AN EDUCATIONAL DESIGN FOR COURSEWARE RELATING TO HEATING LOAD CALCULATIONS IN BUILDINGS

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ABSTRACT

Courseware is educational software, designed to create an instructional environment, for the purpose of facilitating learning. Courseware is being developed to support training in a wide range of engineering disciplines, including Heating Ventilating and Air Conditioning (HVAC) design. It is anticipated that courseware will be used much more, to support current training practices in HVAC design, in order to make training more effective, efficient, and accessible. Current practices in courseware design indicate very few courseware products are designed using formal methods. This has led to courseware, that in many ways, fails to address learner's needs. If courseware is to be effective, in supporting training in HVAC design, then courseware must be developed using formal methods.

In this paper, a formal courseware design model is described. An Educational Design (ED) is carried out, for courseware relating to heating load calculations in buildings, resulting in a detailed conceptual description of how the courseware appears to the user. Sixteen screens are shown, depicting how the courseware guides the user, in learning how to perform heating load calculations in buildings.

1. INTRODUCTION

Current training methods, aimed at professional engineers involved in Heating Ventilating and Air Conditioning (HVAC) design, consist of seminars and courses offered by organisations such as ASHRAE [ASHRAE 1990]. These courses are designed to expand and/or refresh an engineer's knowledge and skills on a variety of HVAC design topics. These courses are characteristically brief, compact, delivered at a very fast pace, and expensive.

Professor Damon Gowan, the president of ASHRAE, has stated that new methods, that would support the training of HVAC engineers in HVAC design, are being sought by ASHRAE [Gowan 1990]. Professor Gowan felt that to improve the quality and number of professionals entering the HVAC industry, training must be made more effective, efficient, and accessible.

Computer software is used as an educational support tool in training HVAC design. An example of this is HVAC simulation software. The user in learning how to use this kind of software (e.g. DOEII), identifies the inputs, required to run the program. As a result, he/she learns how to use the software, and more importantly, gains experience of a wide range of HVAC systems, their properties and dynamic behaviour. More recently, computer software specifically designed to address educational and training issues has emerged in the field of Computer Aided Learning (CAL). Courseware is computer software designed to create an instructional environment for the purpose of facilitating learning [Jonassen 1988]. Courseware has been developed for a number of areas in engineering design. These include Thermodynamics [Eustis 1989], and Heat Transfer [l'Agence Francaise De L'Energie, 1990]. Given the future trends associated with the development of sophisticated software engineering tools, and more powerful computer hardware, the authors anticipate that courseware will offer a relatively low cost, effective, efficient alternative educational support tool, in engineering training.

This paper focuses on the design of courseware relating to the performance of heating load calculations in buildings. The reason for focusing on this topic, is that heating load calculation must be performed in every HVAC design, regardless of the building type. It is a fundamental step in the design process, and must be learnt by any aspiring HVAC engineer.

Courseware design, in general, consists of five stages, namely;

1. Educational Design.
2. Software Analysis and Design.
3. Implementation.
4. Testing and Revision.
5. Maintenance.

The objective of this paper is to carry out an Educational Design (ED) relating to Heating Load calculations in buildings, to identify the following;

1. The HVAC instructional goals.
2. The skills and knowledge embodied in those goals.
3. The instructional strategy required to facilitate the acquisition of the skills.

The approach taken is to identify a systematic approach to courseware design by investigating systematic courseware design models. The steps involved in Educational Design of courseware are identified. An Educational Design is then carried out on the basis of a chosen courseware design model. A written description results, describing in detail the conceptual requirements of the courseware, such as the subject matter to be taught, the instructional events that will bring about the required learning, and the sequence in which this events should be executed.

The following section describes the steps involved in HVAC design. Training in HVAC design is investigated, with a view to identifying the methods used by organisations, such as the American Society of Heating Refrigerating and Air conditioning Engineers (ASHRAE).

2. HEATING VENTILATING AND AIR CONDITIONING DESIGN AND TRAINING

2.1 HVAC Design

Heating Ventilating and Air Conditioning (HVAC) systems are used to control air temperature, humidity, and quality in buildings, to facilitate comfort and environmental conditions suited to human occupation and/or equipment operation. HVAC systems achieve this by [Pita 1981];

1. Control of air temperature at desired values at all times, by either heating or cooling.
2. Control of air humidity by humidification or dehumidification.
3. Control of air movement at a desired velocity.
4. Introduction of outside ventilation air as required.
5. Control of air quality (cleanliness) by removal of dirt particles and odorous gases through filtration.
6. Control of sound produced by the air conditioning system itself.

Deciding what HVAC system best suits the building owner's needs involves decisions on the type of system to use, calculations of heating and cooling loads, piping and duct sizing, selection of the type and size of equipment, and planning the locations of equipment in the building [Pita 1981]. HVAC engineers need to be trained to make these decisions.

The following section investigates current training and educational practices used to train engineers in the HVAC industry. Following this, current research into using computers to support training in HVAC design is investigated.

2.2. Training HVAC Design

Training in the HVAC industry, world-wide, is carried out by organisations such as: the American Society for Heating Refrigerating and Air conditioning Engineers (ASHRAE), the American Society for Mechanical Engineers (ASME), the Chartered Institute for Building and Services Engineers (CIBSE), and other private training organisations. These organisations offer courses, seminars, and home study courses on a wide range of topics.

ASHRAE professional development series offers seminars for professional development on topics ranging from [ASHRAE 1990];

1. Air system design and retrofit.
2. Water system design and retrofit.
3. Simplified energy calculations.
4. Automatic air temperature controls.
5. DDC for HVAC.
6. Testing, adjusting and balancing of HVAC systems.

ASME offer short and mini-courses on Building Heating and Cooling Load Estimations. Items discussed include [ASME 1990];

1. Overall heat transfer coefficients and design conditions.
2. Heating load estimation.
3. Cooling load estimation.
4. Air conditioning system calculations.
5. Heat recovery techniques.
6. Basic passive solar considerations.

The development and management of training in a wide range of disciplines, including HVAC and Energy design, is led by the European Communities (EC), universities, and other private or state owned training organisations.

COMETT [CALENER 1989] is an EC project whose objectives include, advancement of training technology, development of training programs, and the fostering of cooperation between universities and industry in the context of training.

EUROBUILD [CALENER 1990] is a project within COMETT, aimed at developing training in design, construction, and management of buildings, including HVAC systems.

CALENER [CALENER 1989] is also a project running under COMETT. CALENER is a COMETT UETP (University Enterprise Training Partnership). The CALENER project focuses on energy management. Some of CALENER activities include;

1. CALENER-EMIS: This is a training project for Energy Managers in the Industrial Sector (EMIS).
2. CALENER-EMEB: This is joint training project for Energy Management for Existing Buildings (EMEB). This project is currently under way.

Universities in the UK offer courses on air conditioning (Southbank Polytech), and infiltration, psychrometrics, and mechanical ventilation (University of Glasgow). EOLAS, the Irish Science and Technology Agency, offers courses on air conditioning.

Gowan [Gowan 1990], called for ways of improving the effectiveness, efficiency, and accessibility of training in the HVAC industry. Computer software offers such a way.

The following sections describe early efforts in the use of computer software as an educational/training support tool for HVAC training. Also described are the new innovations into the development of educational software (courseware), specifically aimed at engineering design.

2.3 Computer Software as an Educational Tool in HVAC Engineering Education

The role of computer software as educational/training support tools, in HVAC training, has been mainly confined to simulation [Damshala 1987] [Lorsch 1987]. Students are encouraged by their tutors to use commercially available HVAC simulation software to model and analyse various HVAC design problems. By doing this, the students gain computing skills and an exposure to a wide range of HVAC software applications, and HVAC design problems. Students are also required to write programs to analyse various heat transfer problems, using the finite difference technique. The students by writing these programs gain a thorough understanding of the rationale behind the analysis.

However new innovative approaches to using computer software as an educational support tool are emerging in the form of Computer Aided Learning (CAL).

