]}
{TARG_DEM[1]} {TARG_RED_N[1]}"
  DISPLAY " 0:30 am      {INST_DEM[2]}      {NEW_DEM[2]}
{TARG_DEM[2]} {TARG_RED_N[2]}"
  DISPLAY " 1:00 am      {INST_DEM[3]}      {NEW_DEM[3]}
{TARG_DEM[3]} {TARG_RED_N[3]}"
  DISPLAY " 1:30 am      {INST_DEM[4]}      {NEW_DEM[4]}
{TARG_DEM[4]} {TARG_RED_N[4]}"
  DISPLAY " 2:00 am      {INST_DEM[5]}      {NEW_DEM[5]}
{TARG_DEM[5]} {TARG_RED_N[5]}"
  DISPLAY " 2:30 am      {INST_DEM[6]}      {NEW_DEM[6]}
{TARG_DEM[6]} {TARG_RED_N[6]}"
  DISPLAY " 3:00 am      {INST_DEM[7]}      {NEW_DEM[7]}
{TARG_DEM[7]} {TARG_RED_N[7]}"
  DISPLAY " 3:30 am      {INST_DEM[8]}      {NEW_DEM[8]}
{TARG_DEM[8]} {TARG_RED_N[8]}"
  DISPLAY " 4:00 am      {INST_DEM[9]}      {NEW_DEM[9]}
{TARG_DEM[9]} {TARG_RED_N[9]}"
  DISPLAY " 4:30 am      {INST_DEM[10]}     {NEW_DEM[10]}
{TARG_DEM[10]} {TARG_RED_N[10]}"
  DISPLAY " 5:00 am      {INST_DEM[11]}     {NEW_DEM[11]}
{TARG_DEM[11]} {TARG_RED_N[11]}"
  DISPLAY " 5:30 am      {INST_DEM[12]}     {NEW_DEM[12]}
{TARG_DEM[12]} {TARG_RED_N[12]}"
  DISPLAY " "
  DISPLAY " "
  DISPLAY "Press any key to see screen 2 of 4.~"
  CLS

```

```

DISPLAY " The following summarizes the proposed/targeted
changes"
DISPLAY " "
DISPLAY " "
LOAD DISPLAY " PERIOD CURRENT LOAD MODIFIED LOAD TARGET
TARGET REDUCTION"
DISPLAY " STARTING kVA kVA kVA
kVA"
DISPLAY " "
DISPLAY " 6:00 am {INST_DEM[13]} {NEW_DEM[13]}
{TARG_DEM[13]} {TARG_REDN[13]}"
DISPLAY " 6:30 am {INST_DEM[14]} {NEW_DEM[14]}
{TARG_DEM[14]} {TARG_REDN[14]}"
DISPLAY " 7:00 am {INST_DEM[15]} {NEW_DEM[15]}
{TARG_DEM[15]} {TARG_REDN[15]}"
DISPLAY " 7:30 am {INST_DEM[16]} {NEW_DEM[16]}
{TARG_DEM[16]} {TARG_REDN[16]}"
DISPLAY " 8:00 am {INST_DEM[17]} {NEW_DEM[17]}
{TARG_DEM[17]} {TARG_REDN[17]}"
DISPLAY " 8:30 am {INST_DEM[18]} {NEW_DEM[18]}
{TARG_DEM[18]} {TARG_REDN[18]}"
DISPLAY " 9:00 am {INST_DEM[19]} {NEW_DEM[19]}
{TARG_DEM[19]} {TARG_REDN[19]}"
DISPLAY " 9:30 am {INST_DEM[20]} {NEW_DEM[20]}
{TARG_DEM[20]} {TARG_REDN[20]}"
DISPLAY "10:00 am {INST_DEM[21]} {NEW_DEM[21]}
{TARG_DEM[21]} {TARG_REDN[21]}"
DISPLAY "10:30 am {INST_DEM[22]} {NEW_DEM[22]}
{TARG_DEM[22]} {TARG_REDN[22]}"
DISPLAY "11:00 am {INST_DEM[23]} {NEW_DEM[23]}
{TARG_DEM[23]} {TARG_REDN[23]}"
DISPLAY "11:30 am {INST_DEM[24]} {NEW_DEM[24]}
{TARG_DEM[24]} {TARG_REDN[24]}"
DISPLAY " "
DISPLAY " "
DISPLAY "Press any key to see screen 3 of 4.~"
CLS

```