Courseware is an example of CAL. Examples of courseware HVAC and Energy design are;

1. **ThermoWare** [Eustis 1989]: ThermoWare (Thermodynamics courseWare) is courseware designed as a supplement to engineering thermodynamics courses. It was developed by Professor R.H. Eustis, at Stanford University. ThermoWare was designed to work on Apple Macintosh, and includes a series of software tutorials intended for use in an introductory engineering thermodynamic. The topics which it covers are;

1. Basic Concepts - system definition, energy, work, heat, and the First Law.
2. Properties and States.
3. First Law Applications.
4. Rankine Cycle.
5. Brayton Cycle.

2. **Gradient Thermique du Batiment** [l'Agence Francaise DE l'Energie 1990]: This courseware was developed by the Centre D'Energetique at Ecoles Des Mines, Paris to teach students how to calculate heat losses through walls in buildings. The topics that it covers are;

   1. Modes of heat loss through walls (e.g. conduction, convection).
   2. Thermal resistance concepts and values related to walls in buildings.
   3. Composite wall structures in the context of overall thermal resistances.
   4. Estimation of overall U-values for walls.

3. **BEMS** [BEMS 1989]: Provides courseware on a wide range of topics that include;

   1. Building and Plant Interface. This includes types of sensors in common use, activators and plant switch interfaces, signal conditioning technology, and field wiring types

Although some early courseware is available today, to the authors knowledge, no formal approach to HVAC courseware design has been published. This paper focuses on the systematic design of courseware relating to heat loss calculations, based on existing courseware design models.

The following sections describe courseware in the context of;

1. The different courseware types.
2. Courseware design.
3. Courseware design models.
4. Educational Design (ED) of courseware.

3. COURSEWARE

Computer software which is designed to create an instructional environment for the purpose of facilitating learning is known as courseware [Jonassen 1989]. Courseware is a relatively recent name given to Computer Assisted Instruction (CAI), or Computer Aided Learning (CAL).

Courseware has been traditionally classified into the following three categories;

1. Drill and Practice applications.
2. Tutorials or Instructional applications.
3. Simulation.

These are defined below.

Drill and Practice

Drill and Practice applications use the computer to store and randomly present practice items to support specific instructional objectives.

Tutorial

Tutorial programs teach learners in an interactive dialogue by;

1. Presenting information.
2. Providing practice.
3. Adapting instruction and/or feedback based on learners response.

Simulation

Real world problems are presented in a computer environment. These require integration and synthesis of subject matter knowledge into a course of action. The consequences of any action simulate the consequences of such an action in the real world. The realistic nature of such activities provides a relevance that motivates learner involvement, and therefore learning.

In the past, courseware design was not much more than designing a few screens and specifying their sequence [DEEP 1989]. This approach was generally suited to Drill and Practice courseware types, but because of the growing sophistication of emerging courseware, this design approach is no longer valid. The following section describes how courseware design has evolved from the past to it's present state.

4. COURSEWARE DESIGN

Since the mid-eighties, systematic courseware design models have come into existence [Jonassen 1989]. Generally speaking, these courseware design models lead to designs, which may be put into two categories [Jonassen 1989].

1. Interactive designs.
2. Adaptive designs.

Interactive Designs

Interactive designs involve interactive dialogue between the learner and the computer, brought about by kinesthetic (keypresses by the learner) input, and visual output (by the computer). The degree of interaction depends on the following factors.

1. **Learners Response**: Does the learner respond using the computer's keyboard, or, are other input devices available that the user must use.
2. **The Nature of the Processing**: This depends on how complicated the tasks that the learner must carry out so that he can respond.
3. **The Level of Computer Processing**: The level of processing that the computer must be capable of due to the learners response.

These variables combine to form types of interactive programs. Typical examples of such courseware are Drill, Tutorial, Simulation, Knowledge based courseware. Another feature of interactive courseware is the degree of intelligence it exhibits. Intelligent courseware is still in the development stage.

Adaptive Designs

The main feature of adaptive courseware is it's ability to adapt the presentation of material to meet the needs of the learner, or curriculum. Adaptive designs are essentially the same as interactive designs, except that they include an adaptive component. This component facilitates variation of the way learning material is presented to the learner. Presentation is varied in style, substance, and rationale. Adaptive designs can be implemented to facilitate the adaption of;

1. Style of presentation.
2. Subject matter.
3. Rationale behind how the subject matter should be presented.

These adaptations are based on learner characteristics, such as special aptitudes, disabilities, and estimated attainment of learning.

The following section describes the different systematic courseware design models. A ten point list is outlined that contains the design steps common and fundamental to all effective and efficient systematic courseware design models. The aim of the following section is to clearly describe the component stages of a courseware design model.

5. SYSTEMATIC COURSEWARE DESIGN MODELS

Andrews and Goodson [Andrews and Goodson 1980] investigated over sixty systematic courseware design models. They found that, in general, five distinct design stages could be identified in each of these models. These stages are;

1. Educational Design.
2. Software Analysis and Design.
3. Implementation.
4. Testing and Revision of courseware.
5. Maintenance of courseware.

Each of these design stages can be further divided into a number of steps. Goodson and Anderson, reviewing the work of Gropper[Gropper 1977], found that Gropper compiled a ten point list, which depicts the steps involved at each of the design stages. These are;

(1) Educational Design

1. Formulation of broad goals and subgoals stated in observable terms.
2. Development of pretests and posttests matching goals and subgoals.
3. Analysis of goals and subgoals to determine the types of skills/learning that are required.
4. Sequencing of goals and subgoals to facilitate learning.
5. Characterization of learner type in terms of past learning history, special aptitudes, disabilities, and estimated attainment of current and prerequisite goals.
6. Formulation of instructional strategy to match subject matter and learner requirements.
7. Selection of media to implement strategies.

(2) Software Analysis Design

8. Analysis and design of the educational software (courseware) architecture.

(3) Implementation

1. Programming of the courseware.

(4) Testing and Revision of Courseware

9. Empirical tryout of courseware with learner population, diagnosis of learning and courseware failures, and revision of courseware based on diagnosis.

(5) Maintenance of Courseware

10. Development of materials and procedures for installing, maintaining and periodically updating the courseware.

The following section describes an educational design for courseware relating to heating load calculations in buildings. Identified are the instructional goals and subgoals involved, the skills they contain, and an instructional strategy that will facilitate the acquisition of those skills.

6. THE EDUCATIONAL DESIGN

The approach taken in this section is to examine heating load calculations with a view to determining;

1. The skills required of a HVAC engineer to perform a heating load calculation.
2. An instructional strategy that will facilitate the acquisition of those skills.

The skills may be classified as follows.

6.1 Skills Classification

Skills can be classified into the following categories;

1. Intellectual skills.
2. Motor skills.
3. Communication skills.

This paper focuses on learning, so that only intellectual skills will be discussed. These intellectual skills are defined in the following section.

Intellectual skills, are skills that enable the learner to do something that requires cognitive processing, i.e. it is procedural knowledge [Gagne 1989].

Robert Gagne, through his research in learning theory, classifies learning into five categories which he called learning outcomes or skills [Gagne 1989]. One of these learning outcomes is intellectual skills. Gagne further classified intellectual skills into five categories. In order to make this classification more meaningful in the context of this paper, while at the same time, taking none of it's original meaning away, the author chose to take this classification and express it as follows;

Gagne's Classification of Intellectual Skills	Author's Interpretation of Gagne's Classification
1. Concrete Concepts 2. Defined Concepts	1. Conceptual Skills
3. Rule 4. Higher Order Rule	2. Selective Skills 3. Retention Skills 4. Retrieval Skills 5. Numerate Skills
5. Cognitive Strategies	6. Cognitive Strategies

Conceptual Skills

Conceptual skills are skills that enable the learner to abstract , and interpret real-world phenomena into forms such as: a) written descriptions or tables, b) Graphical drawings, c) Mathematical equations.

Cognitive Strategies

Cognitive strategies play an important role in problem solving. Cognitive strategies enter into the problem solving process by aiding the learner in the selection of suitable intellectual skills, and in their timing and their use.

Selective Skills

This is an intellectual skill that enables the learner to identify an object from a class of objects. For example, such a skill would be used in identifying the graphic symbol that represents a window, in an architectural drawing.

Retention Skills

This skill involves the learners ability to memorize knowledge.

Retrieval Skills

This skill involves the learners ability to retrieve information from long-term memory.

Numerate Skills

Numerate skills enables the user to perform basic numerical calculations.

The following sections define the instructional goals and subgoals for courseware relating to heating load calculations in buildings. These are then taken and skills are identified according to the skills classification already discussed. An instructional strategy is then described

6.2 Instructional goals and Subgoals

The steps involved in the performance of heating load calculations are;

1. Select indoor/outdoor design temperatures from tables [ASHRAE 1989].
2. Use architectural plans or, on the site, measure dimensions on the job of walls, windows, doors, roofs, ceilings, through which there will be heat transfer for each room
3. Calculate areas of surfaces.
4. Calculate or select heat transfer coefficient U(W/m^{2}K) or k(w/m^{2}K) values for each material [ASHRAE 1989].
5. Calculate the heat transfer through each surface in a room and the room total heat transfer loss.
6. Find the length of cracks for each window from architectural plans or on the site.
7. Find air infiltration rates for the cracks from the tables [ASHRAE 1989].
8. Calculate infiltration heat losses for each room.
9. Find total room heating load by summing room heat transmission loss and room infiltration loss.
10. Find total building heating load by summing the room heat transmission losses and building infiltration and/or ventilation loss.

The following section takes these HVAC design steps and expresses them as Instructional Goals (IGs). Instructional goals (IGs) are developed to train students to be able to perform each of the above calculation steps. These goals are taken and decomposed into the skills discussed previously.

6.3 Analysis of skills in Instructional Goals

IG 1 Selecting Design Conditions

This goal involves cognitive strategies (i.e. knowing how to read the table containing the value), and selective skills (knowing the rule in selecting the correct indoor design temperature, for the different building types).

IG 2 Measuring Dimensions of Building Envelope

This goal involves selection skills (identifying windows, walls, doors etc., from the graphic symbols used in the architectural drawings), conceptual skills, and cognitive strategies. Conceptual skills are required to identify different wall types (say a non-standard wall type) so that the dimensions for the different wall types can be measured. Cognitive strategies are used to decide on whether to use selective skills only (if all of the walls in the building are of the same construction), and/or conceptual skills in identifying the different structural elements.

IG 3 Calculate areas of Building Surfaces

This goal involves numerate skills.

IG 4 Calculation of Material Heat Transmission Coefficients

This involves cognitive strategies and selective skills. The learner must know what tables he/she requires [ASHRAE 1989]. For example, where to look for U-values for walls, windows etc.

He/she must be able to decide, based on a number of structural conditions, such as the orientation (vertical or horizontal) of structural element, direction of heat flow, single or double glaze etc., what U-value to choose. Cognitive strategies are also used in this goal to decide whether a U value is available in the tables [ASHRAE 1989], and if not, how to calculate it using the thermal resistances of the different materials making up the structural element.

IG 5 Calculate Room Transmission Losses

This goal involves conceptual skills. The learner must understand the underlying heat transfer concepts, such as rate of heat transfer, overall thermal resistances, overall heat transmission values, sensible and latent heat transfer etc.. Cognitive skills are then required to order the sequence of how these conceptual skills should be carried out. finally numerical skills are used to carry out the calculations.

IG 6 Measure Window Crack Lengths

Again, selective and numerical skills are required here.

IG 7 Calculate Infiltration Rates

Cognitive strategies, conceptual skills, and numerical skills are involved. How to calculate infiltration rates must be learned. The user must learn about infiltration rates, the concepts involved, and the calculations that must be performed.

IG 8 Calculate Room Infiltration

This goal takes the results form IG 7 and the learner using his/her numerical skills (summing a set of numbers) calculates the room, infiltration room heat losses.

IG 9 Calculate Total Room Heating losses

This goal involves numerate skills only. The total room transmission heat losses, and infiltration loss are added together to give the total room heat loss.

IG 10 Calculate Building Heating Load

This also involves numerate only. All of the room heat transmission heat losses, and infiltration and/or ventilation losses, are summed together to give the building heating load. Same as IG 9.

Having identified the skills contained in each of the instructional goals, the next step is to prescribe an instructional strategy.

6.4 The Instructional Strategy

Gagne [Gagne 1989] derived nine external instructional events specifically aimed at facilitating the acquisition of the different kinds of intellectual skills in a systematic way. External instructional events are a collection of events arranged, so that learning can readily occur. These events, and the internal learning processes to which they are addressed are;

1. ***Gaining*** learner attention: aimed at alerting the learner to receive stimulation.

2. ***Informing*** learner of learning objectives: aimed at acquiring an expectancy of the results of learning.

3. ***Stimulating*** recall of prior learning: aimed at retrieval of items in long-term memory and storage in the working memory.

4. ***Presenting*** stimuli with distinctive features: aimed at encouraging the selective perception of the patterns that enter into learning. In learning, we tend to identify patterns to aid us in our learning. For example, if we are trying to remember a definition, we may take the first letter of each of the words in the definition and memorize them. The letters will be used at a later stage as a means of retrieving the definition. Therefore, presenting stimuli that encourage selective perception of patterns stimulates learning.

5. ***Providing*** learning guidance: aimed at the semantic encoding of presented material, to attain a form for long term storage and ready retrieval.

6. ***Eliciting*** performances: the purpose of this instructional event is that the learner responds with a performance that verifies learning. This kind of assessment is for when the lesson has just been completed.

7. ***Providing feedback***: aimed at reinforcement of learning.

8. ***Assessing performance***: this instructional event is used to assess recall of information by using cues.

9. ***Enhancing retention*** and ***Learning transfer***: aimed at generalizing performance to new situations.

These external events of instruction are used in the following section to provide us with a detailed conceptual description of an instructional strategy relating to heat loss calculations in buildings. This strategy describes the learning objectives, the learning prerequisites, and how the learning is to be presented both in terms of content and sequence, how learning is to be supported assessed and reinforced, using Gagnes's external events of instruction as formal guide-lines.

6.4.1 Instructional Strategy for Courseware relating to Heating Load Calculations

If we recall the steps involved in an Educational Design (ED), we will remember that the last step involves the selection of media, through which the instructional strategy is implemented. This step will be considered before the instructional strategy is described. This is done because an instructional strategy is subject to practical considerations. For example, can such a strategy be implemented in software ?. Before an instructional strategy is put forward, it is important to have a clear idea, what software tools are available to implement this strategy, and if there is a clear path to integrating these tools. The courseware strategy should consider existing software, and software tools. This is done to avoid any unnecessary software development, during the software analysis and design stage, of the courseware development. The following choice of software tools make the instructional strategy (yet to be described) one, that can be considered realistic in the context of implementation.

value for an exterior non-standard wall. Screen fifteen (Figure 15.) describes how to calculate the net surface area for a wall.

13. Finally screen sixteen tells the learner the wall's UA-value is got, by multiplying the wall's U-value by it's net surface area.

Results and Conclusions

Courseware provides the engineering community with the opportunity, to make training, in the various engineering disciplines, such as HVAC design, more effective, efficient, and accessible. For courseware to be both effective, and efficient, it must be designed using systematic methods. Courseware that is not designed using systematic methods, has been found to present learning in an unstructured, unsystematic way, causing the learner to become sometimes confused, intimidated, and eventually disinterested [SAFE 1990]. From a maintenance perspective, courseware that has been developed using non-systematic methods, is characteristically inflexible in terms of adding to and/or updating it [SAFE 1990].