```

DISPLAY " The following summarizes the proposed/targeted
changes"
DISPLAY " "
DISPLAY " "
LOAD DISPLAY " PERIOD CURRENT LOAD MODIFIED LOAD TARGET
TARGET REDUCTION"
DISPLAY " STARTING kVA kVA kVA
kVA"
DISPLAY " "
DISPLAY "12:00 am {INST_DEM[25]} {NEW_DEM[25]}
{TARG_DEM[25]} {TARG_REDND[25]}"
DISPLAY "12:30 pm {INST_DEM[26]} {NEW_DEM[26]}
{TARG_DEM[26]} {TARG_REDND[26]}"
DISPLAY " 1:00 pm {INST_DEM[27]} {NEW_DEM[27]}
{TARG_DEM[27]} {TARG_REDND[27]}"
DISPLAY " 1:30 pm {INST_DEM[28]} {NEW_DEM[28]}
{TARG_DEM[28]} {TARG_REDND[28]}"
DISPLAY " 2:00 pm {INST_DEM[29]} {NEW_DEM[29]}
{TARG_DEM[29]} {TARG_REDND[29]}"
DISPLAY " 2:30 pm {INST_DEM[30]} {NEW_DEM[30]}
{TARG_DEM[30]} {TARG_REDND[30]}"
DISPLAY " 3:00 pm {INST_DEM[31]} {NEW_DEM[31]}
{TARG_DEM[31]} {TARG_REDND[31]}"
DISPLAY " 3:30 pm {INST_DEM[32]} {NEW_DEM[32]}
{TARG_DEM[32]} {TARG_REDND[32]}"
DISPLAY " 4:00 pm {INST_DEM[33]} {NEW_DEM[33]}
{TARG_DEM[33]} {TARG_REDND[33]}"
DISPLAY " 4:30 pm {INST_DEM[34]} {NEW_DEM[34]}
{TARG_DEM[34]} {TARG_REDND[34]}"
DISPLAY " 5:00 pm {INST_DEM[35]} {NEW_DEM[35]}
{TARG_DEM[35]} {TARG_REDND[35]}"
DISPLAY " 5:30 pm {INST_DEM[36]} {NEW_DEM[36]}
{TARG_DEM[36]} {TARG_REDND[36]}"
DISPLAY " "
DISPLAY " "
DISPLAY "Press any key to see screen 4 of 4.~"
CLS

```

```

DISPLAY " The following summarizes the proposed/targeted
        changes"
DISPLAY " "
DISPLAY " "
LOAD   DISPLAY " PERIOD      CURRENT LOAD      MODIFIED LOAD      TARGET
        TARGET REDUCTION"
        DISPLAY " STARTING      kVA              kVA              kVA
        kVA"
        DISPLAY " "
        DISPLAY " 6:00 pm      {INST_DEM[37]}      {NEW_DEM[37]}
        {TARG_DEM[37]}      {TARG_RED[37]}"
        DISPLAY " 6:30 pm      {INST_DEM[38]}      {NEW_DEM[38]}
        {TARG_DEM[38]}      {TARG_RED[38]}"
        DISPLAY " 7:00 pm      {INST_DEM[39]}      {NEW_DEM[39]}
        {TARG_DEM[39]}      {TARG_RED[39]}"
        DISPLAY " 7:30 pm      {INST_DEM[40]}      {NEW_DEM[40]}
        {TARG_DEM[40]}      {TARG_RED[40]}"
        DISPLAY " 8:00 pm      {INST_DEM[41]}      {NEW_DEM[41]}
        {TARG_DEM[41]}      {TARG_RED[41]}"
        DISPLAY " 8:30 pm      {INST_DEM[42]}      {NEW_DEM[42]}
        {TARG_DEM[42]}      {TARG_RED[42]}"
        DISPLAY " 9:00 pm      {INST_DEM[43]}      {NEW_DEM[43]}
        {TARG_DEM[43]}      {TARG_RED[43]}"
        DISPLAY " 9:30 pm      {INST_DEM[44]}      {NEW_DEM[44]}
        {TARG_DEM[44]}      {TARG_RED[44]}"
        DISPLAY "10:00 pm      {INST_DEM[45]}      {NEW_DEM[45]}
        {TARG_DEM[45]}      {TARG_RED[45]}"
        DISPLAY "10:30 pm      {INST_DEM[46]}      {NEW_DEM[46]}
        {TARG_DEM[46]}      {TARG_RED[46]}"
        DISPLAY "11:00 pm      {INST_DEM[47]}      {NEW_DEM[47]}
        {TARG_DEM[47]}      {TARG_RED[47]}"
        DISPLAY "11:30 pm      {INST_DEM[48]}      {NEW_DEM[48]}
        {TARG_DEM[48]}      {TARG_RED[48]}"
        DISPLAY " "
        DISPLAY " "
        !! calculate new savings,
        !! comment on loads ditched (with unit cost savings),
        !! and external shifted load
        DISPLAY "Press any key to continue~";

```