For courseware to have the maximum input into training in HVAC design, it must be designed using formal methods. The Educational Design (ED), is the first step in systematically developing courseware relating to heat loss calculations in buildings.

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1. **The Microsoft^{TM} Software Developers Kit (SDK)** [Microsoft 1990]: This software tool enables the courseware to transmit and receive graphical, textual, and numerical information, to and from the user, in the Microsoft Windows^{TM} style. This tool will take care of all input and output considerations of the courseware.

2. **ASHRAE ACCESS** [ASHRAE ACCESS 1990]: ASHRAE ACCESS is a computerized tool that provides instant access to approximately 350 tables of the 1989 ASHRAE Handbook-Fundamentals [ASHRAE 1989]. It combines features of outliners, spreadsheets, word processors, and database managers. One of it's most important facilities is the transfer of data from these tables, via ASHRAE ACCESS into a running program. This means that the courseware has direct access to all of the tables required to perform a heating load calculation. These tables may be presented to the user via the Microsoft Windows style interface. The user can access values from these tables.

3. **LOAD123** [ref]: LOAD123 calculates 24-hour building heating and cooling loads. Algorithms and psychrometric analysis are based on ASHRAE procedures. Program features include a roof and wall library. This software tool provides the learner with a mechanism, whereby having selected design conditions, U-values, and calculated areas, he/she can immediately observe the heat loss through each of the structural elements, through each of the rooms, and finally the building heating load. The results would be presented in the Microsoft Window style to the user.

The approach taken in this section is to, firstly, give a broad description of the overall instructional strategy. Secondly, this strategy is illustrated by providing the first draft (on paper) of some of the screens, that would appear in the final courseware. During prototyping, of the software, these screens will be further refined, and links between screens will be clarified and strengthened. A detailed description of the instructional strategy is given for heat losses through walls. Within the confines of this paper, it is not possible it is not possible to describe the instructional stratgey for all of the other structural elements (windows, roofs etc.). The instructional stratgey described for the other structural elements will be practically the same as that for walls. All of the units used in the following sections are in Imperial. Future versions of the courseware will offer the learner with the option of learning, using SI or Imperial.

Overall Instructional Strategy

The overall instructional strategy consists of the following steps;

1. Each of the stages involved in the training module are described (Instructional Event 1).

2. The module learning objectives and prerequisite knowledge are described (Instructional Events 2 and 3).

3. The architectural plans of a building are presented and the heat losses indicated (Instructional Events 4 and 5).

4. The building heat loss calculation is described.

5. Heat loss calculations for each of the structural elements are described. The learner is asked to practice some examples (Instructional Events 5 and 6). The learner is informed of his/her progress (Instructional Event 7). Depending on the learners performance, the learning program continues, or the learner is asked to repeat step 5 (Instructional Events 7 and 8).

6. Heat losses through walls, windows etc. are totalled, as well as losses due to infiltration, giving the building heating load (Instructional Event 9).

Detailed Instructional Stratgey for Walls

1. The user is informed as to the stages involved in the learning program (Screen One, Figure 1.).

2. The learner is informed of the learning objectives included in the learning program (Screen Two, Figure 2.).

3. The learner is informed about the learning prerequisites (Screen Three, Figure 3.).

4. Screen Four is presented to the learner (Screen Four, Figure 4.). The learning objective that the learner should investigate is indicated by an arrow. A dialogue box below the figure, informs the user that he/she may choose the learning objective by pointing the mouse at it, and clicking the left-most button of the mouse. The user may only select learning objectives indicated by an arrow, or learning objectives that he/she has previously selected. Learning objectives previously selected by the user are indicated by the box, containing the objective, being shaded. The learner can therefore, observe his/her place in the learning program, and where he/she must proceed to continue.

5. The learner, having selected "Heat Loss in Buildings", is presented with a screen, that describes the various heat losses in buildings (Screen Five, Figure 5.).

6. Having finished learning how heat is lost in buildings, the learner is presented with the next learning objective (Screen Six, Figure 6.). This learning objective deals with building design conditions.

7. Having selected "Design Conditions", the learner is presented with screen seven (Figure 7.). The learner learns how to determine quantities, such as indoor and outdoor temperatures, and relative humidity, and their importance in terms of comfort and energy conservation.

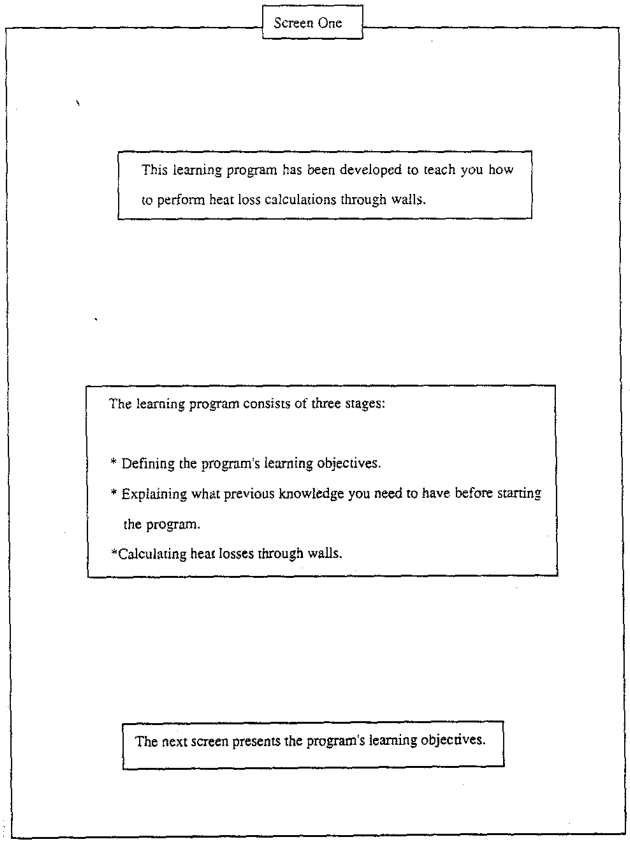
8. The learner is presented with screen eight (Figure 8.). The learner is asked by the learning program to select the third learning objective. The learner, having selected this learning objective, is informed as to the quantities that he/she needs to be able to evaluate, in order to calculate heat transfer, and infiltration losses (Figure 9).

9. The learner is presented with screen ten (Figure 10.), and asked to select the "Walls" learning objective.

10. Screen eleven appears, informing the learner about the quantities, that need to be evaluated, in order to calculate heat loss through walls.

11. Screen twelve asks the learner to select the "UA" option, so as to learn how to determine the values described in screen eleven (Figure 11.).

12. The learner, having selected the "UA" learning objective, is presented with screen thirteen (Figure 13.) This screen teaches the learner how to determine U-value for exterior walls with a standard construction. This screen is followed by screen fourteen (Figure 14.), which teaches the learner how to calculate the U-



Screen One

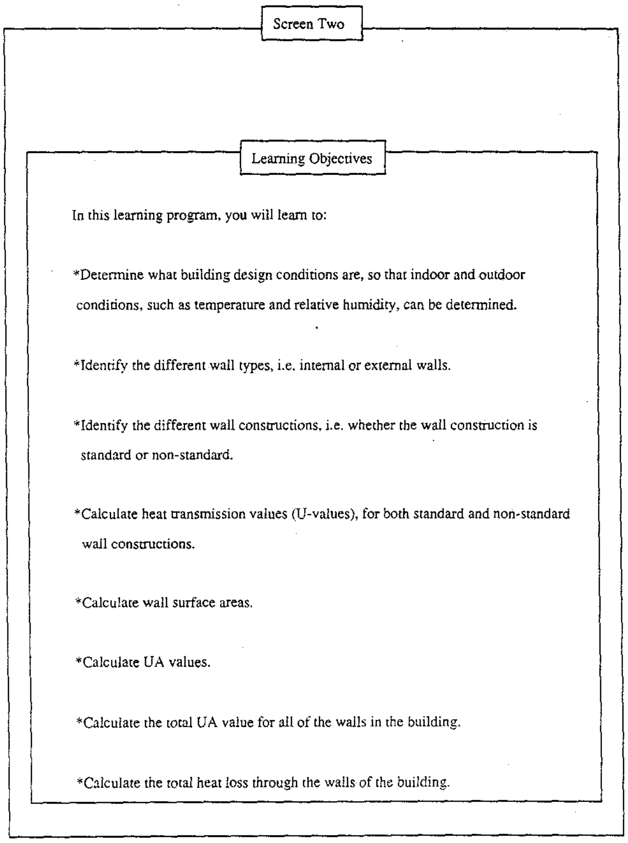
This learning program has been developed to teach you how to perform heat loss calculations through walls.

The learning program consists of three stages:

- * Defining the program's learning objectives.
- * Explaining what previous knowledge you need to have before starting the program.
- *Calculating heat losses through walls.

The next screen presents the program's learning objectives.

Figure 1.



Screen Two

Learning Objectives

In this learning program, you will learn to:

*Determine what building design conditions are, so that indoor and outdoor conditions, such as temperature and relative humidity, can be determined.

*Identify the different wall types, i.e. internal or external walls.

*Identify the different wall constructions, i.e. whether the wall construction is standard or non-standard.

*Calculate heat transmission values (U-values), for both standard and non-standard wall constructions.

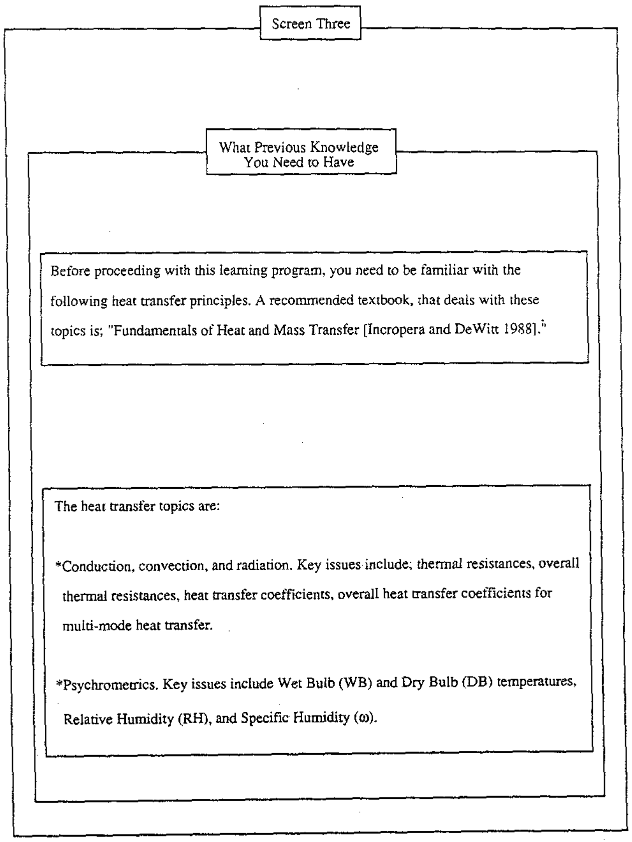
*Calculate wall surface areas.

*Calculate UA values.

*Calculate the total UA value for all of the walls in the building.

*Calculate the total heat loss through the walls of the building.

Figure 2.



Screen Three

What Previous Knowledge You Need to Have

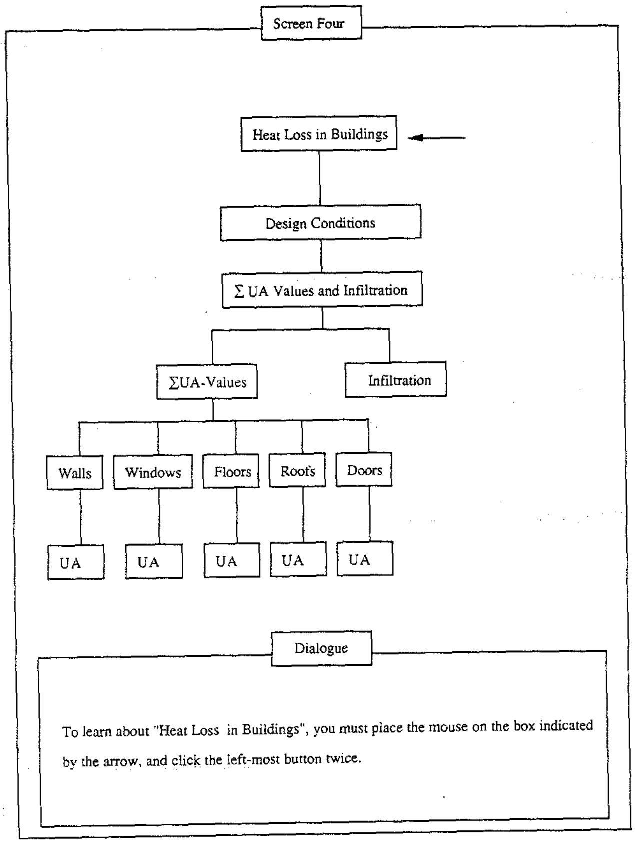
Before proceeding with this learning program, you need to be familiar with the following heat transfer principles. A recommended textbook, that deals with these topics is; "Fundamentals of Heat and Mass Transfer [Incropera and DeWitt 1988]."

The heat transfer topics are:

*Conduction, convection, and radiation. Key issues include; thermal resistances, overall thermal resistances, heat transfer coefficients, overall heat transfer coefficients for multi-mode heat transfer.

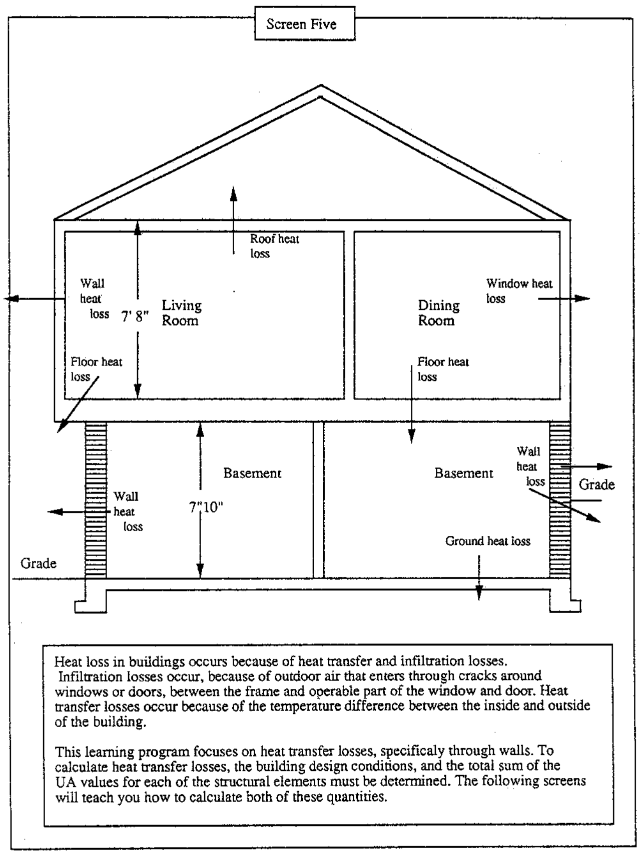
*Psychrometrics. Key issues include Wet Bulb (WB) and Dry Bulb (DB) temperatures, Relative Humidity (RH), and Specific Humidity (ω).

Figure 3.



To learn about "Heat Loss in Buildings", you must place the mouse on the box indicated by the arrow, and click the left-most button twice.