```

RULE CONT3
IF          SATISFIED = MOVE_[OTHER]_LOADS
THEN       CONT = YES
          !! ESTABLISH TIME INTERVAL FROM WHICH LOAD IS TO BE
          SHIFTED

          CLS
          DISPLAY " Change load patterns in which time interval ?"
          DISPLAY " "
          RESET AM_PM
          RESET HOUR
          RESET HALF_HR
          RESET X
          RESET TIME
          FIND TIME
          FORMAT HOUR, 2.0
          FORMAT HALF_HR, 2.0
          C_HOUR      = (HOUR)
          C_HALF_HR  = (HALF_HR)
          C_AM_PM    = (AM_PM)
          C_X        = (X)
          CLS
          DISPLAY "For the 30 minute interval starting at
                  {C_HOUR}:{C_HALF_HR} {C AM PM} ,"
!! ESTABLISH LOAD SHED, MOVE ETC FOR THIS INTERVAL
          DISPLAY " "
          DISPLAY " What loads;"
          RESET DITCH
          RESET DITCH_LOAD
          FIND DITCH
          RESET EXT_MOVE
          RESET MOVED_EXT
          FIND EXT_MOVE
          RESET INT_MOVE
          RESET MOVED_INT
          FIND INT_MOVE
          RESET IN_MOVE
          RESET ADDED_LOAD
          FIND IN_MOVE

!! SUMMARY OF CURRENT "TRANSACTION"
          RESET MOVE_SUMMARY
          FIND MOVE_SUMMARY

!! DISPLAY WARNINGS ETC RE LOAD MOVEMENTS
          PPK = 0
          RESET NEW_PEAK_WARN
          FIND NEW_PEAK_WARN

          RESET ZEROCHECK
          FIND ZEROCHECK

          RESET IMPORTCHECK
          FIND IMPORTCHECK
          DISPLAY " "
          DISPLAY " "
          DISPLAY " Press any key to continue~";

```

```

RULE CONT4
  IF      SATISFIED = LOAD_SPREADSHEET
  THEN    CONT = YES
          DISPLAY " This option will load the new values for
                daily demand back"
          DISPLAY " to the spreadsheet (the old spreadsheet
                values will not be"
          DISPLAY " overwritten. "
          RESET CCONF
          RESET GOAHEAD
          FIND CCONF;

RULE CONT5
  IF      SATISFIED = SET_IMPORT_LOAD
  !! Get load to be added from other MD charge periods
  THEN    CONT = YES
          CLS
          DISPLAY " How much (if any) load from other MD
                charge periods do you "
          DISPLAY " want to (re) distribute within this MD
                charge period ?"
          RESET IN_MOVE_TOT
          FIND  IN_MOVE_TOT
          TOT_IN_MOVE = (IN_MOVE_TOT)
  ELSE    TOT_IN_MOVE = 0;

RULE CCONFIRM
  IF      GOAHEAD = YES
  THEN    CCONF = FOUND
          DISPLAY "Loading data to Spreadsheet"
          PWKS NEW DEM, NAMED = NEW DEM, LJRVAL4
          DISPLAY " All data has been loaded into spreadsheet;
                press any key to continue~";

RULE CHECK48
  IF      X <= 47
  THEN    CHECK48 = KNOWN
          X = (X + 1);

RULE MORNING_TIME
  IF      AM_PM =AM
          AND HOUR <> UNKNOWN
          AND HALF_HR <> UNKNOWN
  THEN    X = ( 2 * HOUR + (HALF_HR / 30) )
          TIME = KNOWN;

RULE AFTERNOON
  IF      AM_PM =PM
          AND HOUR <> UNKNOWN
          AND HALF_HR <> UNKNOWN
  THEN    X = ( 24 + ( 2 * HOUR + (HALF_HR / 30) ) )
          TIME = KNOWN;

```

```

RULE T_OF_D
  IF      X > 24
  THEN    T_OF_D = pm
          X = (X - 24)
  ELSE    T_OF_D = am;

RULE INT HOUR
  IF      X >= 2
  THEN    INT HOUR = FOUND
          X = (X - 2)
          HR = (HR + 1);

RULE INT_MIN
  IF      X = 1
  THEN    MINTIME = 30
  ELSE    MINTIME = 00;

RULE THISMD
  IF      THISMD1 > 0
  THEN    THISMD = FOUND;

RULE MAX_MM
  IF      NMN < 1
  THEN    NEWPEAKTIME = (X)
          NEWMAX      = (NEW_DEM[X])
          MMAX_MM     = FOUND;

RULE DITCH
  !! LOAD WHICH CAN BE DITCHED FROM THIS INTERVAL
  IF      DITCH_LOAD <> UNKNOWN
  THEN    NEW_DEM[X] = ((NEW_DEM[X]) - (DITCH_LOAD))
          FORMAT NEW_DEM[X], 9.3
          TOT DITCH = ((TOT DITCH) + (DITCH_LOAD))
          FORMAT TOT DITCH, 6.0
          DITCH = FOUND;

RULE EXT_MOVE
  !! LOAD WHICH CAN BE MOVED OUTSIDE THIS MD CHARGE PERIOD
  IF      MOVED_EXT <> UNKNOWN
  THEN    NEW_DEM[X] = ((NEW_DEM[X]) - (MOVED_EXT))
          FORMAT NEW_DEM[X], 9.3
          TOT_EXT_MOVE = ((TOT_EXT_MOVE) + (MOVED_EXT))
          FORMAT TOT_EXT_MOVE, 6.0
          EXT_MOVE = FOUND;

RULE INT_MOVE
  !! LOAD WHICH CAN BE MOVED WITHIN THIS MD CHARGE PERIOD
  IF      MOVED_INT <> UNKNOWN
  THEN    INT_MOVE = FOUND
          NEW_DEM[X] = ((NEW_DEM[X]) - (MOVED_INT))
          FORMAT NEW_DEM[X], 9.3;

```



```

RULE ADDED_LOAD
IF      ADDED_LOAD <> UNKNOWN
THEN    NEW_DEM[X] = ((NEW_DEM[X]) + (ADDED_LOAD))
        TOT_IN_MOVE = ((TOT_IN_MOVE) - (ADDED_LOAD))
        FORMAT NEW_DEM[X], 9.3
        FORMAT TOT_IN_MOVE, 6.0
        IN_MOVE = FOUND;