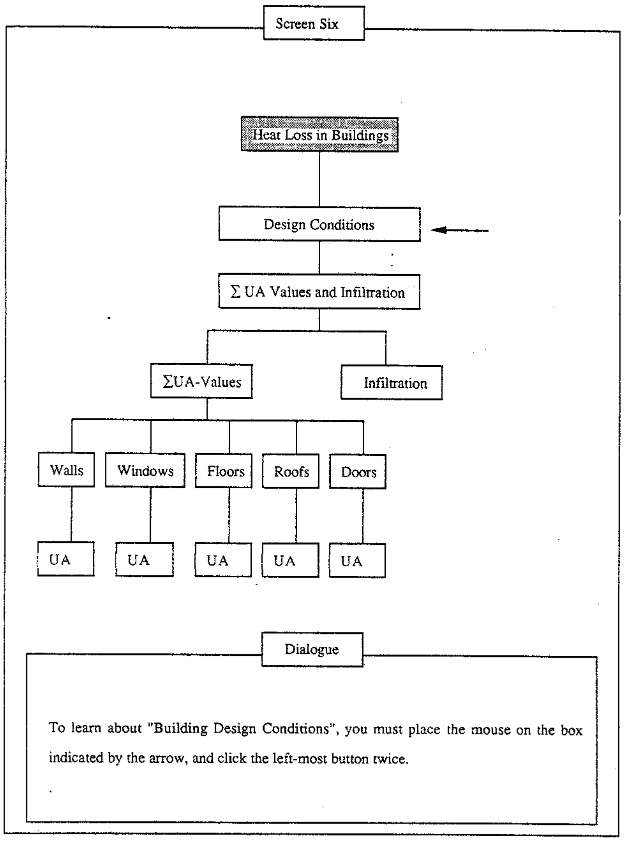
Figure 4.



Heat loss in buildings occurs because of heat transfer and infiltration losses. Infiltration losses occur, because of outdoor air that enters through cracks around windows or doors, between the frame and operable part of the window and door. Heat transfer losses occur because of the temperature difference between the inside and outside of the building.

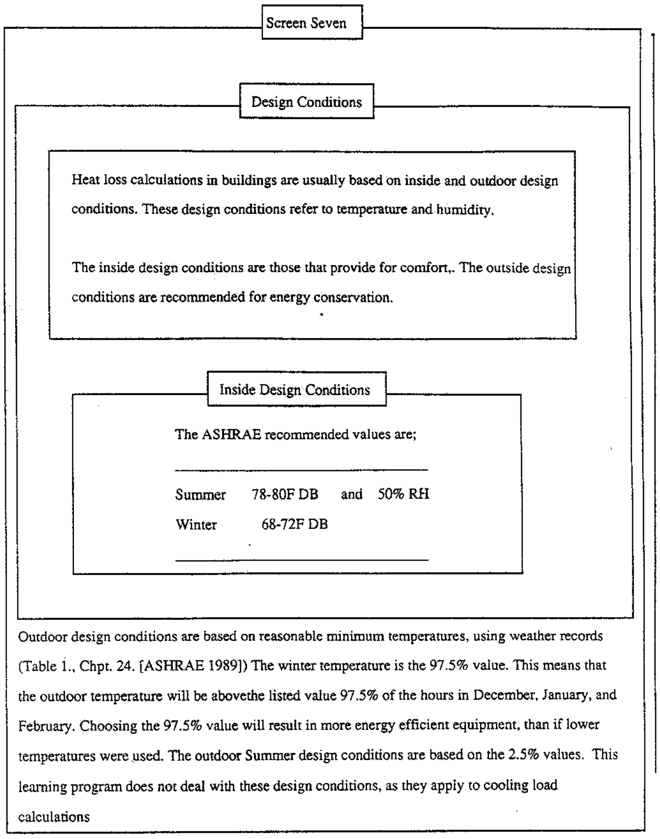
This learning program focuses on heat transfer losses, specificaly through walls. To calculate heat transfer losses, the building design conditions, and the total sum of the UA values for each of the structural elements must be determined. The following screens will teach you how to calculate both of these quantities.

Figure 5.



To learn about "Building Design Conditions", you must place the mouse on the box indicated by the arrow, and click the left-most button twice.

Figure 6.



Heat loss calculations in buildings are usually based on inside and outdoor design conditions. These design conditions refer to temperature and humidity.

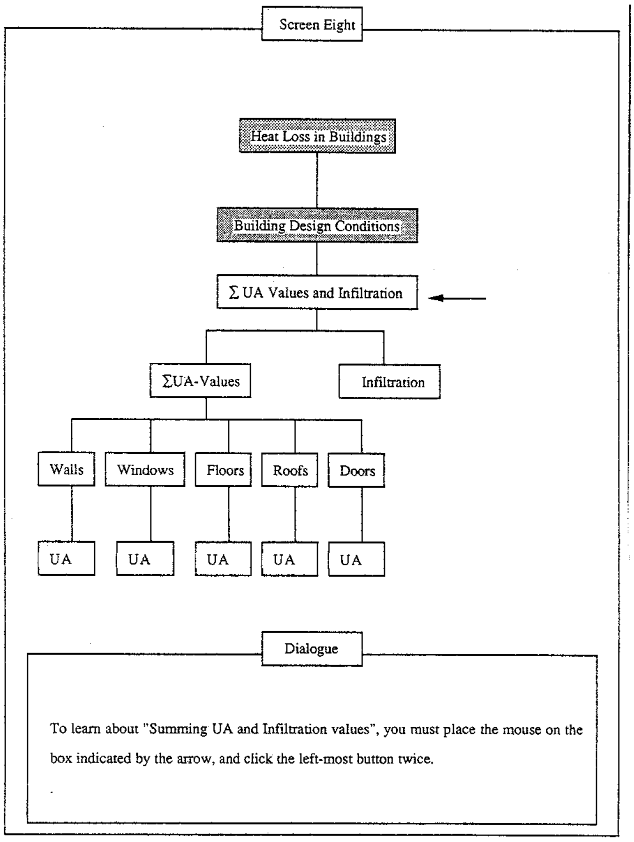
The inside design conditions are those that provide for comfort,. The outside design conditions are recommended for energy conservation.

The ASHRAE recommended values are;

Summer 78-80F DB and 50% RH
Winter 68-72F DB

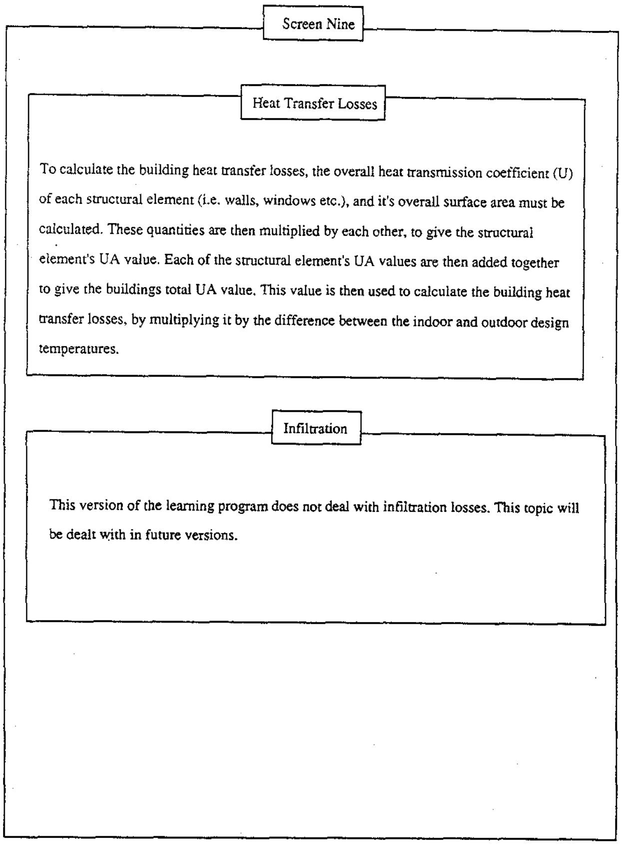
Outdoor design conditions are based on reasonable minimum temperatures, using weather records (Table 1., Chpt. 24. [ASHRAE 1989]) The winter temperature is the 97.5% value. This means that the outdoor temperature will be abovethe listed value 97.5% of the hours in December, January, and February. Choosing the 97.5% value will result in more energy efficient equipment, than if lower temperatures were used. The outdoor Summer design conditions are based on the 2.5% values. This learning program does not deal with these design conditions, as they apply to cooling load calculations

Figure 7.