RULE MOVE_SUMMARY
IF      MOVED_INT > 0
THEN    CLS
        OLDTIME = (X)
        DISPLAY "Destination of this load (Time interval) ?"
        RESET AM_PM
        RESET HOUR
        RESET HALF_HR
        RESET X
        RESET TIME
        FIND TIME
        DEST_TIME = (X + 1)
        !! DISPLAY LOAD MOVEMENT FOR THIS INTERVAL
        CLS
        DISPLAY " "
        DISPLAY " -- SUMMARY OF LOAD MOVEMENT ---- "
        DISPLAY " "
        DISPLAY " PERIOD          CURRENT LOAD
        PROPOSED LOAD"
        DISPLAY " "
        DISPLAY " {C_HOUR}:{C_HALF_HR} {C_AM_PM}
        {INST_DEM[C_X]}          {NEW_DEM[C_X]}"
        NEW_DEM[DEST_TIME] = ((NEW_DEM[DEST_TIME]) +
        (MOVED_INT))
        FORMAT NEW_DEM[DEST_TIME], 9.3
        DISPLAY " {HOUR}:{HALF_HR} {AM_PM}
        {INST_DEM[DEST_TIME]}
        {NEW_DEM[DEST_TIME]}"
        X = (OLDTIME)
        MOVE_SUMMARY = FOUND
ELSE    CLS
        MOVE_SUMMARY = FOUND
        DISPLAY " "
        DISPLAY " ---- SUMMARY OF LOAD MOVEMENT ---- "
        DISPLAY " "
        DISPLAY " PERIOD          CURRENT LOAD
        PROPOSED LOAD"
        DISPLAY " "
        DISPLAY " {C_HOUR}:{C_HALF_HR} {C_AM_PM}
        {INST_DEM[C_X]}          {NEW_DEM[C_X]}"
        DISPLAY " ";

```

```

RULE NEW_PEAK_WARN1
IF NEW_DEM[DEST_TIME] > (MAX_INST_DEM)
THEN NEW_PEAK_WARN = FOUND
PPK = (NEW_DEM[DEST_TIME] - MAX_INST_DEM)
DISPLAY "*****"
DISPLAY " WARNING ! MOVING THIS LOAD HAS ACTUALLY
        CAUSED A PEAK WHICH "
DISPLAY " IS {PPK} kVA HIGHER THAN IN THE ORIGINAL
        DAILY PATTERN !!!"
DISPLAY "*****";

```

```

RULE NEW_PEAK_WARN2
IF NEW_DEM[C_X] > (MAX_INST_DEM)
THEN NEW_PEAK_WARN = FOUND
PPK = (NEW_DEM[C_X] - MAX_INST_DEM)
DISPLAY "*****"
DISPLAY " WARNING ! MOVING THIS LOAD HAS ACTUALLY
        CAUSED A PEAK WHICH "
DISPLAY " IS {PPK} kVA HIGHER THAN IN THE ORIGINAL
        DAILY PATTERN !!!"
DISPLAY "*****"

ELSE
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " ";

```

```

RULE ZEROCHECK
IF NEW_DEM[X] < 0
THEN ZEROCHECK = FOUND
GENTOT = ( -1 * NEW_DEM[X] )
DISPLAY "*****"
DISPLAY " YOU APPEAR TO BE GENERATING (NOT
        CONSUMING) {GENTOT} kVA OF POWER !!"
DISPLAY "*****"

ELSE ZEROCHECK = FOUND
DISPLAY " "
DISPLAY " "
DISPLAY " ";

```

```

RULE IMPORTCHECK
IF TOT_IN_MOVE < 0
THEN IMPORTCHECK = FOUND
NEGTOT = ( -1 * TOT_IN_MOVE )
DISPLAY "*****"
DISPLAY " YOU HAVE IMPORTED {NEGTOT} kVA MORE LOAD
        FROM OTHER CHARGE PERIODS"
DISPLAY " THAN YOU ORIGINALLY INDICATED WAS
        NECESSARY"
DISPLAY "*****"

ELSE
DISPLAY " "
DISPLAY " "
DISPLAY " "
DISPLAY " ";

```

```

RULE LF_TARG
IF
THEN
    TARG_TYPE = LOAD_FACTOR
    TARG_FOUND = YES
    RESET TARG_LOAD_FACT
    FIND TARG_LOAD_FACT
    TARG_MAX_DEM = ((MEAN_INST_DEM) / (TARG_LOAD_FACT))
    X = 1
    CUT = 0
    FILL = 0
    WHILEKNOWN CHECK48
        RESET TARGETMD
        FIND TARGETMD
        FORMAT TARG_DEM[X], 9.3
        FORMAT TARG_REDN[X], 6.0
        RESET CHECK48
        FIND CHECK48
    END
    CUT_FILL_RATIO = ((CUT) / (FILL))
    RESET FEASIBLE
    FIND FEASIBLE;

```