To learn about "Summing UA and Infiltration values", you must place the mouse on the box indicated by the arrow, and click the left-most button twice.

Figure 8.



Screen Nine

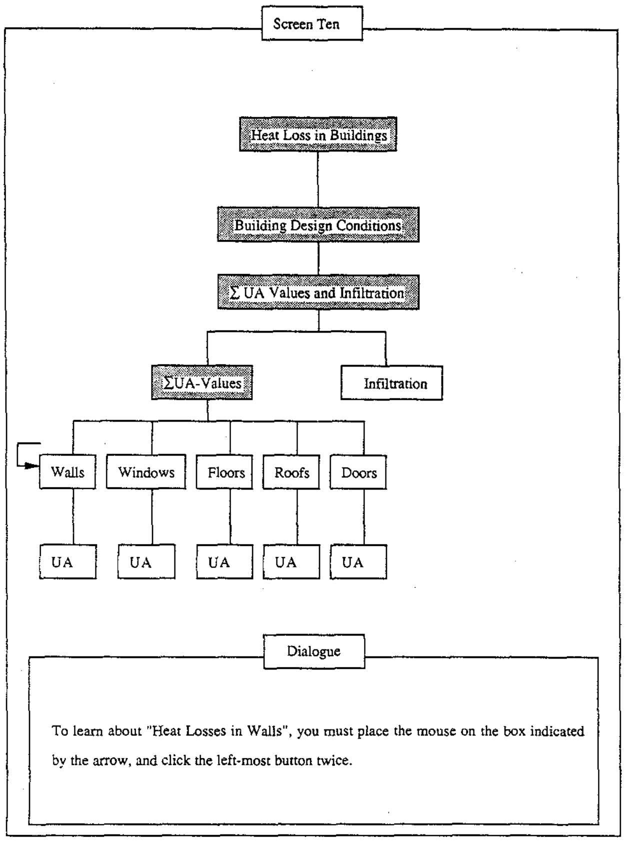
Heat Transfer Losses

To calculate the building heat transfer losses, the overall heat transmission coefficient (U) of each structural element (i.e. walls, windows etc.), and it's overall surface area must be calculated. These quantities are then multiplied by each other, to give the structural element's UA value. Each of the structural element's UA values are then added together to give the buildings total UA value. This value is then used to calculate the building heat transfer losses, by multiplying it by the difference between the indoor and outdoor design temperatures.

Infiltration

This version of the learning program does not deal with infiltration losses. This topic will be dealt with in future versions.

Figure 9.

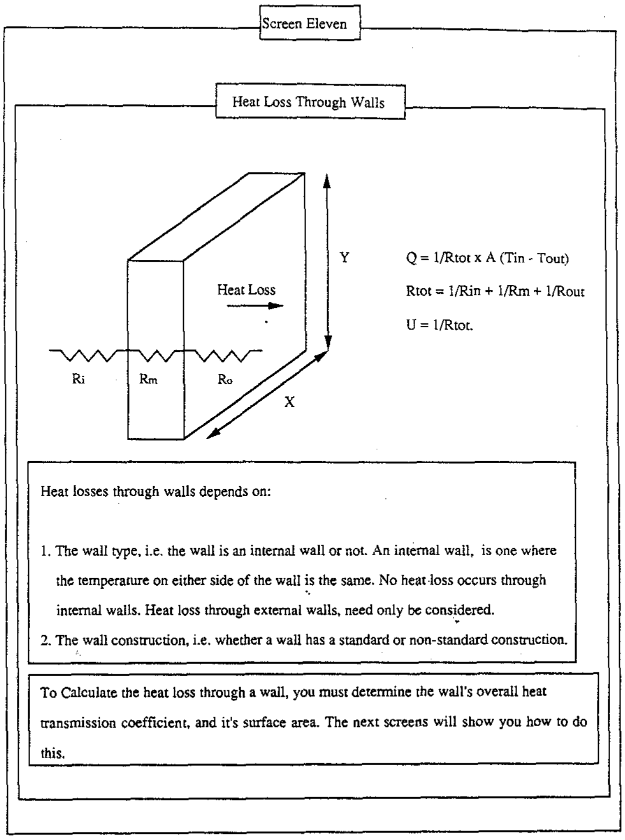


Screen Ten

Dialogue

To learn about "Heat Losses in Walls", you must place the mouse on the box indicated by the arrow, and click the left-most button twice.

Figure 10.



Screen Eleven

Heat Loss Through Walls

Q = 1/Rtot x A (Tin - Tout)

Rtot = 1/Rin + 1/Rm + 1/Rout

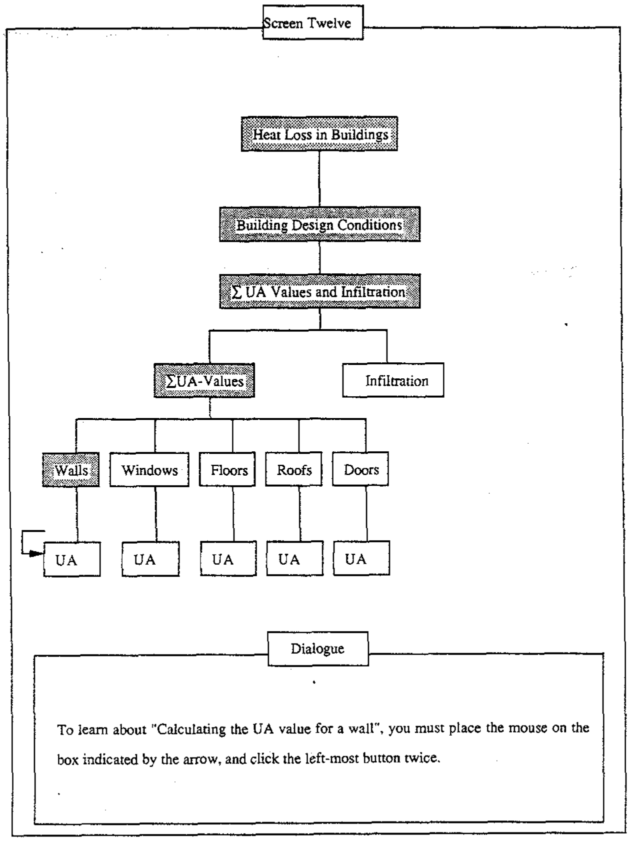
U = 1/Rtot.

Heat losses through walls depends on:

1. The wall type, i.e. the wall is an internal wall or not. An internal wall, is one where the temperature on either side of the wall is the same. No heat loss occurs through internal walls. Heat loss through external walls, need only be considered.
2. The wall construction, i.e. whether a wall has a standard or non-standard construction.

To Calculate the heat loss through a wall, you must determine the wall's overall heat transmission coefficient, and it's surface area. The next screens will show you how to do this.

Figure 11.