```

RULE MD_TARG
IF
THEN
    TARG_TYPE = MAXIMUM_DEMAND
    TARG_FOUND = YES
    RESET TARG_MAX_DEM
    FIND TARG_MAX_DEM
    X = 1
    CUT = 0
    FILL = 0
    WHILEKNOWN CHECK48
        RESET TARGETMD
        FIND TARGETMD
        FORMAT TARG_DEM[X], 9.3
        FORMAT TARG_REDN[X], 6.0
        RESET CHECK48
        FIND CHECK48
    END
    CUT_FILL_RATIO = (@ABS((CUT) / (FILL)))
    RESET FEASIBLE
    FIND FEASIBLE;

```

```

RULE TARG_MD1
IF
THEN
    INST_DEM[X] > (TARG_MAX_DEM)
    TARGETMD = FOUND
    TARG_DEM[X] = (TARG_MAX_DEM)
    TARG_REDN[X] = (NEW_DEM[X] - TARG_MAX_DEM)
    CUT = (CUT + (INST_DEM[X] - TARG_MAX_DEM));

```

```

RULE TARG_MD2
IF
THEN
    INST_DEM[X] <= (TARG_MAX_DEM)
    TARGETMD = FOUND
    TARG_DEM[X] = (INST_DEM[X])
    TARG_REDN[X] = 0
    FILL = (FILL + (TARG_MAX_DEM[X] - INST_DEM[X]));

```

```
RULE NO_TARG
  IF FEASIBLE
  THEN
    TARG_TYPE = NONE
    RESET FEASIBLE
    TARG_FOUND = YES
    X = 1
    WHILEKNOWN CHECK48
      TARG_DEM[X] = (INST_DEM[X])
      TARG_REDN[X] = 0
      FORMAT TARG_DEM[X], 9.3
      FORMAT TARG_REDN[X], 6.0
      RESET CHECK48
      FIND CHECK48
    END;

RULE FEASIBLE
  IF
  THEN
  ELSE
    CUT_FILL_RATIO > 1
    FEASIBLE = NO
    RESET FEASIBLE;
    !! IE, MORE LOAD HAS BEEN CUT THAN CAN BE FILLED
    IN !!
    !! NB THIS IS NOT NECESSARILY IMPOSSIBLE; IT JUST
    MEANS THAT
    !! LOAD HAS TO BE MOVED TO OTHER MD CHARGE PERIODS
```

ASK SATISFIED: " What do you want to do next ?";  
CHOICES SATISFIED: Help, Set\_import\_load, Move [other]\_loads,  
Current\_situation, Show\_all\_intervals,  
Load\_spreadsheet, Finish;

ASK HALF\_HR: " How many minutes past the hour ?";  
CHOICES HALF\_HR: 00,30;

ASK HOUR : "What hour of day ?";  
CHOICES HOUR : 00,01,02,03,04,05,06,07,08,09,10,11,12;

ASK AM\_PM : " am, or pm ?";  
CHOICES AM\_PM: am,pm;

ASK DITCH\_LOAD: " A) Can be simply turn off ?";

ASK MOVED\_EXT : " B) Can be rescheduled to another MD  
charge period ?";

ASK MOVED\_INT : " C) Can be rescheduled (within the same MD  
charge period) ?";

ASK ADDED\_LOAD: " D) Transferred from another MD charge  
period can be operated here ?";

ASK IN\_MOVE\_TOT : "";

ASK THISMD: "What is the MD rate (\$/kVA) for this month ?";

ASK GOAHEAD : "Do you wish to proceed ?";  
CHOICES GOAHEAD : Yes,No;

ASK TARG\_TYPE: "What type of target do you want to set for yourself  
?";  
CHOICES TARG\_TYPE: None, Load\_factor, Maximum\_demand;

ASK TARG\_LOAD\_FACT: "What load factor (target) would you like to  
aim for ?";

ASK TARG\_MAX\_DEM: "What Maximum Demand target figure (kVA) would  
you like to aim for ?";

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