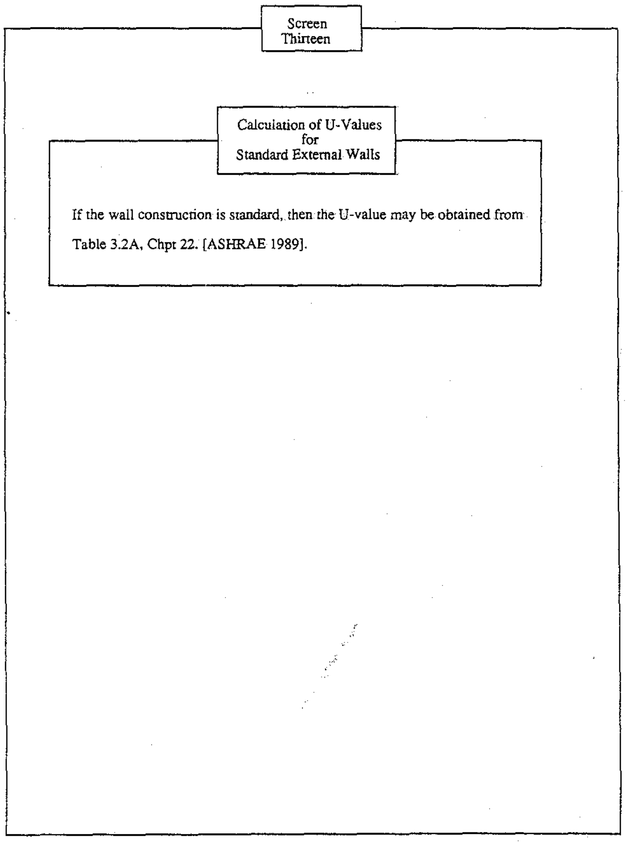


Screen Twelve

Dialogue

To learn about "Calculating the UA value for a wall", you must place the mouse on the box indicated by the arrow, and click the left-most button twice.

Figure 12.

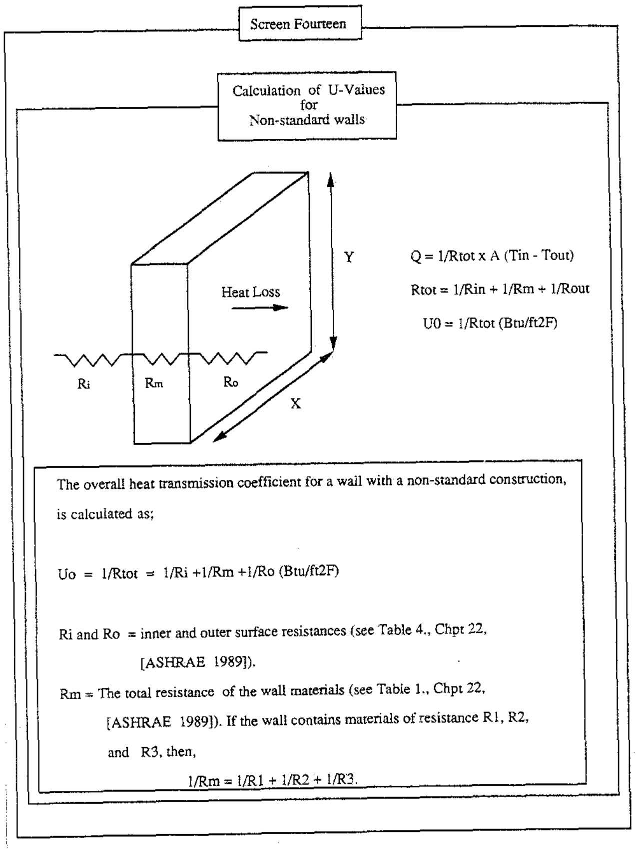


Screen Thirteen

Calculation of U-Values for Standard External Walls

If the wall construction is standard, then the U-value may be obtained from Table 3.2A, Chpt 22. [ASHRAE 1989].

Figure 13.



Screen Fourteen

Calculation of U-Values for Non-standard walls

Q = 1/Rtot x A (Tin - Tout)

Rtot = 1/Rin + 1/Rm + 1/Rout

U0 = 1/Rtot (Btu/ft2F)

The overall heat transmission coefficient for a wall with a non-standard construction, is calculated as;

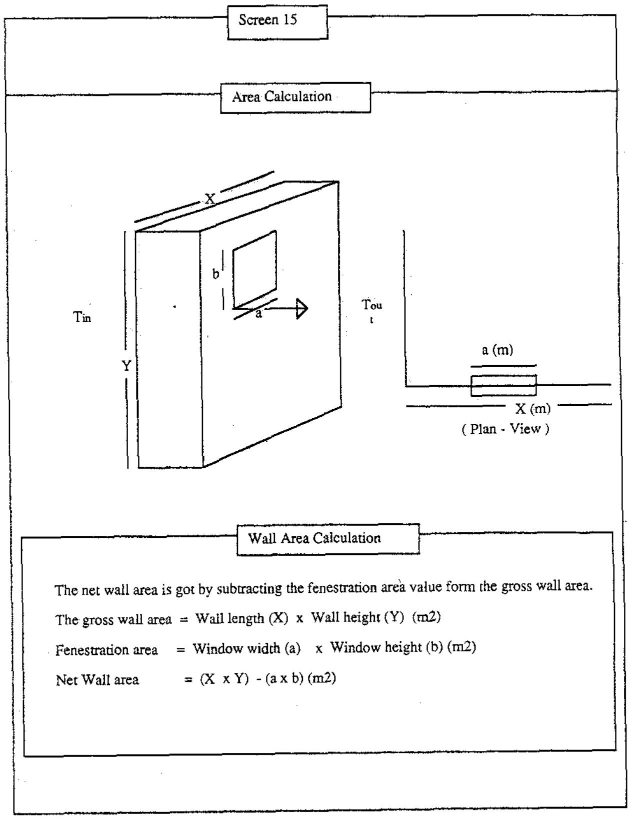
Uo = 1/Rtot = 1/Ri +1/Rm +1/Ro (Btu/ft2F)

Ri and Ro = inner and outer surface resistances (see Table 4., Chpt 22, [ASHRAE 1989]).

Rm = The total resistance of the wall materials (see Table 1., Chpt 22, [ASHRAE 1989]). If the wall contains materials of resistance R1, R2, and R3, then,

1/Rm = 1/R1 + 1/R2 + 1/R3.

Figure 14.



Screen 15

Area Calculation

Wall Area Calculation

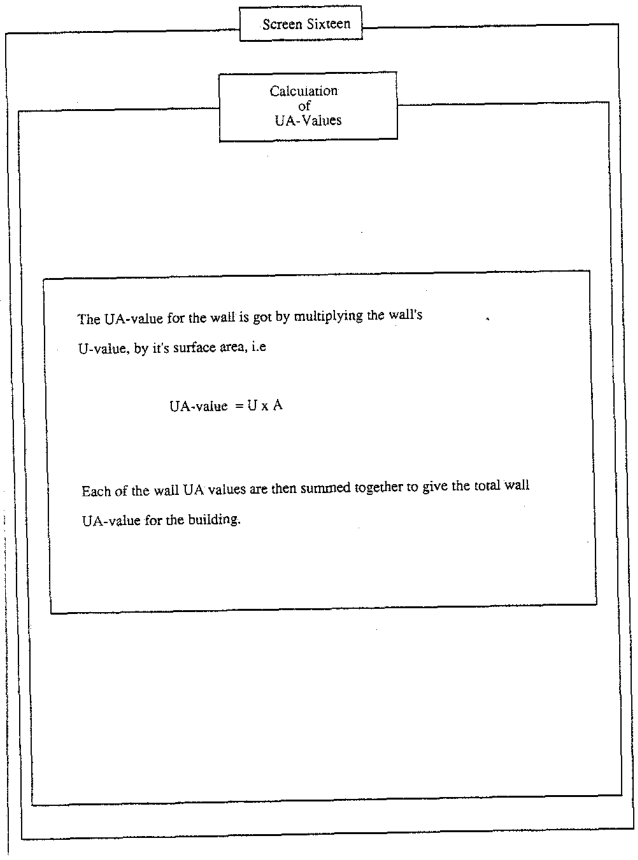
The net wall area is got by subtracting the fenestration area value form the gross wall area.

The gross wall area = Wall length (X) x Wall height (Y) (m2)

Fenestration area = Window width (a) x Window height (b) (m2)

Net Wall area = (X x Y) - (a x b) (m2)

Figure 15.



Screen Sixteen

Calculation of UA-Values

The UA-value for the wall is got by multiplying the wall's U-value, by it's surface area, i.e

UA-value = U x A

Each of the wall UA values are then summed together to give the total wall UA-value for the building.

Figure 16.